Sheep Management Calendar

A management calendar of suggested practices to follow is useful to the beginning as well as experienced producers in managing the sheep flock. Sheep production evolves around the lambing season. Therefore, the production cycle starts approximately 6 months prior to the date you want your first lambs to be born.

The following guidelines are not intended to fit every sheep operation but merely serve as suggested practices that might be useful if they fit your operation. Because every sheep operation is different, a separate sheep calendar should be tailored to fit a flock’s needs.

Prior to Breeding

- Purchase rams 45-60 days prior to start of breeding season.
- Drench ewes and rams for internal parasites.
- Trim feet (do rams 30 days prior to start of breeding season).
- Shear rams.
- Provide cool environment for rams.
- Condition rams by giving some grain if too thin. Shoot for a 3.5 body condition score.
- Vaccinate ewes for campylobacteriosis (vibrio) and enzootic abortion (EAE).
- Begin flushing ewes 2-3 weeks prior to start of breeding season and continue into breeding.

Breeding

- Use marker on rams - change color every 17 days.
- Observe breeding activity of rams, remove boss rams, rotate rams.
- If weather is hot, run rams with ewes at night and keep in cool environment during day.
- Remove rams after 51 days.

Prior to Lambing - Early Pregnancy (First 15 weeks)

- Vaccinate all ewe lambs and new ewes in the flock with their second injection for campylobacteriosis (vibrio) and enzootic abortion (EAE).
- Watch general health of ewes. Sort off thin ewes to increase body condition score.
- Use lower quality roughages at this time - save higher quality feeds for later stages of pregnancy. Utilize other marginal feedstuffs during this time.
Prior to Lambing - Late Pregnancy (4-6 weeks before lambing)

- Begin increasing plane of nutrition by supplementing with grain, high quality roughages, or pasture.
- Trim and check feet.
- Treat for internal parasites.
- Shear at least two weeks prior to lambing. If you do not shear the ewes at this time, crutch or tag ewes instead.
- Vaccinate ewes for enterotoxemia (about 30 days prior to lambing).
- Prepare lambing quarters, check supplies, and equipment.

Lambing

- Be ready for first lambs 142 days after turning rams with ewes even though normal gestation period is 147 days.
- Watch ewes closely. Lambing time should be the time where you concentrate your labor. The extra effort will be repaid with more lambs at weaning. Additional help might be money well spent.
- Provide assistance when needed.
- Place ewes that lamb in jugs or lambing pens.
- Clip, Dip, Strip, and Sip: Clip the navel to 1-1/2" length; Dip the navel in 7% tincture of iodine; Strip the teat of the ewe to remove the wax plug from teat canal; and see that lamb gets first Sip of colostrum.
- Check lambs and ewes in jugs several times each day to insure ewes are claiming lambs and lambs are getting enough to eat.
- Remove ewes and lambs from jugs (1-3 days) and place in small group of 4-8 ewes for further observation and then combine these groups into a workable size unit. Ewes with twins should be separated from those with singles.
- Begin to feed ewe at recommended levels for lactation about 3 days after lambing.
- Watch lambs for signs of pneumonia and scours.
- Give lambs Vitamin E - Selenium injection.
- Vaccinate lambs for soremouth at 1-2 weeks of age if it is a problem in your flock. Also vaccinate lambs for enterotoxemia if ewes were not vaccinated prior to lambing.
- Castrate and dock lambs as soon as they are up and off to a good start (2 days to 2 weeks of age).

End of Lambing

- Continue to feed ewes for lactation based on number of lambs suckling. Feed at this level until 6 weeks after lambing.
- Get lambs started on creep feed when 10-14 days old if this is part of lamb production system.
- Give lambs first vaccination for enterotoxemia at 5 to 7 weeks of age. This would be time to give second booster to lambs if ewes were not vaccinated prior to lambing.
- Observe ewes for signs of mastitis and lambs for signs of starvation.
Weaning

- Wean lambs at 50 to 60 days of age or older.
- One week prior to weaning, discontinue grain feeding and reduce quantity and quality of hay.
- At weaning, place ewes on poor quality hay to help stop milk production and reduce mastitis problems.
- Continue to feed lambs on growing, finishing ration.

Weaning to Pre-Breeding

- Drench ewes and rams for internal parasites.
- Cull ewes and market barren producers. Use your records.
- Market lambs either as feeders or finished lambs when they reach appropriate size and weight.
- Purchase replacement ewes and rams (if needed or you do not raise own replacement ewes).
- Observe condition of ewes - don't allow them to get overly fat or too thin.

June 2012

James Thompson (https://extension.oregonstate.edu/people/james-thompson)
Sheep Specialist (Retired)

Source URL: https://extension.oregonstate.edu/animals-livestock/sheep-goats/sheep-management-calendar
What Does MUMS Mean?

MUMS aren’t just fall flowers. MUMS also stands for Minor Use and Minor Species.

What are minor species?

- All animals are minor species except horses, dogs, cats, cattle, pigs, turkeys, and chickens. Those seven are major species.
- Some minor species are important in farming like sheep, goats, catfish, gamebirds (like pheasants), llamas, bison, and honey bees.
- Other minor species are zoo animals, ornamental fish (like bettas and koi), parrots, ferrets, guinea pigs, and other small pets.

What is a minor use?

- Minor use refers to when drugs are used to treat one of the major species (horses, dogs, cats, cattle, pigs, turkeys and chickens) for a disease that is rare.
- A disease can be rare because it occurs only in certain areas of the country, or because it affects only a small number of animals each year.

What did Congress do to help MUMS?

- In 2004, Congress passed a law called the Minor Use and Minor Species Animal Health Act to help make more drugs available for minor uses and minor species.
- The law encourages drug companies to develop more drugs for diseases of minor species, like fish and honey bees, and for minor uses, like to treat pain in dogs with bone cancer.

Why is a law needed to help MUMS?

- When a drug company wants to sell a drug, it needs to prove to the Food and Drug Administration (FDA) that the drug is safe and that it works (that it’s effective).
- It is very expensive for a drug company to develop an animal drug, get it approved by FDA, and on the market for sale.
Drug companies often can’t afford to develop new drugs for minor uses or minor species because they won’t sell enough of the drug to pay for their expenses. For example, a company won’t sell a lot of drugs for pheasants because there aren’t a lot of pheasants raised on farms in the U.S. On the other hand, billions of chickens are raised in the U.S. and a company can make a lot of money selling drugs for chickens.

So, Congress passed the Minor Use and Minor Species Animal Health Act to help make it less expensive for drug companies to get drugs approved for minor uses and minor species.

What is FDA doing to help MUMS?

In the FDA’s Center for Veterinary Medicine, there is an Office of Minor Use and Minor Species Animal Drug Development (OMUMS for short) and an Office of New Animal Drug Evaluation (ONADE). Both offices help make sure safe and effective drugs are available for minor uses and minor species.

OMUMS manages grants and other ways to help drug companies afford to get drugs approved for minor uses and minor species. OMUMS also runs a program that makes it easier for drug companies to legally sell some drugs for minor species that are not eaten as food by people or other animals.

When a drug company sends FDA an application to get a drug approved for a minor use or a minor species, ONADE looks at the information in the application to make sure the drug is safe and effective. Even though the drug is for a smaller market, the standards for drug approval are the same as for a drug for a major species.

OMUMS and ONADE work with other federal agencies, such as the U.S. Fish and Wildlife Service, and other groups, such as scientists at a university, to support studies of potential drugs for minor uses and minor species.

Additional Information

Lions and Tigers and Bears! OMUMS! (/animal-veterinary/animal-health-literacy/lions-and-tigers-and-bears-omums)
Drugs approved for small ruminants

Alistair I. Webb, BVSc, PhD, DACVA; Ronald E. Baynes, DVM, PhD;
Arthur L. Craigmill, PhD; Jim E. Riviere, DVM, PhD; Scott R. R. Haskell, DVM, PhD

For the purpose of this FARAD Digest, small ruminants are considered to include sheep, goats, deer, and camels. In the United States, the small ruminant population is low, and they are all considered minor species under the Food, Drug, and Cosmetics Act (Table 1). Minor species are defined by exclusion from major species (ie, cats, dogs, horses, swine, cattle, chickens, and turkeys). In the United States, sheep were only considered to be minor species in regard to efficacy and target animal safety requirements and remained a major species when human food safety was being evaluated. This exception was attributed to the high consumption of lamb and mutton at the time of the original classification in 1983. It was not until August 2002 that the sheep drug approval process was amended so that sheep were reclassified as a minor species with regard to human food safety requirements. Classification as a minor species allows the FDA flexibility in permitting new drug applications when

Table 1—Drugs approved for various small ruminants and the US populations for those species

<table>
<thead>
<tr>
<th>Active ingredient</th>
<th>Sheep</th>
<th>Goats1</th>
<th>Deer2</th>
<th>Camels3</th>
<th>Drug availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albenzole</td>
<td></td>
<td>A</td>
<td></td>
<td></td>
<td>DTC</td>
</tr>
<tr>
<td>Ampicillin</td>
<td></td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbenedil citrate</td>
<td></td>
<td>A, ANRSP-7</td>
<td>A, ANRSP-7</td>
<td>A, ANRSP-7</td>
<td>Rx &amp; C-II</td>
</tr>
<tr>
<td>Cefotaxim sodium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlortetracycline</td>
<td>A</td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cloxacillin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decoquinomate</td>
<td>A, ANRSP-7</td>
<td>A, ANRSP-7</td>
<td>A, ANRSP-7</td>
<td>A, ANRSP-7</td>
<td>DTC</td>
</tr>
<tr>
<td>Fenbendazole</td>
<td>A, ANRSP-7</td>
<td>A, ANRSP-7</td>
<td>A, ANRSP-7</td>
<td>A, ANRSP-7</td>
<td>Rx &amp; DTC</td>
</tr>
<tr>
<td>Follicle stimulating hormone</td>
<td>A</td>
<td>A, ANRSP-7</td>
<td>A, ANRSP-7</td>
<td>A, ANRSP-7</td>
<td>Rx</td>
</tr>
<tr>
<td>Ivermectin</td>
<td>A</td>
<td>NA</td>
<td>A, ANRSP-7</td>
<td></td>
<td>DTC</td>
</tr>
<tr>
<td>Lovoagelid</td>
<td>A</td>
<td>NA</td>
<td></td>
<td></td>
<td>DTC</td>
</tr>
<tr>
<td>Lomuloside</td>
<td>A</td>
<td>NA</td>
<td></td>
<td></td>
<td>DTC</td>
</tr>
<tr>
<td>Monensin</td>
<td></td>
<td>A, ANRSP-7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morantel tartare</td>
<td></td>
<td>A, ANRSP-7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naiotirazone</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td>DTC</td>
</tr>
<tr>
<td>Nosomycin</td>
<td>A</td>
<td>NA</td>
<td></td>
<td></td>
<td>DTC</td>
</tr>
<tr>
<td>Neostigmime</td>
<td>A</td>
<td>NA</td>
<td></td>
<td></td>
<td>DTC</td>
</tr>
<tr>
<td>Oxytetracycline</td>
<td>A</td>
<td>NA</td>
<td></td>
<td></td>
<td>DTC</td>
</tr>
<tr>
<td>Oxytocin</td>
<td>A</td>
<td>NA</td>
<td></td>
<td></td>
<td>DTC</td>
</tr>
<tr>
<td>Penicillin G (procaine)</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td>DTC</td>
</tr>
<tr>
<td>Selenium &amp; vitamin E</td>
<td>A</td>
<td>NA</td>
<td></td>
<td></td>
<td>DTC</td>
</tr>
<tr>
<td>Tilmicosin</td>
<td>A, ANRSP-7</td>
<td>A, ANRSP-7</td>
<td>A, ANRSP-7</td>
<td>A, ANRSP-7</td>
<td>Rx</td>
</tr>
<tr>
<td>Xylazine hydrochloride</td>
<td>A</td>
<td>NA</td>
<td></td>
<td></td>
<td>DTC</td>
</tr>
<tr>
<td>Zeranol</td>
<td>A</td>
<td>NA</td>
<td></td>
<td></td>
<td>DTC</td>
</tr>
</tbody>
</table>

*United States population of the species. 1Camelid population represents 145,000 llamas and 30,000 alpacas. A = Drug approved for this species. ANRSP-7 = Approvals that were obtained using a National Research Support Program #7 (NRS-7) public master file. NA = No approval; National Research Support Program #7 has developed a public master file, but no manufacturer has used it to obtain an approval. DTC = Over-the-counter drug. Rx = Prescription drug. C-II = Schedule II drug.
extrapolating already accepted efficacy and safety data from a major species (e.g., in the case of the small ruminants, it is cattle) to support new minor species claims. The reduction in regulatory requirements is supposed to act as a stimulus to gain new drug approvals in minor species, however, this has not worked well, as many approved drugs for cattle have not been approved for many of these small ruminants (Table 1 and 2). In fact, most new animal drug approvals for minor species have been obtained through partnerships between the USDA-sponsored Agriculture Experimental Station-based program National Research Support Program #7 and pharmaceutical companies.

Clinical needs—This review of drugs approved for use in small ruminant species quickly demonstrates the problems facing minor species in gaining support of pharmaceutical companies pursuing drug approval (Table 1). Camelids (llamas and alpacas) have no drugs approved for use, and only 4 drugs are approved for cervidae (deer). Goats are marginally better off with 6 marketed drugs, compared with sheep, which have 16. What makes these observations of even more concern to small ruminant producers and veterinarians is the limit in scope of approved therapeutic indications (Table 2 and 3). The 2001 National Animal Health Monitoring System Survey found that 80% of diseases in sheep were related to gastrointestinal parasites, respiratory tract infections, mastitis, and footrot, and they respectively ranked as the second, third, and fifth (the last 2 combined) causes of death in flocks studied. A 1996 survey of small ruminant veterinarians and producers reflected similar needs, although they ranked

Table 2—Food and Drug Administration information for drugs approved for use in sheep and goats as of June 2003

<table>
<thead>
<tr>
<th>Active ingredient</th>
<th>Drug availability</th>
<th>Indication</th>
<th>Route</th>
<th>Dose*</th>
<th>WDT meat (d)</th>
<th>WDT milk (h)</th>
<th>Dose</th>
<th>WDT meat (d)</th>
<th>WDT milk (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albendazole</td>
<td>OTC</td>
<td>Anthelmintic</td>
<td>PO</td>
<td>7.5 mg/kg</td>
<td>7</td>
<td>0</td>
<td>1–2 mg/kg</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ceftiofur sodium</td>
<td>Rx</td>
<td>Antimicrobial, respiratory tract disease</td>
<td>IM &amp; SC</td>
<td>1–2 mg/kg</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloramphenicol</td>
<td>OTC</td>
<td>Antimicrobial, prevent vibriosis, growth promotant</td>
<td>PO</td>
<td>80 mg/animal [vibriosis]</td>
<td>0</td>
<td>n/v</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decoquinate</td>
<td>OTC</td>
<td>Coccidiostat</td>
<td>PO</td>
<td>0.5 mg/kg</td>
<td>n/v</td>
<td>n/v</td>
<td>0.5 mg/kg</td>
<td>0</td>
<td>n/v</td>
</tr>
<tr>
<td>Fenbendazole</td>
<td>OTC or Rx</td>
<td>Anthelmintic</td>
<td>IV, IM &amp; SC</td>
<td>5 mg/kg</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ivermectin</td>
<td>OTC</td>
<td>Anthelminic</td>
<td>PO</td>
<td>200 µg/kg</td>
<td>11</td>
<td>n/v</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lasalocid (sodium)</td>
<td>OTC</td>
<td>Coccidiostat</td>
<td>PO</td>
<td>15–70 mg/animal</td>
<td>0</td>
<td>n/v</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxytetacycline dihydrate</td>
<td>OTC</td>
<td>Rumen &amp; intestinal stimulant</td>
<td>PO</td>
<td>0.02 mg/kg</td>
<td>0</td>
<td>n/v</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxytetacycline hydrochloride &amp; polymyxin B sulfate</td>
<td>OTC</td>
<td>Antimicrobial, ocular infections</td>
<td>Ophthalmic</td>
<td>2–4 X/d</td>
<td>0</td>
<td>n/v</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxytocin</td>
<td>Rx</td>
<td>Antimicrobial, respiratory tract disease</td>
<td>IV, IM &amp; SC</td>
<td>30–50 IU/mouse</td>
<td>0</td>
<td>n/v</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Penicillin G (procaine)</td>
<td>OTC</td>
<td>Antimicrobial, respiratory tract disease</td>
<td>IM</td>
<td>6,000 U/kg</td>
<td>6–9</td>
<td>n/v</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selenium (sodium selenite &amp; vitamin E)</td>
<td>Rx</td>
<td>Treat &amp; prevent white muscle disease</td>
<td>IM &amp; SC</td>
<td>1 ml/18 kg</td>
<td>14</td>
<td>n/v</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Telimicosin phosphate</td>
<td>Rx</td>
<td>Antimicrobial, respiratory tract disease</td>
<td>SC</td>
<td>10 mg/kg</td>
<td>28</td>
<td>n/v</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zanamol</td>
<td>OTC</td>
<td>Growth promotant</td>
<td>SC</td>
<td>12 mg pellet [lamb]</td>
<td>40</td>
<td>n/v</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Doses cited in Table 4 and 5 are in mg/kg but can be converted to mg/lb by dividing the dose by 2.2. Nonmetric versions of the tables are available by contacting the authors.

WDT = Withdrawal time. n/v = Convention to indicate the FARAD database has no value for that field; it may be that it is not available, or it may be inappropriate (e.g., a milk withdrawal time for a nonlactating species).

See Table 1 for remainder of key.
pneumonia higher than mastitis and footrot. The authors argued that the extent of extralabel drug use (ELDU) in the small ruminant industry necessities the need for increased research relating to preharvest safety of drugs and residue depletion. Two new antimicrobials have been approved in recent years—ceftiofur for sheep and goats and tilmicosin for sheep only. Both antimicrobials are limited to use by licensed veterinarians. Notably, there are neither drugs for treatment of mastitis nor any anti-inflammatory or analgesic drugs approved for small ruminants.

It is obvious that with so few approved small ruminant drugs, the reliance on ELDU is extremely high. AMDUCA enabled veterinarians acting within the constraints of a valid veterinarian-client-patient relationship to use drugs approved in other species for the relief of pain and suffering. This required the veterinarian to establish a substantially extended withdrawal period supported by appropriate scientific information. For the most part, this has been supplied by FARAD Access Centers in one-on-one, expert-medi-
Table 5—Comparison of FDA label doses and WDTs for drugs that are approved in cattle and small ruminants

<table>
<thead>
<tr>
<th>Drug</th>
<th>Cattle Dose (mg/kg)</th>
<th>WDT Meat (d)</th>
<th>Milk (h)</th>
<th>Sheep Dose (mg/kg)</th>
<th>WDT Meat (d)</th>
<th>Milk (h)</th>
<th>Goats Dose (mg/kg)</th>
<th>WDT Meat (d)</th>
<th>Milk (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albendazole</td>
<td>10</td>
<td>27</td>
<td>n/v</td>
<td>7.5</td>
<td>7</td>
<td></td>
<td>1-2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Ceftriaxone sodium</td>
<td>0.5-1</td>
<td>0</td>
<td>0</td>
<td>80</td>
<td>0</td>
<td>0</td>
<td>0.5</td>
<td>0</td>
<td>n/v</td>
</tr>
<tr>
<td>Doxycycline</td>
<td>0.25</td>
<td>0</td>
<td>0</td>
<td>95</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fenbendazole</td>
<td>5</td>
<td>8</td>
<td>n/v</td>
<td>5</td>
<td>11</td>
<td></td>
<td>5</td>
<td>3</td>
<td>n/v</td>
</tr>
<tr>
<td>Follicle stimulating hormone</td>
<td>10-50 mg/animal</td>
<td>24</td>
<td>n/v</td>
<td>200</td>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
<td>n/v</td>
</tr>
<tr>
<td>Ivermectin</td>
<td>0.25-1</td>
<td>0</td>
<td>0</td>
<td>5-10</td>
<td>15-70</td>
<td></td>
<td>20 g/t feed</td>
<td>0</td>
<td>n/v</td>
</tr>
<tr>
<td>Lasalocid</td>
<td>1.7</td>
<td>2</td>
<td>n/v</td>
<td>8</td>
<td></td>
<td></td>
<td>22 mg</td>
<td>2</td>
<td>n/v</td>
</tr>
<tr>
<td>Levamisole</td>
<td>0.1-1</td>
<td>0</td>
<td>n/v</td>
<td>9.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monensin</td>
<td>5.7</td>
<td>14</td>
<td>n/v</td>
<td>22 mg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morantel tertrate</td>
<td>22</td>
<td>1</td>
<td>n/v</td>
<td>22 mg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neostigmine</td>
<td>0.02</td>
<td>n/v</td>
<td>n/v</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neomycin</td>
<td>0.2 mg/kg, 3-5 mg/kg</td>
<td>0.28</td>
<td>n/v</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Penicillin G (procaine)</td>
<td>6,000</td>
<td>4</td>
<td>n/v</td>
<td>30-50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selenium &amp; vitamin E</td>
<td>1 mL/cow</td>
<td>30</td>
<td>n/v</td>
<td>1 mL/18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tilmicosin</td>
<td>3×12 mg pellets/animal</td>
<td>0</td>
<td>n/v</td>
<td>1 pellet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

See Tables 1 and 2 for key.

small ruminant species (Table 5). Those drugs with zero WDTs are similar between species with the notable exception of oxytetracycline. Oxytetracycline’s labeled use in cattle has a zero WDT, whereas the label for sheep has a 5-day WDT, presumed to be based on the sheep dose being 100-fold greater than that used in cattle. Another danger in species extrapolation is toxicity. Tilmicosin is approved for treatment of respiratory tract disease in cattle and sheep but is toxic to goats. Another more recent concern is the practice of oral administration of Cydectin (moxidectin) to goats that are not responding to fenbendazole or ivermectin. Although moxidectin is approved for topical use in cattle with zero milk and meat WDTs, this does not imply that the meat and milk WDTs will be zero if given orally to goats. In fact, FARAD has determined that the meat WDI in goats can be as much as 23 days after administration of the approved cattle dose of 0.5 mg/kg (0.22 mg/lb; Table 3).

Future outlook—With the sheep industry slowly declining and the goat population gaining, the drug availability situation is troublesome. Today, the need for new drug approval exceeds the pharmaceutical industry’s research and development capacity and financial ability. However, there is the MUMS bill before Congress to promote drug availability for minor uses in major species and general use in minor species. The bill establishes new ways to lawfully market new animal drugs and provides a process for designating certain drugs to qualify for financial incentives. It will also include the establishment of division within the FDA-CVM to overlook and facilitate new minor species drug approvals.

References

JAVMA, Vol 224, No. 4, February 15, 2004
Vet Med Today: FARAD Digest
Correction: Drugs approved for small ruminants

In the FARAD Digest article "Drugs approved for small ruminants" published in the February 15, 2004, issue (J Am Vet Med Assoc 2004;224:520-523), the units for milk withdrawal intervals following administration of ivermectin in goats in Table 4 are incorrect. Milk withdrawal intervals following administration of ivermectin in goats should be listed in days, not hours.
Extralabel drug use in small ruminants

Krysta L. Martin PharmD
Maaike O. Clapham BS
Jennifer L. Davis DVM, PhD
Ronald E. Baynes DVM, PhD
Zhouneng Lin BMed, PhD
Thomas W. Vickroy PhD
Jim E. Riviere DVM, PhD
Lisa A. Tell DVM

From the Food Animal Residue Avoidance and Depletion Program (FARAD), Department of Medicine and Epidemiology, School of Veterinary Medicine, University of California-Davis, Davis, CA 95616 (Martin, Clapham, Tell); FARAD, Department of Biomedical Sciences and Pathobiology, Virginia-Maryland College of Veterinary Medicine, Blacksburg, VA 24061 (Davis); FARAD, Department of Population Health and Pathobiology, College of Veterinary Medicine, North Carolina State University, Raleigh, NC 27606 (Baynes, Riviere); FARAD, Institute of Computational Comparative Medicine, Department of Anatomy and Physiology, College of Veterinary Medicine, Kansas State University, Manhattan, KS 66506 (Lin, Riviere); and FARAD, Department of Physiological Science, College of Veterinary Medicine, University of Florida, Gainesville, FL 32610 (Vickroy).

Address correspondence to Dr. Tell (lstell@ucdavis.edu).

In the present FARAD Digest, common medications used to treat small ruminants in the United States and FARAD-recommended WDIIs following ELDU in small ruminants will be reviewed. For this digest, we use the term small ruminants to refer only to sheep and goats. In the United States, sheep and goats are considered minor species by the FDA and are therefore exempt from many of the rules used to regulate drug use in the major species (horses, cats, dogs, cattle, swine, turkeys, and chickens). From 2007 to 2012, the overall number of sheep and goats in production in the United States declined by 7.8% and 16.5%, respectively; however, the number of dairy goats increased by 23.5%.1 Despite a decrease in the overall number of sheep and goats in production, FARAD has had a steady increase in the number of requests for information regarding WDIIs following ELDU in small ruminants since 2007. The purpose of this digest is to update a previous FARAD Digest2 concerning small ruminants and provide veterinarians with summary information regarding ELDU in small ruminants.

FDA-Approved Drugs for Sheep and Goats

In the United States, there are fewer FDA-approved drugs for minor species (such as sheep and goats) than for the major species. Currently, there are 70 and 25 FDA-approved drugs for domesticated and nondomesticated sheep and goats, respectively.3 Information regarding FDA-approved drug dosages, WDTs for milk and meat following administration of an FDA-approved drug at the approved dosage, and established tolerance (ie, the drug or chemical concentration that the FDA deems safe for human consumption) for drug residues in meat and milk intended for human consumption can be accessed from the FDA Animal Drugs5 and FARAD VetGRAM6 websites. It is important to note that, when a drug is administered to a food animal species for which it is not approved, tolerances have not been established for acceptable residues of that drug or its metabolites in meat and milk obtained from treated animals, and detection of any drug residue in the meat or milk of treated animals marketed for human consumption is considered a violation and subject to regulatory action (ie, there is a zero tolerance for residues of that drug or its metabolites in meat and milk).

ELDU of medicated feeds for sheep and goats

The FDA prohibits extralabel use of medicated feeds in major species but not in minor species. The guidelines for extralabel use of medicated feeds in minor species are outlined in CPG 615.115.5 That CPG does not establish legally enforceable responsibilities but does provide FDA field inspectors guidance regarding when to take regulatory action against veterinarians or producers following discovery of extralabel use of medicated feeds in food-producing animals. Extralabel use of medicated feeds in minor species must meet all stipulations for ELDU set forth by the AMDUCA6 in addition to the guidelines outlined in CPG 615.115.5 In minor species, extralabel use of medicated feeds is limited to products approved by the FDA for administration in or on animal feed. A medicated feed is administered in an extralabel manner.

ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPG</td>
<td>Compliance Policy Guide</td>
</tr>
<tr>
<td>ELDU</td>
<td>Extralabel drug use</td>
</tr>
<tr>
<td>FARAD</td>
<td>Food Animal Residue Avoidance and Depletion Program</td>
</tr>
<tr>
<td>IMM</td>
<td>Intramammary</td>
</tr>
<tr>
<td>VFD</td>
<td>Veterinary feed directive</td>
</tr>
<tr>
<td>WDI</td>
<td>Withdrawal interval</td>
</tr>
<tr>
<td>WDT</td>
<td>Withdrawal time</td>
</tr>
</tbody>
</table>

JAVMA | OCT 15, 2018 | VOL 253 | NO. 8
when it is used for a minor species or for an indication not listed on the product label or when the FDA-approved WDT is extended. Medicated feeds can be administered only to minor species similar to those for which it is approved. In the case of sheep and goats, medicated feeds administered in an extralabel manner must be approved for use in other mammalian species. Extralabel use of a medicated feed in a minor species requires a written recommendation by a licensed veterinarian within the confines of a valid veterinarian-client-patient relationship and is limited to confined or farmed species for therapeutic purposes or when the health of the animals is threatened. Also, extralabel use of a medicated feed cannot be advertised by veterinarians, producers, or feed distributors.

When recommending extralabel use of an over-the-counter medicated feed, veterinarians need to provide the client with a written recommendation dated within 6 months of actual use of the product that includes the indication (diagnosis), drug, dose, duration of treatment, and WDI. The veterinarian should maintain a copy of the written recommendation and make it available to the FDA upon request. When recommending extralabel use of a VFD-medicated feed, veterinarians need to provide the client with a written recommendation dated within 6 months of actual use of the product that includes the indication, drug, dose, duration of treatment, and WDI. The veterinarian should maintain a copy of the written recommendation for a minimum of 2 years and make it available to the FDA upon request. The veterinarian must also complete a VFD form, and in the special instructions section include the species for which the medicated feed is intended, an appropriate WDI for extralabel use, and the following statement: “This VFD is being issued in accordance with CPG 615.115.”

**Number of sheep and goat-related queries to FARAD**

During the period from 2004 through 2017, FARAD received 23,688 queries for WDI recommendations following ELDU in various food animal species, and the percentages for each of those species were summarized (Figure 1). The annual percentage of queries related to sheep and goats increased from 13% in 2004 to 25% in 2017. For both sheep and goats, queries to FARAD were most frequently prompted by ELDU of antimicrobials, anthelmintics, and other therapeutic drugs (Figure 2). The 10 most common active ingredients for which WDIs were requested for sheep and goats in 2017 were summarized (Table 1).

**FARAD-recommended WDIs for drugs commonly used in an extralabel manner in sheep and goats**

Several FARAD Digests have provided standardized WDIs for various drugs following ELDU in small ruminants.7-9 Those WDIs, along with WDIs from this digest, were derived by FARAD on the basis of data that were available at the time (Table 2). Also, FARAD-recommended WDIs often differ substantially from the WDIs for FDA-approved drugs following administration in accord with the label directions. When species-specific pharmacokinetic data are unavailable for a particular drug, FARAD will not provide a standardized WDI but will provide as much information as possible with a cautionary statement that the recommendation is based on limited or extrapolated data. Veterinarians are encouraged to contact FARAD for WDIs, even for products for which FARAD has traditionally not been able to recommend WDIs, because new data may have become available in the intervening period.

**Ampirolium** To our knowledge, ampirola is not approved for use in sheep or goats in the United States or any other country. However, it is frequently used in small ruminants for the treatment of coccidiosis, despite the fact that scientific studies regarding the incidence or duration of ampirola residues in the meat or milk of treated sheep and goats are lacking. Owing to the lack of data for small ruminants, FARAD encourages veterinarians to submit a WDI request because new data may become available in the future that necessitates updated recommendations.

![Pie chart](image-url)

**Figure 1**—Pie chart that depicts the percentage of queries (n = 23,688) submitted to FARAD between January 1, 2004, and December 31, 2017, by species.
Ceftiofur—Ceftiofur is a third-generation cephalosporin. Currently, there are 3 FDA-approved ceftiofur formulations (ceftiofur sodium, ceftiofur crystalline-free acid, and ceftiofur hydrochloride) available for use in veterinary species in the United States. The FDA strictly prohibits ELUO of cephalosporins in all major food-producing species (cattle, swine, chickens, and turkeys), but minor species such as sheep and goats are excluded from that prohibition. The AMDUCA requires that a drug containing the desired active ingredient and approved for use by the FDA in the species of interest must be used first unless the veterinarian judges the approved drug to be clinically ineffective or unavailable. Ceftiofur sodium is approved for IM administration in sheep and goats and has a 0-day WDT for both meat and milk when used in accordance with the FDA-approved label. Therefore, FARAD recommends that ceftiofur sodium be used for sheep and goats whenever possible to comply with AMDUCA.

Ceftiofur crystalline-free acid is an extended-release formulation that is approved by the FDA for use in cattle. The FDA-approved WDTIs (meat, 13 days; milk, 0 hours) for cattle are based on the drug being administered SC in the base of an ear in accordance with the label directions. Ears are discarded at slaughter as are any drug residues that may be present in the ear tissues. When ceftiofur crystalline-free acid is administered SC at a location other than the base of an ear, it can diffuse into the underlying muscle, thereby increasing the risk for violative tissue drug residues. The pharmacokinetics of ceftiofur crystalline-free acid in sheep and goats have been described in multiple studies, but those studies did not include any data regarding depletion of tissue drug residues. Consequently, veterinarians should submit a request to FARAD for a recommended WDI whenever ceftiofur crystalline-free acid is administered to sheep and goats.

Scientific pharmacokinetic and tissue drug residue data for ceftiofur hydrochloride in small ruminants are sparse. The ceftiofur concentration in milk and serum following IM administration of ceftiofur hydrochloride to healthy goats was evaluated in 1 study. However, because the goats of that study were healthy, veterinarians should contact FARAD for a WDI.

Figure 2—Pie charts that depict the percentage of WDI queries submitted to FARAD between January 1, 2004, and December 31, 2017, on the basis of specific drug classes and contaminants in sheep (A: n = 1,398 total queries) and goats (B: 3,359).

Table 1—The 10 drugs for which FARAD most frequently received WDI requests for sheep and goats in 2017.

<table>
<thead>
<tr>
<th>Drug</th>
<th>No. of WDI requests for sheep</th>
<th>No. of WDI requests for goats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flunixin meglumine</td>
<td>29</td>
<td>49</td>
</tr>
<tr>
<td>Tylosin</td>
<td>26</td>
<td>42</td>
</tr>
<tr>
<td>Florfenicol</td>
<td>24</td>
<td>42</td>
</tr>
<tr>
<td>Oxytetracycline</td>
<td>17</td>
<td>31</td>
</tr>
<tr>
<td>Penicillin G procaine</td>
<td>15</td>
<td>23</td>
</tr>
<tr>
<td>Ceftiofur hydrochloride</td>
<td>14</td>
<td>17</td>
</tr>
<tr>
<td>Ceftiofur crystalline-free acid</td>
<td>13</td>
<td>19</td>
</tr>
<tr>
<td>Meloxicam</td>
<td>11</td>
<td>27</td>
</tr>
<tr>
<td>Amprolium</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>Fenbendazole</td>
<td>8</td>
<td>26</td>
</tr>
</tbody>
</table>

JAVMA | OCT 15, 2018 | VOL 253 | NO. 8 | 1003
Table 2—Current FARAD recommendations for meat and milk WDIs for drugs commonly administered to sheep and goats in an extralabel manner.

<table>
<thead>
<tr>
<th>Drug</th>
<th>Dose or dosage</th>
<th>Route</th>
<th>Sheep</th>
<th>Goat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetromazine</td>
<td>&lt; 0.13 mg/kg</td>
<td>IV</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>&lt; 0.44 mg/kg</td>
<td>IM</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Aspirin</td>
<td>All usual doses</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>5 mg/kg, once</td>
<td>PO</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>40 mg/kg, once</td>
<td>SC</td>
<td>42</td>
<td>70^*</td>
</tr>
<tr>
<td></td>
<td>20 mg/kg, q 48 h, twice</td>
<td>IM</td>
<td>60^*</td>
<td>60^*</td>
</tr>
<tr>
<td>Florfenicol</td>
<td>5 mg/kg, once</td>
<td>PO</td>
<td>25</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>40 mg/kg, once</td>
<td>SC</td>
<td>42</td>
<td>70^*</td>
</tr>
<tr>
<td></td>
<td>20 mg/kg, q 48 h, twice</td>
<td>IM</td>
<td>60^*</td>
<td>60^*</td>
</tr>
<tr>
<td>Flunixin</td>
<td>2.2 mg/kg, once</td>
<td>IM</td>
<td>10^*</td>
<td>15^*</td>
</tr>
<tr>
<td></td>
<td>2.2 mg/kg, once</td>
<td>IV</td>
<td>10^*</td>
<td>6</td>
</tr>
<tr>
<td>Ivermectin</td>
<td>0.2 mg/kg</td>
<td>PO</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>0.2 mg/kg</td>
<td>SC</td>
<td>14</td>
<td>21</td>
</tr>
<tr>
<td>Ketamine</td>
<td>&lt; 2 mg/kg</td>
<td>Scalp</td>
<td>7</td>
<td>24</td>
</tr>
<tr>
<td>Ketoprofen</td>
<td>3.3 mg/kg</td>
<td>IV, IM</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Lignocaine</td>
<td>0.5 mg/kg</td>
<td>SC</td>
<td>35</td>
<td>35^*</td>
</tr>
<tr>
<td>with epinephrine</td>
<td>Local infiltration</td>
<td>Epidural</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Meloxicam</td>
<td>1 mg/kg, once</td>
<td>PO</td>
<td>15^*</td>
<td>15^*</td>
</tr>
<tr>
<td>Methadon</td>
<td>0.2 mg/kg</td>
<td>PO</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>Long-acting oxytetracycline</td>
<td>20 mg/kg, once</td>
<td>SC</td>
<td>35^*</td>
<td>35^*</td>
</tr>
<tr>
<td>Thiopental</td>
<td>&lt; 5 mg/kg</td>
<td>IV</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Tularthromycin</td>
<td>2.5 mg/kg, once</td>
<td>SC</td>
<td>34</td>
<td>1,080^*</td>
</tr>
<tr>
<td>Xylazine</td>
<td>0.016–0.1 mg/kg</td>
<td>IV</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>Yohimbine</td>
<td>&lt; 0.3 mg/kg</td>
<td>IM</td>
<td>72</td>
<td>72</td>
</tr>
</tbody>
</table>

^*Plus test” indicates that FARAD recommends testing the milk from treated animals to ensure it is free of residues of the parent drug and drug metabolites before it is marketed for human consumption.

^*Recommendation based on limited data; veterinarians are encouraged to submit a WDI request to FARAD each time this drug is used in an extralabel manner in the event that new data become available.

^Insufficient data currently available for FARAD to recommend a WDI.

^To convert mg/kg to mg/lb, divide by 2.2.

recommendation when ceftiofur hydrochloride is administered to small ruminants. Also, owing to the lack of data regarding drug residue depletion in milk, it is advised that the milk of small ruminants treated with ceftiofur in an extralabel manner be tested for residues of the drug before it is marketed for human consumption.

Fenbendazole—In the United States, fenbendazole is approved for the removal and control of stomach worms (Haemonchus contortus and Teladorsagia circumcincta) in nonlactating goats at a dose of 5 mg/kg (2.3 mg/lb), PO, with retreatment after 4 to 6 weeks, if necessary. The FDA-approved WDT for meat is 6 days following administration in accordance with the label directions, but a WDT for milk has not been established. Fenbendazole is approved for use in lactating goats at a dose of 5 mg/kg, PO, with a withdrawal period of 24 hours and 35 days in Australia and New Zealand, respectively, for milk.57,58 Milk residues following PO administration of fenbendazole at a single dose of 5 mg/kg to goats have been evaluated in 2 studies.11,12 However, because fenbendazole is not approved by the FDA for use in lactating goats, the detection of fenbendazole residues in milk marketed for human consumption is considered a violation. On the basis of the collective data available, FARAD currently recommends a 5-day WDI for milk from goats treated with a single dose of fenbendazole (5 mg/kg, PO).

Fenbendazole is not currently approved by the FDA for use in sheep in the United States. It is approved for use in sheep in Australia, Ireland, New Zealand, and the United Kingdom at a dose of 5 mg/kg, PO, with withdrawal periods for meat that vary from 10 to 28 days.57,60 Fenbendazole residues deplete the slowest in the liver, which is the target tissue for goats and cattle in the United States. Liver tissue concentrations of fenbendazole in sheep following administration of a single dose of the drug (5 mg/kg, PO) have been evaluated in 3 studies.11,13,14 On the basis of the results of those studies and foreign approvals, FARAD currently recommends a 29-day meat WDI for sheep administered a single dose of fenbendazole (5 mg/kg, PO).

Florencicol—Florencicol is not approved by the FDA for use in sheep or goats in the United States. Nevertheless, FARAD commonly receives WDI requests following ELDU of florencicol in small ruminants. Sheep and goats are frequently administered florencicol consistent with the label dosages for cattle (ie, 20 mg/kg [9.1 mg/lb], IM, q 48 h twice or 40 mg/kg [18.2 mg/lb], SC, once). A few studies60-66
have evaluated the use of florfenicol in goats, but none include information regarding depletion of tissue drug residues. Currently, FARAD recommends a 60-day meat and 7-day milk WDI for goats administered 2 IM doses of florfenicol (20 mg/kg) separated by a 48-hour interval and a 70-day meat and 26-day milk WDI for goats administered a single SC dose of florfenicol (40 mg/kg); FARAD also recommends that the milk from all treated goats be tested and free of florfenicol and metabolite residues before it is marketed for human consumption. This is especially important after SC administration because results of a study 67 in cattle suggest that florfenicol residues remain detectable in milk for a prolonged period.

In the United Kingdom, florfenicol is approved by the European Medicines Agency for use in sheep at a dose of 20 mg/kg, IM, every 24 hours for 3 doses, with the volume per injection site not to exceed 4 mL and a meat withdrawal period of 39 days. 69 Currently, FARAD recommends a 60-day meat and 7-day milk WDI for sheep administered 2 IM doses of florfenicol (20 mg/kg) separated by a 48-hour interval; FARAD also recommends that milk of treated sheep be tested and free of florfenicol residues before it is marketed for human consumption. Given the limited number of published studies, 60,68-70 involving IM administration of florfenicol to sheep and the lack of data regarding depletion of tissue drug residues, veterinarians are encouraged to contact FARAD for a WDI recommendation whenever florfenicol is administered by the IM route to sheep. Results of 1 study indicate that the half-life of florfenicol in sheep is 10.3 days in liver, the target tissue for cattle, following SC administration of the drug. On the basis of calculations performed by means of the FDA tolerance limit method, 71 FARAD currently recommends a 42-day meat WDI for sheep administered a single SC dose of florfenicol (40 mg/kg).

Flunixin meglumine—For sheep and goats, requests for WDIs following ELDU of flunixin meglumine are the most common queries received by FARAD. Although multiple studies 72-76 have assessed the use of flunixin meglumine in sheep and goats, none have evaluated depletion of tissue drug residues. Because flunixin meglumine is not approved by the FDA for use in sheep and goats, the detection of flunixin meglumine residues in any sheep or goat product marketed for human consumption is considered a violation. The FDA considers NSAIDs, including flunixin meglumine, drugs of high regulatory concern, and food animal tissues and products (eg, milk) are commonly screened for NSAID residues. Currently, FARAD recommends a 15-day meat and 96-hour milk WDI for sheep and goats following IM administration of a single dose of flunixin meglumine up to 2.2 mg/kg (1.0 mg/lb) and a 10-day meat and 72-hour milk WDI for sheep and goats following IV administration of a single dose of flunixin meglumine (2.2 mg/kg). Because those recommendations are based on the limited data currently available and NSAIDs are drugs of high regulatory concern, veterinarians are encouraged to contact FARAD for WDI recommendations following ELDU of flunixin meglumine in small ruminants in the event that new information becomes available.

Combined florfenicol–flunixin meglumine formulation—A combined florfenicol–flunixin meglumine formulation is approved by the FDA for use in cattle but not small ruminants. It is labeled for SC administration and has a 38-day meat WDT; it is not approved for use in dairy cattle > 20 months old regardless of lactation status. Because the product is not approved for use in sheep and goats, the detection of drug residues in sheep and goat products marketed for human consumption is considered a violation. Moreover, because the product is labeled for SC administration, residues are likely to persist for a prolonged period at the site of administration. The FDA-approved WDT for cattle was dictated by the florfenicol component of the formulation. Veterinarians should contact FARAD for WDI recommendations whenever this formulation is administered to small ruminants.

Meloxicam—In the United States, meloxicam is not approved by the FDA for use in any food-producing species. In Canada, New Zealand, and Australia, meloxicam is approved for use in non-lactating sheep at a single dose of 1 mg/kg (0.45 mg/lb), SC, in the neck behind the ear, with an 11-day meat withdrawal period. 57,58,59 Because meloxicam is not approved for use in small ruminants in the United States, the detection of meloxicam residues in any sheep or goat product marketed for human consumption is considered a violation. Meloxicam is frequently administered orally to sheep and goats. The pharmacokinetics of meloxicam following oral administration to sheep 78 and goats 79-81 has been evaluated in only a limited number of studies. Currently, FARAD recommends a 15-day meat WDI following PO administration of a single dose of meloxicam (1 mg/kg) to small ruminants. Owing to the limited data available and the fact that NSAIDs are of high regulatory concern, veterinarians should contact FARAD for WDI recommendations whenever meloxicam is administered to small ruminants.

Oxytetracycline—Currently, there are no FDA-approved oxytetracycline products for parenteral use in sheep or goats. In 2017, the most frequent request FARAD received regarding oxytetracycline in both sheep and goats was for WDI recommendations following SC administration of long-acting formulations. Subcutaneous administration of oxytetracycline to sheep 58 and goats 57 has been evaluated in 2 studies. Currently, FARAD recommends a 35-day meat and at least a 6-day milk WDI for small ruminants following SC administration of a single dose of oxytetracycline (20 mg/kg). Intravenous and IM administration of oxytetracycline to sheep and goats is discussed further in a previous FARAD Digest. 52
Penicillin G procaine—In the United States, multiple penicillin G procaine products are approved for IM administration to various food-producing species. Some of those products are available over the counter, whereas others are available only by prescription. In California, Senate Bill 2785 prohibits the over-the-counter sale of medically important antimicrobials, and penicillin G procaine can be obtained only by a prescription from a veterinarian issued within the confines of a valid veterinarian-client-patient relationship. Penicillin G procaine products approved by the FDA for use in sheep have meat WDTs that vary from 8 to 9 days; milk WD Ts have not been established for sheep. However, for most penicillin G procaine products, the label dose is generally considered ineffective, and the drug is often administered at doses 3 to 6 times the label dose, which is ELDU and necessitates the observation of extended WDUs. There are no penicillin G procaine products approved by the FDA for use in goats; thus, there is a zero tolerance for penicillin residues in goat products marketed for human consumption, and extended meat and milk WDUs are generally necessary. Owing to variation in dosing of penicillin G procaine in small ruminants in general, and the lack of pharmacokinetic data for goats in particular, veterinarians should contact FARAD for WDI recommendations following ELDU of penicillin G procaine in small ruminants. It is also advised that treated animals be screened for penicillin residues before milk or meat from those animals is marketed for human consumption.84-88 Milk and urine samples from treated animals can be screened for penicillin residues at most veterinary diagnostic laboratories, and in-house (or on-farm) commercial test kits for screening milk and urine for β-lactams are available. In fact, the kit used to screen milk for β-lactams has been validated for use in individual goats.89 When administering penicillin G procaine to small ruminants, it is important that the vial or bottle be agitated well to ensure the contents are evenly suspended so that the correct dose is loaded into the syringe, that the drug be administered by the IM route, and that the volume injected per injection site is limited to that recommended on the label to minimize the risk for violative residues.

Tulathromycin—Results of multiple studies indicate that the pharmacokinetics of tulathromycin following SC administration to goats is similar to the pharmacokinetics of tulathromycin for cattle. Currently, FARAD recommends a 34-day meat WDI for goats following SC administration of a single dose of tulathromycin (2.5 mg/kg [1.1 mg/lb]). Like all macrolides, tulathromycin persists for an extended period in the milk of treated animals.89,90 For the lactating goats of 1 study,91 tulathromycin residues were still detectable in milk 45 days after administration of a single dose of the drug (2.5 mg/kg, SC). Therefore, administration of tulathromycin to lactating animals is not recommended. Additionally, because tulathromycin is not approved for use in goats, it is important to remember that the detection of tulathromycin residues in goat products marketed for human consumption is considered a violation.

In the United Kingdom, tulathromycin is approved for use in sheep at a dose of 2.5 mg/kg, IM, once.92 On the basis of WDJ requests submitted to FARAD, it appears that sheep and goats are frequently administered the cattle dosage (2.5 mg/kg, SC, once) of tulathromycin. To our knowledge, only 1 study has been published in which SC administration of tulathromycin was evaluated in sheep, and depletion of tissue drug residues was not assessed in that study. Because of the lack of published data regarding administration of tulathromycin to sheep, veterinarians should contact FARAD for WDI recommendations following ELDU of tulathromycin in sheep.

IMM drug formulations—Mastitis causes both physical and chemical alterations in the mammary glands and milk composition, and those changes can affect the distribution and elimination of drugs administered by the IMM route.92 For IMM drug formulations, administration of the FDA-approved dose for cattle (ie, 1 tube/mammary gland) to sheep and goats results in a much higher dose on a milligram-per-kilogram basis than that achieved for cattle. Because of the size discrepancy between small ruminants and cattle, FARAD hypothesizes that milk residues of IMM-administered drugs may be prolonged in small ruminants relative to cattle, but to our knowledge, data to validate or refute that hypothesis are not currently available. Results of 1 study indicate that, following IMM infusion of cefuroxime, cephalixin, or cloxacillin, drug elimination from milk was quicker in high-producing goats than in low-producing goats. A similar phenomenon has been described for lactating cattle.93,94 In another study, the duration of detectable milk drug residues varied greatly and was much longer than that for cattle when lactating dairy goats were administered a commercially available IMM antimicrobial in accordance with the label directions for dairy cattle. The investigators of that study attributed differences in the duration of detectable milk drug residues between goats and cattle to factors such as differences in body size, milk volume, and extent of flushing within the mammary gland. Results of other studies also indicate that stage of lactation and milk production contribute to drug elimination differences between small ruminants and cattle following IMM drug administration. However, results of another study indicate that the milk discard time for goats was similar to that for cattle following IMM infusion of the cattle dose for each of 4 IMM antimicrobial formulations. Results of other studies suggest that dairy sheep and goats receiving the cattle dose (1 tube/mammary gland) of a dry cow treatment immediately after the last milking before the dry period (ie, period before parturition during which female dairy animals [sheep, goats, and cows] are not milked) were at low risk for drug residues in milk following parturition, likely owing to the fact that the dry period of dairy sheep and goats is often longer than that for dairy cows. However, extrapolation of data from bovine studies in regard to IMM administration of
drugs in small ruminants may not be appropriate owing to interspecies differences and differences in the mastitis status of individual animals.\textsuperscript{105}

Although the gross composition of caprine milk is similar to that of bovine milk, there are some differences that may affect the absorption, distribution, and elimination of drugs following IMM infusion. The composition of the casein and whey proteins fractions of caprine milk differs from that of bovine milk, and caprine milk has a higher proportion of free fatty acids and smaller fat globules than bovine milk.\textsuperscript{105} Additionally, milk is secreted by an apocrine process in goats and a merocrine process in cows; consequently, milk of healthy goats has a higher somatic cell count than the milk of healthy cows.\textsuperscript{106} All of those factors can affect the pharmacokinetics of drugs following IMM infusion. Veterinarians are encouraged to contact FARAD for recommended WDIs following ELDU of IMM drug formulations in small ruminants.

**Summary**

The purpose of this FARAD Digest was to provide US veterinarians guidance regarding ELDU in small ruminants. The lack of FDA-approved drugs for sheep and goats frequently necessitates ELDU in those species. When the FDA approves a drug for use in a particular species, it establishes a tolerance for that drug in the various tissues or products (e.g., milk or eggs) of that species that might be consumed by people. When a drug not labeled for use in a small ruminant is administered in an extralabel manner, there is a zero tolerance for residues of the parent drug or its metabolites in the edible tissues or products of treated animals, and detection of the parent drug or metabolites in any product marketed for human consumption is considered a violation and subject to regulatory action. Given the lack of tolerance and pharmacokinetic and tissue depleation data for many drugs administered in an extralabel manner to small ruminants, extended meat and milk WDIs are generally required to ensure that drug residues are undetectable. Veterinarians need to be cognizant of the requirements for legal ELDU in food-animal species to safeguard the human food supply while continuing to promote the health and welfare of small ruminants.

**Acknowledgments**

The FARAD Program is funded by a USDA National Institute of Food and Agriculture grant.

**Footnotes**

a. Baynes RE, Department of Population Health and Pathobiology, College of Veterinary Medicine, North Carolina State University, Raleigh, NC. Unpublished data, 2018.


c. MeatSafe β-Lactam Test, Silver Lake Research Corp, Monrovia, Calif.

**References**


Sheep and Goat Insect Management

John B. Campbell, Extension Entomologist

Most of the insects that infest sheep also infest goats, but some of the goat lice species are specific for goats. Very few insecticides are approved for lactating goats. For listings of insecticides for control of insect pests of sheep see EC1550, Nebraska Management Guide for Arthropod Pests of Livestock and Horses. John Lloyd, University of Wyoming, has provided much of the information used here on sheep parasites.

Sheep Ked

The sheep ked is a wingless fly that resembles a tick. Keds spend their entire life cycle on sheep, transferring between animals by contact. The female deposits living individually on wool strands. A red puparium (case) is formed around the ked. After about 21 days the fully developed ked emerges from the case and begins to feed on blood.

Sheep keds are detrimental only when the sheep are on a poor nutritional plane (poor range). Keds feed by piercing the skin and consuming blood. This causes a condition known as “cockle.” Hide buyers downgrade sheep skins with “cockle” because it weakens the hide.

Sprays, dips and power or hand-dusting with insecticides are all effective methods for controlling sheep ked. Shearing time is the most convenient and efficient time to treat.

Several sheep-producing states have adopted a sheep ked-free program which was initiated in Wyoming. All sheep in the program were treated for keds at shearing time. All replacement or breeding stock were treated prior to being placed in the flock. Sheep marketed from the participating states were certified as being ked-free.

Sheep Lice

The African sheep louse, sheep foot louse and goat-sucking louse are all blood-sucking lice. The sheep-bit ing louse feeds on skin. Distribution and abundance of these species is not well-known. The lice cause sheep to rub and scratch, sometimes to the point of denuding areas of skin. Anemia is a common result of high populations of lice and may predispose the animal to respiratory or other diseases.

Low pressure insecticide sprays and dusts are adequate for sheep lice control. Adding detergent to the spray will increase its sticking ability.

Goat Lice

Several species of lice infest goats and separate species may occur on meat goats and Angora goats. Lice species may intermingle if the two goat types are run together. A few individuals of all species may be found on both goat types.

Two species of blood-sucking lice are found on goats; the goat-sucking louse and the African goat louse. These species are similar in appearance and are bluish-gray.

There are three species of chewing or biting lice parasites on goats. Bovicola crassipes (Rudow), a large yellow louse, and the Angora goat biting louse are normally found on Angora goats. The goat biting louse, Bovicola caprae (Guret) is commonly found on meat goats.

Goat lice, like other lice species, spend their life on the animal. They can transfer from one animal to the other on close contact. Eggs are attached to hairs by a viscid substance secreted by the female. The life cycle ranges from 20-40 days depending on temperature.

The presence of lice on goats is accompanied by scratching and rubbing. The effect depends on the number of lice present. Blood-feeding lice cause the most severe symptoms. Excessive feeding causes scabby, bleeding areas that may lead to bacterial infection. Mohair on Angora goats may be damaged to the extent of reduction in value of 10-25 percent.

Sheep Seab

Psoroptic scab (scabies), a highly contagious skin disease of sheep, is included in the Federal Quarantine Act. Federal and state quarantines and treatment have reduced the incidence of this pest to only a few cases per year.

Uneven wool that looks picked and thin and scabbing surface wounds are signs of the mite. Positive diagnosis can be made by scraping lesions and examining the scrapings microscopically for mites. Federal regulations require infected sheep to be dipped twice within a 10- to 14-day period with a special formulation of sulfur or injected with Ivomec.

Sheep Nose Bot Fly

The female bot deposits living larvae (maggots) in the nostrils of sheep. The larvae migrate to the head sinuses and, after development, migrate back down the nasal passages, dropping to the ground where they complete development to the adult form. There are two or more generations per year in most of the United States. A packing house survey (1983-1987) by Wyoming indicated that 90 percent of the sheep from Wyoming, Colorado, Nebraska and Idaho had sheep nose bot infestations during 11 months of the year.
The "strikes" of the fly while depositing the larvae in the nostril irritates sheep. They bunch and keep their noses down to the ground in an effort to avoid the strikes. When the bots are migrating to and from the head sinuses, the nasal membranes are irritated and secondary infections can occur at the irritation sites.

Blood flecks in the nasal discharge and sheep banging their heads against feed bunks, fences or the ground indicate the presence of nose bots. Severely infested older or weak sheep may die as a result of the bots.

Presently, only one product is registered for control of the sheep nose bot. Ivomec (ivermectin) is registered as an 0.08 percent Al oral drench, administered at a rate of 3.0 ml/26 lb body weight. The treatment-slaughter interval is 11 days. Treat after hard frost, which kills the bot fly and assures no reinfestations.

Flies

Some species of blow flies (the black blow fly in particular) lay eggs in dirty wool, usually in the crotch area or on wounds. Upon hatching, the fly maggots spread over the animal and feed on the skin surface. Maggot-infested sheep become restless, stamp their feet, try to bite the irritated areas and may leave the flock to hide in secluded places. Care and medication of wounds, early shearing or clipping, and cleaning dirty areas before the spring blow fly season should be considered as part of the control program.

House flies, stable flies and face flies also bother sheared sheep in the summer. These flies feed on shearing wounds or the thin, exposed skin. This delays wound healing or causes wounds. Sheep react to these flies as they do the blow flies, which can cause decreased animal performance.

Biting Gnats

In Nebraska, several species of blood-feeding gnats (midges) in the genus Culicoides feed on livestock. Of particular importance to sheep is C. varipennis because it transmits bluetongue, a viral disease. This disease is particularly serious to sheep and white-tail deer.

Infected sheep have inflammation, swelling and hemorrhaging of the mucous membranes of the mouth, nose and intestines. Inflammation and soreness of the feet also are associated with the disease. The tongue and membranes of the mouth may look red or dirty blue, hence the name. The mortality rate for infected sheep is about 50 percent. Secondary effects include abortions and deformed lambs.

In areas where bluetongue is endemic, some management practices will reduce the incidence of the disease:

- Graze sheep away from aquatic areas — the breeding sites of the gnats.
- Drain and clean runoff areas from feedlots. Gnats breed in standing water rich in organic matter.
- Vaccinate sheep in areas with a history of the disease.

West Nile (WN) virus has been positively identified as the cause of death for at least one lamb in Nebraska. WN virus is transmitted by mosquitoes. The first three management practices listed for the reduction in the incidence of bluetongue would also be helpful in reducing mosquito feeding on sheep.

Spinose Ear Tick

This tick is a parasite of several domestic animals, including sheep, with cattle as its primary host. It is found primarily in arid range areas in southwestern states. Its occurrence in Nebraska is usually on sheep or cattle shipped into the state. The adults do not feed and are found around corral or loafing areas frequented by sheep. Eggs are deposited in these areas.

Young larvae crawl up on vegetation and wait for contact with a host animal. After contact and attachment, they move to the ear, crawl to the inner folds of the outer ear, and begin to suck blood or lymph. The larval form changes to a nymphal form that also feeds on blood. When nymphal development is completed, the tick drops to the ground and completes development to the adult form. The feeding area within an animal's ear may become infected (canker ear). The irritation causes animals to become dull and unthrifty, decreasing animal performance. Heavily infested older or young animals may die.

Early in the spring, sheep in small flocks that are encouraged to graze in shelter belts and other vegetative areas around the farmstead may become infected with a few wood or American dog ticks. Sheep are not preferred hosts so the tick usually will drop off before engorging.

Resources


UNL Extension publications are available online at: http://extension.unl.edu/publications.

Index: Insects and Pests
Livestock
1993, Revised July 2006
Internal parasites are a significant threat facing today’s small ruminant producer. Problems associated with parasites, particularly those of the gastrointestinal tract of sheep and goats can cause irreversible damage or even death to the animal, reduced performance and economic loss for the producer. Animals that are overburdened with parasites can be hindered in their reproductive performance, experience reduced growth rates, and become less productive overall, whether their purpose be meat, fiber, or milk. Prevention and control of the parasites that infect sheep and goats are becoming increasingly difficult due to generations of overuse and improper use of the available anthelmintic dewormers, which results in increasing resistance by parasites to common anthelmintics.

This paper will be used to give producers a general understanding of the parasites that affect their animals, how they live, and methods that can be used to lower their costs and losses due to parasite infestations.

Sheep and goats are affected for the most part by the same parasites. By far the most deadly internal parasite to small ruminants in the Midwestern United States is the gastrointestinal roundworm *Haemonchus contortus*, also known as the barber pole worm and a variety of other names. *Haemonchus contortus* is a blood sucking parasite that can cause severe anemia, protein loss and death in goats and sheep, and thus is the most important to control. Some other parasites that affect sheep and goats are those of the *Trichostrongylus* family, particularly *Teladorsagia circumcincta* and *Trichostrongylus axei*, and the protozoa coccidia. *Haemonchus contortus* is the most dangerous parasite to sheep and goats in many parts of the United States, although other parasites may be important in different regions outside the Midwest.

However, by developing a parasite control plan aimed at *Haemonchus*, the majority of other dangerous parasites will be controlled as well.

**Lifecycle**

Sheep and goats are generally affected by the same parasites, although certain parasites may affect one species more severely than the other. Treatment methods may vary between sheep and goats. In order to know how best to prevent future problems with parasites and control current infestations, it is necessary to understand the general life cycle of the parasites most common to sheep and goats.

![Figure 1: The lifecycle of a gastrointestinal parasite. This image is courtesy of Virginia Tech Cooperative Extension.](image-url)
*Haemonchus* has a lifecycle that takes approximately 21 days to complete (see Figure 1). The cycle begins when the larvae in the infective L3 stage of development are ingested from the grass and travel to the abomasum, or true stomach, of the host. Once in the abomasum the larvae will follow one of two paths. They may proceed with further larval stages and the eventual development into adults, or they will go into hypobiosis. This is an inhibited, or arrested development state, that occurs when conditions are not conducive for the entire life cycle to be complete.

When the L3 stage larvae enter the abomasum, provided that environmental conditions are favorable, they will molt into the L4 stage of larval development and will then molt once more into adults. Factors that induce the molting of the L4 larvae into adults include: greening of grass, a rise in environmental temperature, rain following a drought period, increased estrogen levels in the host, and possible even a photoperiod stimuli. Once the molt into an adult form is complete adults then begin to lay eggs in the abomasum.

In the case of *Haemonchus* and *Ostertagia*, the L4 larvae can go into arrested development, or hypobiosis. Hypobiosis is a period of dormancy that occurs when the environment is not conducive to the lifecycle of these parasites. Larvae in different regions may go into hypobiosis in different times during the year, depending on the environment. For example, in the Midwestern states, Haemonchus larvae will likely become dormant during harsh winters. In southern parts of the country, hypobiosis may occur when the weather is too hot or dry for larvae to survive.

During hypobiosis the L4 larvae hibernate in glands in the abomasum without developing further or causing problems for the host. They remain metabolically inactive until they receive signals that indicate it is time for them to resume development and then begin to lay eggs. The signals that spur the L4 larvae to come out of hypobiosis are the same signals mentioned above that indicate to them to develop in the first place. Once larvae leave hypobiosis, they resume the normal lifecycle and begin to lay eggs.

*Haemonchus* adults require about 14 days to begin laying eggs (see Figure 2) in the stomach after reaching adulthood. The *Haemonchus* adult female can lay up to 5,000 eggs per day, yet another reason why *Haemonchus* is so difficult to control and so dangerous to sheep and goats. Females that have gone through hypobiosis over the winter generally resume development two to four weeks prior to lambing or kidding and begin to produce eggs. This phenomenon is called the "periparturient rise" in fecal egg counts (will be discussed later). The eggs laid in the abomasum are expelled from the body via the feces.

Eggs in the feces generally remain inactive for a few days in the environment, until the environment and temperature become favorable for the development of these eggs into larvae. The larvae hatch from the egg and then emerge from the pellets and move through larval stages L1, L2 and L3 of development. Once the larvae reach the L3 stage, the infective stage, they emerge from the fecal pellet and climb up onto blades of grass (see Figure 3) where they wait to be ingested by a grazing animal, thus completing the lifecycle. In
order for the larvae to emerge from the fecal pellet in which it was expelled from the body, the environment has to be in a condition that keeps the pellet moist and pliable. Optimal conditions for the L3 larvae to emerge from the pellet are warm, wet conditions, like those that usually occur in the early spring.

An important characteristic of these larvae that must be taken into account when designing a parasite control plan is that the L3 larvae can survive on pasture for extended periods of time, making pasture management a key component in the prevention and control of parasite infection. The L3 larvae can survive on pasture for up to 90 days in the summer, and up to 180 days in the fall or winter. The *Haemonchus* larvae thrive in temperatures ranging from 70° to 80° Fahrenheit where there is an average of approximately 2 inches of rainfall per month. Extremely hot or dry environments will cause egg laying to stop, but the larvae can survive temperatures below 32° F. *Ostertagia* larvae prefer cooler temperatures, with their optimum temperature for development being around 40° Fahrenheit. These larvae are very resistant to adverse winter conditions, and can over-winter on pasture.

**Animal Susceptibility**

Individual goats and sheep vary in their degree of susceptibility to *Haemonchus* and other parasites. Some animals, by means of their genetics, are much more resistant or resilient to parasitic infections, and can survive parasite levels without showing any symptoms while another animal may be killed by that level of infestation. This genetic resistance can be used when selecting breeding stock, since a herd that exhibits more innate resistance to parasites will cost less to maintain and will ultimately be more profitable to the producer.

Animal age and stage of development also have a significant impact on the susceptibility to parasites. As animals age, they are exposed to more and more parasites and develop some immunity to infection. This is more likely with sheep than with goats. Resistance describes an animal’s ability to resist infection from parasites, while resilience describes the animal’s ability to withstand infection from parasites once it has occurred.

Young animals that are growing and are on continuous permanent pasture are the most susceptible to parasites. These animals have very low levels of immunity, and are extremely susceptible to infection from parasites on pasture. They are also exposed to many eggs at a young age due to the periparturient egg rise of the ewe or doe. The lambs and kids will begin to develop some immunity to parasites around six to eight weeks of age, provided that they do not reach pathogenic levels of parasites in their system before this time. Lactating ewes and does on pasture follow the lambs and kids with slightly increased resistance to infection. Lactating animals are often in a negative energy balance, and therefore are weaker and less able to resist the effects of parasites on their body. Goats at any reproductive stage are more susceptible to parasitic infection than sheep.

Ewes or does in late gestation, and for a short period after parturition lose much of their resistance to parasites due to hormonal and photoperiod effects. During this period, the ewe or doe is no longer able to resist worm development or egg production. This phenomenon is termed the “periparturient egg rise,” and is a critical time in the parasite control plan. It is particularly important because it coincides with a time when the number of susceptible animals (kids or lambs) increases significantly. Finally, mature dry ewes are the least susceptible to parasitic infections. These animals have some immunity due to their age, and are under no real stress to their system that could lower their body’s ability to resist parasitic infections. Goats of any age have little natural resistance or resilience to parasitic infection.

**Recognizing Parasitic Infections**

When animals are heavily burdened with parasites, there are a variety of symptoms that can be used to identify if an animal is infected with parasites, and which parasites are causing the problem. Some general symptoms typical of parasite infections are diarrhea, weight loss or reduced weight gain, unthriftness, loss of appetite, and reduced reproductive capacity and performance.

In the case of *Haemonchus*, anemia and edema, or swelling, are key symptoms. The *Haemonchus* parasite can consume up to 1/10th of an animal’s total blood volume in a day. Anemia is most easily identified in small ruminants by the color of the mucous membranes, particularly those in the lower eyelid. A normal animal will have healthy, red mucous membranes, while one heavily burdened with *Haemonchus* will exhibit light pink or white membranes. Edema may also occur in animals heavily burdened with *Haemonchus*. This accumulation of fluid will be most obvious as a swelling in the lower jaw, a condition known as “bottle jaw” (see Figure 4). Diarrhea is not a common
symptom of *Haemonchus* infection, although it has been known to occur in some cases.

In order to make a definitive diagnosis of the parasite burden of your herd, it may be necessary to enlist the help of a veterinarian or a laboratory. Fecal egg counts can be done to measure the number of eggs shed in the feces of a random sample of animals in the herd. Fecal egg counts are mainly useful in determining the level of contamination on the pasture, since these numbers vary significantly from herd to herd and animal to animal. Some herds may be quite resistant to parasites, and will have large fecal egg counts with no significant health problems. Other herds may be very susceptible to parasites and a low egg count can still be indicative of some problem. Fecal samples can also be used to determine which species of parasite is infecting the herd in question. In some cases blood tests can also be used as a diagnostic tool for parasitic infection.

**Control**

The main goal in attempting to control *Haemonchus* and other internal parasites is to break the life cycle, which can be done in a variety of ways. The three methods that will be discussed in this publication are use of anthelmintics, animal management, and pasture management. Using a combination of these three will usually give the best results, and the best chance of breaking the life cycle of *Haemonchus* in your herd.

**Pasture Management**

Pasture management is a key aspect in breaking the lifecycle of internal parasites. As mentioned in the previous section, infective larvae can survive for long periods of time on pasture. The grazing habits of sheep and goats make them much more susceptible to parasites than other species. Sheep tend to graze much closer to the ground than other animals, and also show little aversion to grazing in areas with high fecal contamination. These two characteristics drastically increase the numbers of larvae that sheep are exposed to and also the number that they are likely to ingest. Although parasite problems cannot be entirely eliminated by good pasture management, using good rotational grazing techniques combined with an efficient anthelmintic program should significantly lower the parasite problem in the herd.

As was described in a previous section, the infective L3 larvae of *Haemonchus* can survive on pasture for extended periods of time. The goal of pasture management is to allow the pastures enough time to rest so that lower numbers of larvae are infective and will not be a problem to the grazing animals. There are varying ideas of what a “safe” pasture consists of, but a general rule is that a pasture is considered relatively free from *Haemonchus* if it has been tilled or burned since the last time that sheep and/or goats grazed the land. The land would also be considered safe if it has been grazed by other species of animals (especially cattle or horses), or if three months have passed since it was last grazed during the spring or summer and if six months have passed since it was last grazed over the winter. Pasture that has had a crop of hay removed is also considered safe.

Allowing pasture to rest stops the land from having any more parasites deposited on it, and it also allows for new growth, which lowers the risk that sheep and goats will ingest the larvae present in the pasture. When pasture is overgrazed, sheep, which tend to graze close to the ground anyway, are exposed to even more of the larvae that live low down on blades of grass. When done properly, pasture management can reduce the number of parasites that sheep and goats are exposed to. The best way to avoid pasture related parasite problems is to avoid overgrazing areas of pasture, and to implement a rotational grazing system. Rotational grazing implies that once a pasture has been grazed, animals are rotated to another paddock and the pasture is allowed a rest period. If cattle or horses grazing can be incorporated into the grazing system, parasite contamination can be reduced even further. Safe pastures can also be created by planting or utilizing summer annual forage crops. Examples of these would be sorghum x sudan hybrid forages. These forages grow quite tall and animals graze at shoulder or higher height (see Figure 5). This reduces the
opportunity to ingest larvae. Also, goats are natural browsers, and browsing forages or brush well above ground level has the same effect.

**Anthelmintics**

Anthelmintics (see Figure 6) are drugs that either kill egg laying adults, or kill larvae before they become adults and become capable of laying eggs. While some anthelmintics are effective in killing *Haemonchus*, there are two major problems that arise when using anthelmintics. The first problem that affects mainly sheep and goat producers is that there are very few anthelmintics that are actually approved by the FDA for use in small ruminants. The second problem is the resistance that parasites have developed to many anthelmintics. Resistance occurs when a drug is overused and the parasites develop a tolerance to the drug, making it no longer effective in killing them. Resistance makes it very difficult to effectively control *Haemonchus* because it lowers the number of options available to treat the parasite, especially since resistance to one drug often means that a parasite will be resistant to all drugs in that compound class. Resistance will be discussed in more depth in a later section.

Anthelmintics can be used in conjunction with rotational grazing and proper pasture management (discussed in a later section) to lower the number of parasites that the herd is exposed to. It used to be a recommendation to deworm animals and then rotate to a new pasture. More current thinking is this practice allows eggs from resistant parasites to have a competitive advantage on the pasture rotated on, thus enhancing resistance development. After treating animals for parasites they should be left in original pasture for a couple of days before rotating. Under some circumstances, it is recommended to keep animals on a dry lot for 12 to 24 hours after deworming. This ensures that the eggs and larvae that survived the anthelmintics are not deposited on safe pasture. The decision whether or not to dry lot animals after treating with anthelmintics should be based on the season, the type of anthelmintics used, and the diet of the animals. It is usually more important in goats than sheep, since goats tend to metabolize anthelmintics faster than sheep and have a faster passage rate through the intestinal tract.

Ewes and does should also be dewormed prior to breeding and approximately two weeks prior to and one week after lambing or kidding to help combat the pre-parturient egg rise. There may also be a need for treatments throughout the grazing season, depending on the specific situation and condition of your herd. The suggestions described in this section are up to the discretion of the producer and veterinarian. There are a variety of methods that can be used to monitor the parasite levels in one’s herd, and also to lower the chance of developing drug resistant parasites in your herd.

There are three main classes of drugs that are currently used as anthelmintics in sheep and goats. These three are avermectins, benzimidazoles, and imidazothiazoles. These classes contain all of the
anthelmintics that are used in controlling and treating parasites in goats and sheep.

**Benzimidazoles**

Benzimidazoles contain the anthelmintics albendazole, fenbendazole, mebendazole, oxfendazole, and oxibendazole. Fenbendazole is approved for use in goats, and albendazole is approved for use in sheep. This class of anthelmintics is also known as the white drenches. While benzimidazoles have a high margin of safety (meaning that it can safely be given at double or triple the labeled dose) and are effective against many species of intestinal parasites, their efficacy against *Haemonchus* is fairly low. The other problem with benzimidazoles, which is more pronounced in this class of drugs than in others, is that if a parasite is resistant to one of the benzimidazoles, the resistance is most likely widespread among all of the drugs in this class.

**Avermectins**

The main drugs in this class are ivermectin and moxidectin. Both drugs are effective against *Haemonchus* in normal situations, but they are only approved by the FDA for use in sheep, and requires extra-label use in goats. Extra-label use requires that the producer work with a veterinarian to get a prescription for the desired drug, as well as the proper doses and withdrawal times when using the anthelmintics. Sheep should be given the sheep drench form of ivermectin and moxidectin, and goats should receive a higher dose.

**Imidazothiazoles**

The most important drug for sheep and goats in this class is levamisole. Levamisole is approved for use in sheep and is also shown to be very effective against *Haemonchus*. There is less of a resistance problem to levamisole than there is to benzimidazoles.

**Extra Label Use of Anthelmintics**

Many drugs that are not approved for use in sheep and goats are perfectly safe to use, they remain unapproved however because of the expense associated with getting FDA approval for drugs. The small ruminant industry is not prominent enough in this country to warrant the government or the drug companies expending the money necessary to do the research and approve the drug. The goat industry suffers even more than the sheep industry from this perspective, because there are even fewer anthelmintics approved for use in goats. However, although some drugs are not approved for use in a particular species, they can still be used to treat parasite infections through extra-label use.

As mentioned previously, extra-label use requires the producer to work closely with a veterinarian to get a prescription for the desired drug, as well as the proper doses and withdrawal times when using the anthelmintics. Through extra-label use, goats can be treated with ivermectin, doramectin, levamisole, and moxidectin. There are more anthelmintics approved for use in sheep, so there is less necessity for extra-label use than with goats.

**Administration of Anthelmintics**

Anthelmintics can be administered to animals by varying means, with the most common being in the form of oral drenches. Oral drenches are thick liquid suspensions of the anthelmintics that are deposited into the back of the animal's mouth (see Figure 7).

Some anthelmintics are available in the injectable form, but these are not generally recommended for use in small ruminants. It is particularly important when using drugs not labeled for use in sheep and goats that the concentration of the active substance be considered when determining the appropriate dose for the animals. It is also necessary to realize that sheep and goats metabolize many anthelmintics at different rates, with goats usually metabolizing the drugs faster and often requiring a larger dose.

When using products that are not approved for sheep and goats, it is imperative that the amount being given is in fact the recommended dose for sheep or goats, not the species for which the formula is marketed. Some products may be marketed for cattle as injectable or pour on, but will be ineffective if administered to sheep or goats in this manner. Pour-on anthelmintics are formulated to be absorbed through the skin of cattle, but do not absorb in therapeutic amounts.

Figure 7: This picture shows an oral drench being administered to a goat.
through sheep and goat skin due to the wool and hair of these species. It is also important that drenches are mixed in the proper way and administered while they are still effective. If drenches are not mixed properly, they may settle out, and the animal will not receive the effective amount of the anthelmintics. It should also be common practice to check the expiration date of a product before administration.

**Parasite Resistance to Anthelmintics**

Resistance is one of the main reasons why parasites, *Haemonchus contortus* in particular, are such a huge problem for small ruminant producers. Producers may find one method or anthelmintic that appears to effectively control parasites in their herd, but the efficacy of anthelmintics can be significantly lowered when resistance develops. Resistance is very difficult to overcome because it reduces the number of anthelmintics available to treat the herd and may last for years.

Resistance to anthelmintics has developed as a result of years of overuse and improper dosing with available anthelmintics. When producers continuously deworm their herd with the same anthelmintics, fewer and fewer parasites are killed with every treatment, and genetic selection for resistant parasites occurs. This resistance occurs mostly when animals are underdosed, meaning that the amount of anthelmintics administered to the animal is not enough to kill a significant number of parasites. The parasites that are resistant to the drug then begin to reproduce and the number of resistant parasites in the animal continues to multiply until that particular drug is no longer effective at all.

**Checking your herd for resistance**

If a producer suspects that resistance may be present in his herd, there are a few things that need to be considered. Anthelmintics can be ineffective for a variety of reasons, which should be ruled out before resistance is determined as the root of the problem. Improper dosing is a major reason for the reduced or total lack of efficacy in anthelmintics. Before administering the dewormer, it is important to make sure that the dosing gun is calibrated properly and that the proper dose is being delivered to the animal.

When all of these possibilities for ineffectiveness of a dewormer can be ruled out, a Fecal Egg Count Reduction Test may be necessary in order to determine the efficacy of the anthelmintics. This test, more commonly called FECR test, involves taking fecal samples from a random group of animals within the herd. Samples should be taken at the time of deworming and then again 10 to 14 days from the same animals after treating with an anthelmintic. In order for an anthelmintic to be considered effective, there should be at least a 95 percent reduction in the number of eggs between the two samples. If the test shows a reduction of less than 95 percent between the two samples, it is probably time to rotate to a new class of drugs (see Figure 8).

![Figure 8: This picture shows people in a lab reading the results of a Fecal Egg Count Reduction test.](Image)

**Avoiding Resistance**

First and foremost, resistance can be prevented by making certain that herds are all dosed for the heaviest animal in the class, with does, bucks, and kids each making up a separate class within the herd. Most anthelmintics (except levamisole) have a wide safety margin, so it is not dangerous to give the smaller animals a dose higher than the recommended amount. If lambs or kids are included in the herd, all of the lambs or kids should be dosed according to the weight of the heaviest lamb or kid in the herd. It is imperative that the equipment being used to administer anthelmintic medication to animals is calibrated properly, and that the compound itself is effective, not out of date, improperly stored or ineffective due to resistance.

Producers can avoid resistance in their herd by not purchasing animals that already show signs of having resistant parasites. If these animals must be purchased, they should be aggressively treated for parasites, and quarantined from the rest of the herd for 21 to 30 days. They should be treated with anthelmintics from three different classes in order to avoid leaving any worms present that may be resistant to one of the classes of anthelmintics. Using three different drug classes
should kill all of the worms present in the animal. Following deworming, the animal should remain separate from the herd in a dry lot for 21 days, and a fecal egg count should be performed in order to ensure that the deworming achieved the desired results.

Rotation of dewormers is also a common practice in attempting to avoid resistance. Past recommendations advocated that producers switch between different classes of anthelmintics with every deworming. However, this practice has now been shown to increase resistance by selecting for worms that are resistant to different drug classes at the same time. With most anthelmintics, if worms are resistant to one member of that drug class, they will be resistant to all of the members of that class. The current recommendation is that anthelmintic dewormers be rotated on an annual basis, or until the current drug loses its effectiveness. By using the anthelmintic for a longer period of time, the development of resistance is slowed.

It is becoming a common practice to deworm only some of the animals in the herd. This practice is based on the knowledge that in most herds 20 percent of the animals carry approximately 70 to 80 percent of the parasite burden. By only deworming a small portion of the herd, there is a population of worms left in refugia. Refugia refers to the population of worms that are left untreated, and therefore are still susceptible to anthelmintics. By maintaining this sensitive worm population, the anthelmintic resistant genes are diluted among the population, and resistance is slowed down. A system called the FAMACHA system was developed in South Africa based on the refugia concept. It is used as a way to combat resistance and lower the cost to sheep and goat producers of *Haemonchus* loss, treatment, and control.

**FAMACHA**

As was mentioned in the previous section, FAMACHA is a system that was developed in South Africa to aid farmers in combating the problems of parasite resistance and high treatment costs in sheep. The goal of the FAMACHA system is to decrease and delay resistance by only selectively treating the animals in the herd that are showing symptoms of parasite infection.

*Haemonchus* has already been described as a blood sucking parasite that causes severe anemia in its hosts. FAMACHA utilizes the color of the mucous membranes in the lower eyelid to determine the level of anemia that the animal is experiencing. The FAMACHA chart (see Figure 9) assigns a number from 1 to 5 to each level of color in the eyelid. A normal eyelid of a healthy sheep or goat is dark red, indicating that no anemia is present and the animal is presumed to be free of dangerous levels of parasites. The range of colors used in the FAMACHA system goes from Red, to reddish pink, to pink, to pinkish white, to white. The numbers 1 to 5 are assigned to each of these values, respectively. Although some dispute remains as to where the cut off for treatment should be, producers generally treat animals with a score of a 4 or a 5, and in some cases a 3. Since goats are affected more seriously by internal parasites than sheep, the cut offs for treatment in goats may be lower than in sheep to prevent serious loss from occurring. Treatment also depends on class of animal and the relative susceptibility of that class of animal (i.e. buck, doe, kid, lamb). Producers can be trained and certified to

---

**Figure 9:** This image is the FAMACHA chart that depicts the eyelid color associated with each level of anemia and each FAMACHA score.
use the FAMACHA system (see Figure 10). The FAMACHA system can be a valuable tool in helping to delay resistance issues in sheep and goat herds.

**Recommendations for Effective Management of Internal Parasites**

- Remember that effective management of internal parasites cannot be accomplished by using only one management factor; it is a combination of factors that will produce the most effective defense against internal parasites.
- Anthelmintics should be used only to treat animals when necessary, and should be thought of as a limited resource to be used sparingly.
- Rotation between different classes of anthelmintics can slow the development of resistance.
- Remember, if a parasite becomes resistant to one drug in a class, it is probably resistant to all drugs in that class.
- The FAMACHA system can be used to identify which animals are in need of anthelmintic treatment.
- Proper pasture and animal management is a key component to managing internal parasites in sheep and goat operations.

**References**


Fitch, Gerald Q. *Internal Parasite Control of Sheep in Oklahoma.* Oklahoma State University.

Greiner, Scott P. *Control of Internal Parasites in Sheep.* Virginia Cooperative Extension, May 1998.

Hartwig, Nolan, DVM. *Control of Internal Parasites of Sheep.* Iowa State University. April, 2000.

Kaplan, Ray M. DVM, PhD. *Responding to the Emergence of Multiple-Drug Resistant Haemonchus contortus: Smart Drenching and FAMACHA®.* Department of Medical Microbiology and Parasitology, College of Veterinary Medicine, University of Georgia, 2004.


Rook, J.S. DVM. *Available Sheep Anthelmintics (Dewormers).* Michigan State University.


Shulaw, W. & Monahan, C. *Parasite Control in Sheep: Biologic Approaches for the New Millenium.* Ohio State University.

Southern Region USDA Program on Sustainable Agriculture Research and Education. *Smart Drenching for Sheep and Goats.*


Van Wyk, J., Bath, G. *The FAMACHA system for managing haemonchosis in sheep and goats by clinically identifying individual animals for treatment.* University of Pretoria, 2002.


Whittier, W. Dee, DVM; Zajac, Anne; Umberger, Steven H. *Control of Internal Parasites in Sheep.* Virginia State University, October 2003.
Internal parasite management in grazing livestock

Niranjan Kumar · Thakur Krishan Shankar Rao · Anju Varghese · Veer Singh Rathor

Received: 4 October 2012 / Accepted: 26 November 2012 / Published online: 11 December 2012
© Indian Society for Parasitology 2012

Abstract It is a challenging task to control internal parasites in grazing livestock even by applying multi label and multi directional approach. It is impossible to draw general recommendations to control parasitic diseases due to varied geo-climatic conditions and methods adopted for rearing the livestock in the country like India. In view of increasing incidence of anti-parasitic drug resistance in animals, there is an urgent need to design sustainable parasite control strategy which must include on the host as well as off the host control measures to harvest the maximum productivity from the animal for an indefinite period.

Keywords Parasites · Livestock · Grazing · Management

Introduction

The population of livestock in world is 3509.7 million, and most of the animals are kept on grazing based production system (FAOSTAT 2010). India, a developing country is a land of villages and more than 60 % of the human population still depends upon agriculture and livestock sector for their livelihood. According to the 18th livestock census, the total number of livestock population is 529.70 million in which the rural population is 504.96 million (95.33 %) while urban population is 24.73 million (4.67 %) and most of the rural livestock population is still reared on grazing based system (Animal Husbandry statistics series-12 2010).

The grazing animals are always exposed to parasites and are thus constantly being reinfected in chain reactions mode. Several world wide reports have suggested that the parasitic diseases inflict severe economic losses on the livestock industry and adversely affects the health, weight gain, feed conversion efficiency and reproduction of animals. Spithill et al. (1999) due to fasciolosis in livestock estimated significant economic loss at US $ 3.2 billion per annum worldwide, mainly due to condemnation of livers at abattoirs, mortality in infected flocks, persistently depressed growth and feed conversion efficiency, loss of productivity, impaired fertility and also the cost of treatment. Anti-parasitic drugs are effective to minimize the internal parasites in grazing herd. However, it does not able to provide a long term solution. Certain anti-parasitic drugs like benzimidazole, levamisole and ivermectin have developed resistance (FAO 2004; Terrill et al. 2001; Kaplan 2004). Therefore, an integrated approach (Wells 2002; Rahmann and Seip 2007) becomes obligatory to control internal parasites with objective to harvest the optimum productivity from grazing herds. The internal parasites include flukes, tape worms, round worms and protozoa, only a few of them account for the majority of problems for grazing animals.

Prevention and control measures

The various control strategies applied, on the host and off the host with or without chemicals will be useful for
sustainable production of farm animals as per agro-climatic conditions.

Housing management

The animals having good living conditions resist or tolerate better against internal parasites as compared to animals kept under poor housing conditions. Animal shed must be well ventilated and lighted to maintain required humidity and air circulation (Makale et al. 2010). In high humidity and low light there will be accelerated growth of parasites population. Always keep optimum number of animals in the animal shed as overstocking in the animal shed causes large number of livestock population to have parasites at a time. The animal should not be fed on the ground. Feeders which cannot easily be contaminated with faeces should be utilized for grain, hay, and minerals feeding. Water should be clean and free from faecal matter and watering areas should be situated in well drained places with gravel or even cemented floors. Animals must be prevented from the access to parasite infected water bodies. Facilities of proper drainage in the animal shed reduce the chances of survival of the parasites. The newly introduced animals should be quarantined for 4–6 weeks and if required administer the anti-parasitic drugs. Always keep the manure by making heap so that eggs, larvae, cyst, or other stages of parasites are killed due to heat generated during composting (Williams and Warren 2004). The bedding material should be allowed to decompose along with manure for better control of parasites as it act as important source of various parasitic infections like winter coccidiosis. Application of nitrogen fertilizers like urea (1:25) to the surface of manure also eliminate the parasites (Howell et al. 1999).

Nutritional management

Types of diet and availability of vitamins, minerals and other nutrients are directly related with susceptibility of animal to the parasites. Vitamin A, D and B complexes are essential in developing the immunity against parasites. Minerals like zinc, iron, cobalt, sodium, potassium, phosphorus, etc. are very essential for proper functioning of immunological phenomenon going inside the animal’s body to develop functional immunity against the parasites (Hughes and Kelly 2006).

Vitamin A is essential to improve the intestinal epithelial integrity (Villamor and Fawzi 2005). Following deficiency in animals the intestinal immune system is disrupted, presumably weakening the host defense against intestinal parasites (Coop and Kyriazakis 1999). The profile of cytokine production by cells from vitamin A deficient animals is also altered substantially, leading to profound changes in the regulation of immune cell function. Vitamin A polarizes the immune response towards Th2 (Stephensen 2001; Stephensen et al. 2002) acting through principal oxidative metabolite retinoic acid.

The zinc deficient animals have impaired cell mediated cytotoxicity and T helper cell function. Scott and Koski (2000) using a zinc deficient nematode infected mouse model noted that parasites are better able to survive in the zinc deficient hosts than in well nourished hosts; that the production of interleukin-4 in the spleen of zinc deficient mice is depressed, leading to depressed levels of IgE, IgG1 and eosinophils; and that the function of T cells and antigen presenting cells is impaired by zinc deficiency as well as by energy restriction. Cook-Mills et al. (1990) while studying trypanosomosis recorded that NK cell function and phagocytosis by macrophages are impaired in zinc deficient animal, and this may be a consequence of reduced oxidative burst capacity. The deficiency reduces thymulin levels in blood, and thus reduces the CD4/CD8 ratio. Zinc deficiency also reduces the synthesis of Th1 cytokines IL-2 and IFN-γ, but not the Th2 cytokines IL-4, IL-6, and IL10 (Rink and Kirchner 2000).

Cobalt deficiency promotes parasitism as it is essential for vitamin B12 synthesis. Iron supplements are also very important, where animals are affected by blood sucking worms, like Haemonchus spp., Bunostomum spp. etc. The animals should always have access to mineral block and vitamin supplements to compensate for the mineral deficiencies in pastures. Animals on low protein diets are more susceptible to infection because they produce less immunoglobulin IgA. To avoid getting infection directly from the ground, the animals should be fed from feeders in the shed. The weaning age of young animals is an important factor with regard to the parasitic resistance. It has been observed that adequately milk fed calves are markedly less infected by Haemonchus, Cooperia and Oesophagostomum than early weaned calves (Geurden et al. 2008).

In short, nutrition level of the host could have the potential to affect how rapidly immunity is acquired and the effect would be expected to be seen best in internal parasite infections in which the rate of acquisition of immunity is relatively complex.

Pasture management

The scientific management of pasture is an effective way to control internal parasites in grazing livestock (Stuedemann et al. 2004). Ideally, the animals are allowed to graze clean or new pasture to fetch maximum productivity from them. The clean or new pastures are those pastures which have not been grazed since 6–12 months; pasture fields in which a hay or silage crop has been removed; pasture fields which have been
rotated with field crops; and pastures that have been recently renovated by tillage. Regular burning of old or grazed pasture should always be practiced to obtain parasites free pasture land. The timing of insemination of female animals should be planned accordingly, so that the parturition period should tally with the period when risk of contamination is low in the pastures. In India, the winter season seems most appropriate when transmission of parasites is less as compared to rainy and summer season. Overstocking of animals in a small piece of land increases the concentration of parasites. So, allow optimum number of animals to graze in a given piece of land. It is estimated that parasite infections increases with the square of the animal load, per surface unit. Therefore, for a given piece of land, parasitic infestations become quadruples when animal density is doubled.

Population pressure on the land and cheap labour which make other agricultural operations more profitable are the major factors which prevent assigning the land exclusively for pasture and fodder crop cultivation. Thus, in many countries especially developing ones there are only a few defined pasture lands and farmers usually allow their animals to graze in uncultivable ground like government land, road side land, crop field between two crops, etc (Fig.1). Almost the same measures as advised for the livestock exclusively reared on grazing can be applicable in these countries to achieve effective parasite control. An extensive research is now an urgent need in grazing perspective for designing effective and sustainable control measures against various parasites (Table 1).

Pasture rotation and rest

Pasture rotation, or intensive grazing is optimum use of grass by distributing the pastures into parcels of land of varying sizes called paddocks and frequently moving the livestock from one paddock to another (Wells 1999; Johns et al. 2004). The main objective of pasture rotation is not to put the animals back into the same field until the risk of infection has diminished. Theoretically this means that parasitism will decrease, if the number of parcels of land and rotation time is increased. Practically it appears difficult to diminish the parasitic load with intensive grazing. The lifespan of infective stage of parasites are usually greater than the time required between grazing periods for maximum grass use. A rest of 3–6 months is required for an infected pasture to return to a low level of infectivity.

The larvae of most parasites move to the tops of plants when intensity of light is low at sunrise, sunset and overcast sky. Therefore, grazing should be avoided during these conditions. As the density of parasite is generally at a maximum in the rainy season and at a minimum in the summer/winter, it is preferable to limit grazing to the summer/winter months to diminish the level of ingestion. During fall, the animals should ideally be put in a new pasture. About 80% of parasites live in the first 5 cm of vegetation. Parasite infection can be minimized by allowing the livestock to graze up to 10 cm from the ground in a field. The drier the grass, the more parasites will stay at the base of the plants. The risk of infection is greatly lowered by allowing animals to graze only dried grass and not to wet grass. Along with rotational grazing a sufficient pasture rest period is also required for a better pasture management. Animals would graze a pasture for a period of time (grazing period) then the pasture would rest for regrowth (pasture rest period). The length of the grazing period depends on condition of pasture, forage quantity and stocking density. It is commonly recommended that pastures are grazed from a couple of days to a couple of

Fig. 1 Animals grazing in uncultivated government field
Table 1 Different grazing management strategies (Younie et al. 2004)

<table>
<thead>
<tr>
<th>Preventive strategies</th>
<th>Evasive strategies</th>
<th>Diluting strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turning out parasite free animals on clean pastures</td>
<td>Worm challenge is evaded by moving animals from contaminated to clean pasture</td>
<td>Worm challenge is relieved by diluting pasture infectivity</td>
</tr>
<tr>
<td>✔ Delayed turnout</td>
<td>✔ Moving to safe pastures within the same season</td>
<td>✔ Avoid stocking rates close to carrying capacity of plant production</td>
</tr>
<tr>
<td>✔ Changing pastures between seasons</td>
<td>✔ Alternate grazing of different species</td>
<td>✔ Reduction of the general stocking rate</td>
</tr>
<tr>
<td>✔ Moving at weaning</td>
<td>✔ Hay/silage aftermaths</td>
<td>✔ Mixed grazing with other host species</td>
</tr>
<tr>
<td>✔ Late lambing</td>
<td>✔ New grass reseeds</td>
<td>✔ Alternate grazing with other host species</td>
</tr>
<tr>
<td>✔ Grass reseeds</td>
<td>✔ Cultivation of annual forage crops</td>
<td>✔ Mixed grazing with other age groups</td>
</tr>
<tr>
<td>✔ Cultivation of annual forage crops</td>
<td></td>
<td></td>
</tr>
<tr>
<td>✔ Silage/hay aftermaths</td>
<td></td>
<td></td>
</tr>
<tr>
<td>✔ Alternation of different host species</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

weeks. The length of the rest period depends on the time needed to regrow specific forages, the weather, pasture quality and management. It is commonly recommended that pastures should be given a rest for 2–7 weeks. It should be noted that these forage management recommendations are generally excellent for improving nutritional status, but they will not improve parasite control. On the other hand, better nutrition provided by rotational grazing may offset the effects of higher parasite loads on the pasture. Accordingly, pasture rotation with optimum rest period is an important component to minimize internal parasites in grazing animals (Colvin et al. 2008).

Grazing by age group

As susceptibility of animals against parasites varies with age, it is reasonable to graze different age group animals in different fields.

Multispecies grazing

Several parasite species cannot infect two different animal species. Sheep and goats are generally not affected by the same internal parasites (Christensen 2005); similar is the condition with cattle and horses. Consequently, pastures grazed by large ruminant and horses are safer for sheep (Greiner 1998; Hartwig 2000; Scoggins 2000) or and goats (Luginbuhl 1998) and conversely. Sheep or goat can be co-grazed with bovine and/or horses. Pastures can be alternated between sheep and cattle and/or horses. This can help to break the parasite’s life cycles. There are numerous other benefits to multi-species grazing. Each species has different grazing behavior that complements one another. For example, sheep prefer to eat weeds (Whittier et al. 2003), short tender grasses and clover, while cattle prefer to eat taller grasses thus allowing the sun light to reach the ground to kill many parasites.

Zero grazing

Zero grazing means keeping the animal in captivity to reduce the parasitic load. During confinement the animal should be fed off the ground in feeders and watering containers should be kept free from faecal matter.

Alternative forages

The pasture plants containing condensed tannins have anthelmintic properties (Min et al. 2004). Research has shown that animals grazing tannin rich forages have lower faecal egg counts than animals grazing traditional grass pastures. The tannin may also decrease the hatching rate of parasite eggs and larval development in faeces. Forage plant species (Marley et al. 2003) which contain high levels of condensed tannins include sericea lespedeza (warm season legume), birds foot trefoil (perennial legume) and chicory (leafy perennial). Tropical legumes contain more condensed tannins than temperate legumes. Normally trees and shrubs contain higher levels of tannins than pasture grasses (Niezen et al. 1998).

Genetics of animals

Genetics is probably the best long term weapon against internal parasites in animals. Some animal breeds are more resistant and resilient to internal parasites. Extensive research all over the world is going on to identify parasite resistant gene(s) containing animal breeds. On the basis of faecal egg output a parasite resistant or susceptible breed can
be identified. Following molecular test, the parasite resistant
gene can be identified and by animal cloning or by selective
breeding a parasite resistant breed of animal can be created.

**Biological control**

Biological control may be defined as the use of one living
organism to achieve control over the targeted organism like
parasite, and thus reducing the population of pathogen below a
threshold level where it can not causes clinical problems and/
or economic losses in the animals. This is quite a new area and
needs extensive research to know its merits and demerits
before implementing it as a weapon against the parasites.

The biological control with nematophagous fungi are
well documented all over the world. The fungus *Dud-
ingtonia flagrans* is relatively easy to culture and can be
released in the environment against the targeted parasites in
a controlled fashion (FAO 2002; Waller and Thamsborg
2004). So, it is widely used to control gastro-intestinal
parasites of grazing animals by reducing pasture load
(Waller et al. 2006; Sanyal et al. 2008). In the future the
nematode destroying fungi, either as a single species or a
mixture of species and types (trapping and egg parasitic),
can be effectively and environment compatibly used to
control economically important gastro-intestinal parasites.
In spite of various merits, impediment in the adoption of
nematophagous fungi in practical control schemes include
lack of suitable application systems, assessment of long
term environmental effects and finally, acceptance in
principle by the farmers. The natural plough, ‘earthworm’
can ingest worm eggs and larvae during its normal feeding
process thus destroying the egg in the gut or carrying them
below the soil surface. Dung beetles ingest manure, thus
killing eggs and larvae of various parasites.

**Anti-parasitic drugs management strategies**

Anti-parasitic drugs are still an important part of parasite
control in the grazing livestock. As per Indian climatic
conditions the grazing animals must be dewormed at least twice
in year at the onset (May end) and offset of monsoon
(September end). However, strategic use of anti-parasitic
drugs is necessary to ensure effectiveness of treatment and
to slow down the rate of drug resistance development.

Reduce use of anti-parasitic drugs

Injudicious use of anthelmintics leads to faster rate of
development of drug resistance (Stear et al. 2007) than
when used judiciously. Drug use should be minimized to 2
or 3 times per year or on the basis of epidemiology of
parasitic infection. Frequent dosing of same anthelmintics
must be avoided. According to modern concept treat only
those animals that essentially need to be dewormed and do
not give anthelmintics to those which are not in urgent
need.

Use of full dose of anti-parasitic drugs

Selection pressure produced due to under-dosing favors the
survival of resistant parasite population. Herd should be
divided into groups for anti-parasitic drug dosing and drug
dose should be decided from the body weight of heaviest
animals. The anti-parasitic drug dose rate should be as per
the species of animals, the same dose rate for different
species must be avoided. Such as goat takes higher dose of
drugs to reach the same pharmacological effects as in cattle
and sheep, as goat metabolism is physiologically different
from cattle and sheep (Toutain et al. 2010). The thumb rule
is that goat needs twice the drug dosage than sheep or
cattle.

Alternate the type of anti-parasitic drugs

Anti-parasitic drugs should be alternated on an annual basis
but frequent change at every deworming is also not rec-
ommended. The frequent changes may enhance the chan-
ces of development of resistance against a group of
anthelmintics.

Alternative dewormers

Now, various natural products have been identified which
are having anthelmintics properties and can be used as an
alternative to chemical control of parasites. Such products
include herbal dewormers, charcoal and diatomaceous
earth. Copper oxide particles (administered as a bolus) have
been shown to reduce worm infections in ruminant (Burke
et al. 2005). Some common botanical dewormers include
garlic (Worku et al. 2009); wormwood (*Artemisia* spp.);
wild ginger or snake root; goosefoot; conifers (pine, spruce,
or fir); mustard and castor oil (Manthri et al. 2011); squash or pumpkin seeds; carrot and fennel seeds; pyrethrum (plant extract from Chrysanthemum) (Athanasiadou et al. 2007) etc. can be successfully used to eliminate the internal parasites but extensive research is warranted.

Conclusions

The internal parasite is limiting factors for profitable livestock farming by affecting the animal’s performance. In most of parasitism, the economic losses are actually not attributable to mortality but due to impaired productivity of animals. The proper management of internal parasites is extremely important for successful livestock farming especially in the grazing conditions. None of the single control measures will give long term solution. Integration of more than one measure like good farming practices, best breeding strategies, appropriate biological control measures, scientific utilization of biotechnological tools and techniques and appropriate chemical control measures is essential to achieve the sustainable control on the parasites.

References

Animal Husbandry statistics series-12 (2010) Govt. of India, Ministry of Agriculture, Department of Animal Husbandry Dairying and Fisheries, Krishi Bhawan, New Delhi


Christensen K (2005) Internal parasites of the goat. Scientific Animation and Illustration, Oklahoma


Food and Agriculture Organization, Rome (2002) Biological control of nematode parasites of small ruminants in Asia. In: Final proceedings of FAO technical co-operation project in Malaysia TCP/MAL/0065 (T)

Food and Agriculture Organization, Rome, Animal Production and Health Division Agriculture Department (2004) Guidelines resistance management and integrated parasite control in ruminants


Greiner SP (1998) Control of internal parasites in sheep. Virginia Cooperative Extension, Blacksburg

Hartwig N (2000) Control of internal parasites of sheep. Iowa State University, Ames


Kaplan RM (2004) Responding to the Emergence of Multiple-Drug Resistant Haemonchus contortus: Smart Drenching and FAMACHA®. College of Veterinary Medicine, University of Georgia, Department of Medical Microbiology and Parasitology, Athens


Th2 development via retinoid X receptor pathway. J Immunol 168(9):4495–4503
Wells A (1999) Integrated parasite management for livestock. ATTRA, Fayetteville
Introduction

Sheep adapt easily to their environment and readily respond with increased lamb production when appropriate management practices are applied. Sheep producers who are aware of productivity best practices can assess their present inputs of land, labor, capital and management, and then develop a plan to improve reproductive efficiency to a level that meets profitability goals. Reproductive performance may range from a low of 60% to a high of 225% within the same breed of sheep. The ewe's reproductive performance is a result of effective productive inputs and the producer's management practices.

The Increasing Your Lamb Crop Best Practices fact sheet series, of which this is just one, provide specific management practices to integrate into a sheep enterprise based on each producer's situation. The degree to which best practice is implemented varies for each producer, and with each type of management system and geographic location. A benefit to raising sheep is their responsiveness to varying degrees of management. A comparison of sheep production management models will help producers determine which one they currently operate under, and will allow them to evaluate the opportunities to modify management practices to meet reproductive efficiency goals.

Production varies with management, resources, locale

The farm flock production model experiences a completely different level of demands on management, labor and feed resources versus a range flock production model. As these models are considered, it is important to understand that in no situation should animal health and welfare be compromised for the sake of economic gain. Some production systems may experience higher levels of lamb mortality than others. It is always in the best interest of the producer to make certain appropriate management practices are being conducted to ensure the best outcomes for the livestock and the producer. Environment and weather influence reproductive success and producers need to practice due diligence through their management to lessen any negative impacts.

Farm and range flocks can be categorized into low input or high input flock management systems. Lambing and weaning percentages are directly related to the level of management, land, capital and labor invested. Sheep producers who have access to large land resources can expect ewes to meet their nutritional needs for maintenance, breeding, gestation and lactation by grazing standing forage through most of the year. Input costs are lower with less labor involved and less need for physical structures. However, the variability of the weather has greater year-to-year influence on reproductive performance.

Range lambing holds less opportunity to control and manage environmental challenges, but can take advantage of the ewes natural reproductive and maternal instincts. Many range flock producers use shed lambing to reduce lamb loss due to extreme weather, allowing the producer to take advantage of best management practices to improve the ewe's reproductive

Lambing and weaning percentages are directly related to the level of management, land, capital and labor invested.

Continued on next page
Production varies with management, resources ... (cont.)

efficiency. This also allows producers to identify parentage of lambs, so that culling and ewe lamb replacement decisions are based on yearly productivity. When lambs are bonded with ewes and are performing well, the flock is returned to grazing.

Competition for land resources can reduce availability and increase cost of this productive input. Farm flock production systems lessen the need for land resources and the impact of weather by reducing those challenges through greater investment in productive inputs such as labor, capital and higher levels of management. Greater investment in productive inputs requires a greater reproductive performance in order to profit. This system allows sheep producers to lamb out of season and possess a marketing advantage by providing finished lambs when inventories are lowest.

No one best production system

The most appropriate production system varies from operation to operation. The key is to match lambing rate to the available resources. As lambing rates increase from implementation of key management practices, additional planning should be given to the increased prolificacy. Providing additional nutrition for ewes with multiple lambs, methods of rearing orphan lambs and determining optimal weaning dates become priorities for the producer’s flock management.

Sheep producers can compare their current reproductive efficiency against the Reproductive Key Indicators. This activity will provide an objective assessment of the current production system’s reproductive efficiency. Initially, sheep producers are able to identify key indicators that can be targeted for immediate improvement without greatly altering the current production system. For example, a low input farm flock’s “ewe lambs lambed” rate is below 55%, so this farm flock’s producer can address this key indicator by developing ewe lambs through a different management group. Likewise, a low input range flock that does not meet the low input “lambs weaned” key indicator can easily incorporate a number of productivity best practices from available fact sheets such as, “Culling Underperforming Ewes,” by identifying and removing dry ewes at end of the lambing season and/or providing optimal nutrition during breeding, gestation and lactation.

When setting realistic reproductive efficiency goals, producers need to assess the strengths and limitations of the available productive inputs that are dedicated to the current sheep production operation. This assessment will indicate how some inputs are underutilized and how the lack of an input limits the reproductive efficiency. An investment in a specific productive input can overcome the limitation of another input. For example, a sheep producer lacking land resources to provide ewe nutrition with grazing can compensate this limited input by developing a dry lot system to house and feed ewes, provided that knowledge, labor and capital inputs were available to develop and operate a dry lot facility. The level at which the productive inputs are available will dictate which input category, high or low, the producer is able to apply. When considering productive input investment, expected reproductive efficiency must provide enough return to recover the expense and add profitability to the operation. For example, there are management tools available to change a flock’s weaning rate from 85% to 125%. This is a 47% increase in gross flock return. However, failing to invest 25% more inputs (feed, labor, services) to attain a 50% increase in revenue is not uncommon. There is a cost to increasing productivity and, ultimately, profitability. Remember the quote, “nothing ventured, nothing gained”? It applies to increasing reproductive efficiency, too.
Develop an action plan

After completing the "Reproductive Key Indicators" assessment and identifying the level each productive input can be committed to the enterprise, sheep producers should develop an action plan toward achieving realistic reproductive efficiency targets.

Each of the 12 Increasing Your Lamb Crop Best Practices fact sheets provide specific recommendations to implement the practice. Producers should:

1. Select and implement the practices that will have the most immediate and greatest impact to reproductive efficiency.
2. Identify and plan the steps to implement future productivity best practices that require greater consideration of productive input investment.

Resources and support for development and implementation of the 12 lamb crop best practices, and other productivity best practices as they are developed, can be found through the Lamb Resource Center at www.lambresourcecenter.com.

When reproductive efficiency consistently meets or exceeds the key indicator targets within an input category, then those management practices should become standard operating procedures. The addition of other management practices or other productive inputs should be evaluated based on costs and benefits to discover if there is potential for further improvement. Using best practices key indicators to match management to reproductive efficiency will ensure producers are the most successful in their sheep operations.

Reproductive Key Indicators

Which best practices will benefit you?

Reproductive Key Indicators have been developed to help you identify and prioritize which of the Lamb Crop Best Practices you should implement. These key indicators are generalized, yet realistic, goals for both range and farm flocks so that you can assess which best practices will be of greatest value to you. Levels are included for high and low input flock management.

- **High input flocks have these characteristics:** shed lambing, herded, multiple management groups, strategic supplementation and improved pastures
- **Low input flocks have these characteristics:** range/pasture lambing, fenced pastures, simple management groups and limited supplementation

First, identify which Key Indicator(s) you need to improve. Then, refer back to the Lamb Crop Best Practices and pinpoint which ones you need to adopt in order to reach your flock goals.

<table>
<thead>
<tr>
<th>KEY INDICATOR</th>
<th>RANGE FLOCK</th>
<th>FARM FLOCK</th>
<th>MY FLOCK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High Input</td>
<td>Low Input</td>
<td>High Input</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dry Ewes</th>
<th>&lt; 7%</th>
<th>&lt; 10%</th>
<th>&lt; 5%</th>
<th>&lt; 7%</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamb Crop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Born</td>
<td>150%</td>
<td>NA</td>
<td>200%</td>
<td>175%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Docked</td>
<td>NA</td>
<td>120%</td>
<td>NA</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lamb Losses</td>
<td>15%</td>
<td>17%</td>
<td>11%</td>
<td>15%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lambs Weaned</td>
<td>127%</td>
<td>100%</td>
<td>178%</td>
<td>148%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ewe Lambing</td>
<td>50%</td>
<td>30%</td>
<td>85%</td>
<td>65%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data for the Key Reproductive Indicators were generated by the Reproductive Efficiency Task Force based upon research, surveys and industry experience. Lamb losses between docking and weaning. Generally, ewe lambs are not bred in range flocks but this may provide a great opportunity to increase overall productivity.
Author & reviewers

Author: Dave Ollila, M.Ed.

Reviewers: Reid Redden, Ph.D., Texas A&M AgriLife Extension, San Angelo, Texas; Dan Morrical, Ph.D., Iowa State University, Ames, Iowa; Susan Schoenian, M.S., University of Maryland Extension, Keedysville, Maryland; and Rodney Kott, Ph.D., Former Montana State University Extension Sheep Specialist, Fredericksburg, Texas

More information

U.S. Lamb Resource Center
http://lambresourcedata.com/production-resources/productivity/

National Sheep Improvement Program
http://www.nsip.org

U.S. Sheep Industry Roadmap
http://lambresourcedata.com/reports-studies/roadmap/

2015 Sheep Production Handbook Volume 8
This sheep industry reference book includes chapters on reproduction, management, breeding/selection, forages, nutrition, marketing, predator damage control, health, wool and dairy sheep. The cost is approximately $90. Order from the American Sheep Industry Association at 303-771-3500, ext. 108, or go online: http://sheepusa.org/test-sph
Introduction
Annual lambing rate is determined by the proportion of the flock that lambs, and the number of lambs born per ewe lambing. Annual lambing rate is also affected by the frequency of lambing. In temperate regions, the seasonal nature of reproduction in sheep limits the frequency of lambing to once per year; however, three lambings in two years is often obtained in more tropical latitudes.

Seasonal reproduction
Temperate breeds of sheep are considered to be seasonally polyestrous with ewes having regular reproductive estrous cycles during the fall months, after which, reproductive activity decreases, and eventually ceases in late spring and summer months in most of the flock (Figure 1). Seasonal changes in reproduction can be observed by changes in the proportion of females showing sexual receptivity (estrus/heat), but also involves an associated decline in the proportion of females ovulating and the ovulation rate (the number of eggs released each estrous cycle). The ram also shows seasonal changes in reproduction including, lower quantity and quality of semen and reduced sexual aggressiveness.

Overcoming seasonality by getting a proportion of ewes to breed out-of-season will not only increase the average number of lambs weaned per ewe, per year, but can also positively impact marketing of lambs.

Seasonality of reproduction in sheep is governed by and cued to photoperiod/day length. Decreasing photoperiod, or short days as occurs in fall and early winter months, are stimulatory and results in increase secretion of hormones that stimulate the reproductive system. Conversely, increasing day length, as occurs in spring and summer, results in the suppression of reproduction.

Seasonality of reproduction in sheep results in significant variation in the quantity of lamb reaching the market, which often influences price (Figure 1). Therefore, overcoming seasonality by getting a proportion of ewes to breed out-of-season will not only increase the average number of lambs weaned per ewe, per year, but can also positively impact marketing of lambs.

Manage for seasonal changes in reproduction

Figure 1: Breeding out-of-season to obtain higher lamb prices: The seasonal pattern of reproduction in sheep results in most ewes being bred during a narrow window in the fall. The majority of their lambs are born in the spring and marketed late summer and fall resulting in a depression in prices. Breeding ewes out-of-season in spring and summer results in fall lambing allowing producers to take advantage of peak in prices in late fall and early spring.
Overcoming seasonality by getting a proportion of ewes to breed out-of-season will not only increase the average number of lambs weaned per ewe, per year, but can also positively impact marketing of lambs.

Approaches to breeding ewes during the non-breeding season

1. Selecting the right breeds and ewes: The length of the breeding season varies among breeds of sheep. Most breeds of sheep that originated in the tropics, and those with Merino ancestry, have longer breeding seasons which allows for higher lambing rates to be achieved from spring-summer breeding.

2. Photoperiod manipulation: Exposure to an artificial stimulatory sequence of day length changes can be used to successfully breed ewes out-of-season. Specifically, exposing females to 15 to 16 hours of light during late winter/early spring for 45 to 60 days, followed by exposure to 30 to 25 days of a short day photoperiod consisting of 8 to 9 hours of light and 15 to 16 hours of darkness, will induce fertile estrus in ewes. While photoperiod manipulation can be quite effective, it requires an enclosed barn with electricity, three months of photoperiod manipulation and it does not result in synchronized estrus.

3. Melatonin treatment: Melatonin is a hormone that is released by sheep when they are exposed to darkness. Sheep are exposed to a longer duration of melatonin secretion during the short days in fall and winter. This long duration of melatonin secretion triggers the release of other hormones that eventually result in the resumption of regular reproductive cycles and mating. Therefore, treatment of sheep with melatonin for as little as 35 days in late spring after they have been exposed to natural or artificial long day photoperiod induces fertile mating in the summer. The use of melatonin removes the need for holding ewes in barns. However, commercial melatonin implants have not been approved for use in sheep by the Food and Drug Administration (FDA) and can only be used in the United States under the supervision of veterinarian.

4. Ram effect: The estrous period in ewes could be broken by abrupt introduction of novel rams. Pheromones, and to a lesser extent physical and visual perception, stimulates the release of hormones from the ewe that result in two peaks in estrus activity 17 and 24 days after the introduction of rams.
Improving lambing rates of ewes bred out-of-season

The following management practices can be used to improve lambing rates of ewes bred out-of-season:

1. **Use the right genetics:** Hair sheep breeds – Dorsets, Polypay and Finish Landrace – are among breeds that have high reproductive rates from spring-summer breeding. Additionally, improvements in the proportion of ewes that conceive out-of-season can be made through selection. For example, the proportion of cross-bred Dorset ewes lambing from a May breeding season increased from 50% to 60% to over 85% due to selection over five generations. Therefore, using an appropriate breed combination and continuous selection can increase the lambing rate from out-of-season breeding.

2. **Wean lambs and improve the nutritional status of the ewes:** The proportion of ewes lambing to spring breeding is almost twice as high in dry as in lactating ewes (Table 1). Ewes with body condition scores of 2.7 or higher have higher lambing rates from out-of-season breeding than do ewes with lower body condition scores. To improve lambing rates, lambs should be weaned at least one month prior to introduction of rams, and ewes could be supplemented with grain (1 to 2 lbs./day) to allow them to regain body condition.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Lactation Status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weaned</td>
</tr>
<tr>
<td>Estrus</td>
<td>95</td>
</tr>
<tr>
<td>Pregnancy rate (%)</td>
<td>75</td>
</tr>
<tr>
<td>Percent lambing (%)</td>
<td>81</td>
</tr>
</tbody>
</table>

3. **Isolate ewes from rams:** Ewes can become habituated to rams that are in close contact with them and so will not show the ram effect unless the rams are removed for a period of time or new rams are introduced. To maximize the ram effect, separate rams from ewes for approximately one month prior to breeding so ewes cannot smell them.

4. **Have a good age distribution of ewes:** In general, the lambing rate of ewe lambs and yearlings bred out-of-season is lower and more variable than that observed in mature ewes in part due to lower expression of estrus.

5. **Conduct breeding soundness examination on rams prior to use:** Reproductively superior rams will not only breed more ewes, but also have higher first service conception rates, lower early embryonic death rates, and improved lambing rates. To identify superior rams, breeding soundness examinations should be performed and observation of libido, intromission, and social behavior should be done prior to use. Only rams with good sperm concentration, motility, and morphology should be used.

6. **Use rams with high sexual activity:** The sexual activity of the ram, as assessed by the number of mounts and ejaculations, influences the percentage of ewes ovulating in response to ram effect. Sexual activity increases with age, therefore, using older rams will improve fertility. Additionally, photoperiod/melatonin treatments of rams increase their sexual activity. For example, exposing rams to a long day photoperiod (16 hours of light) during late winter, followed by treatment with melatonin or melatonin treatment beginning late spring and early summer, enhances sexual activity and increases the ram effect.

7. **Use a high ram to ewe ratio:** The proportion of ewes ovulating, and subsequently lambing, following ram introduction during the non-breeding season is increased with a greater ram to ewe ratio. This is in part due to the lower semen quality and sexual activity of rams during the non-breeding season and synchronized nature of the induced estrus. In general ram:ewe ratios of more than 1:18, or 6 rams per 100 ewes, is recommended.

8. **Pre-treat ewes with controlled intravaginal drug releasing devices (CIDRs):** When ewes are treated with progesterone (the hormone contained in CIDRs) for 5 to 7 days prior to ram introduction synchronized estrus and ovulation occur in greater than 70% of the ewes between 2 to 4 days after CIDR removal. Lambing rates are at least 60% higher than that observed in ewes introduced to rams only over a 30 day breeding period (Table 2).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent lambing (%)</td>
<td>41 to 45</td>
</tr>
<tr>
<td>Fertility (%)</td>
<td>150</td>
</tr>
<tr>
<td>Lambing rate (%)</td>
<td>60 to 68</td>
</tr>
</tbody>
</table>

Summary of results from studies in which ewes were introduced to rams alone (Control) or pretreated with progesterone (CIDR) for 5 days prior to introduction of rams.
Conclusion

Implementing practices to manage seasonal reproduction requires a small investment and some change in management practices. However, lambing rates that are equal to or greater than the current national average can be achieved from out-of-season breeding. Lambs derived from ewes bred out-of-season demand higher prices and will provide consistency in the quality and quantity of lamb in the market place (Figure 1). Moreover, when used as a component of an accelerated lambing program, out-of-season breeding will result in significantly higher annual lambing rates which will improve the productivity and profitability of your sheep operation.

Author & reviewers

Author: Marion Knights, Ph.D., West Virginia University Division of Animal & Nutritional Sciences, Morgantown, West Virginia

Reviewers: Reid Redden, Ph.D., Texas A&M AgriLife Extension, San Angelo, Texas; Dan Morrical, Ph.D., Iowa State University, Ames, Iowa; Susan Schoenian, M.S., University of Maryland Extension, Keedysville, Maryland; and Rodney Kott, Ph.D., Former Montana State University Extension Sheep Specialist, Fredericksburg, Texas

More information

U.S. Lamb Resource Center
http://lambresourcecenter.com/production-resources/productivity/

National Sheep Improvement Program
http://www.nsip.org

U.S. Sheep Industry Roadmap
http://lambresourcecenter.com/reports-studies/roadmap/

Literature cited


Introduction

Lamb crop is one of the most important factors affecting profitability of a sheep enterprise. Increasing the lamb crop, so long as it is in balance with the environment and production system, should be the goal of every sheep producer.

Many factors affect lambing percentage, and management is a key contributor. Culling underperforming ewes is one of 12 best management practices that has been identified by the American sheep industry for improving lambing percentage.

However, unlike some of the other best management practices, such as breeding ewe lambs or pregnancy scanning, culling underperforming ewes is something all producers, regardless of flock size or production system, can and should do.

Culling underperforming ewes will reduce the cost of maintaining the flock. Underperforming ewes consume feed, take up space, and require labor, while producing less profit than their contemporaries; maybe, even costing the farm money. Thus, culling underperforming ewes is a way to help make sheep production more profitable, sustainable, and viable.

At the same time, overzealous culling is discouraged, as there are numerous costs associated with culling. The value of a cull ewe is considerably less than the value of the ewe lamb that is replacing her. There are also costs associated with developing ewe lambs for breeding. Depending upon the reason for culling, it may be more economical to retain a ewe and breed her to a terminal sire, such as for the production of market lambs.

In a sheep enterprise, it is customary to cull approximately 15% of the flock each year. In purebred or high producing flocks, the rate may be even higher. According to the National Animal Health Monitoring System (NAHMS), 14% of ewes were culled from the national flock in 2011, as compared to 18.3% in 2001.

Culling is when a ewe (or ram) is removed from the breeding flock. There are many reasons to cull ewes, and the reasons will vary by farm or ranch. Not all flocks will have the same breeding objectives. Ewes that are profitable in some flocks may not be profitable in other flocks. Current economic conditions may weaken or strengthen culling standards.

Reasons for culling ewes among all US sheep flocks

<table>
<thead>
<tr>
<th>Primary reason for culling</th>
<th>% of sheep</th>
<th>% of sheep operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>55.6</td>
<td>69.7</td>
</tr>
<tr>
<td>Failure to lamb</td>
<td>7.7</td>
<td>22.0</td>
</tr>
<tr>
<td>Teeth problems</td>
<td>7.6</td>
<td>8.0</td>
</tr>
<tr>
<td>Hard bag syndrome</td>
<td>7.1</td>
<td>24.1</td>
</tr>
<tr>
<td>Mastitis</td>
<td>6.7</td>
<td>20.9</td>
</tr>
<tr>
<td>Poor mothering</td>
<td>4.7</td>
<td>22.3</td>
</tr>
<tr>
<td>Other</td>
<td>3.7</td>
<td>7.6</td>
</tr>
<tr>
<td>Chronic weight loss</td>
<td>2.1</td>
<td>3.6</td>
</tr>
<tr>
<td>Economic issues</td>
<td>1.7</td>
<td>2.8</td>
</tr>
<tr>
<td>Other illness</td>
<td>1.2</td>
<td>2.4</td>
</tr>
<tr>
<td>Single births</td>
<td>1.1</td>
<td>3.9</td>
</tr>
<tr>
<td>Other reproductive problems</td>
<td>0.9</td>
<td>3.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
<td></td>
</tr>
</tbody>
</table>

USDA APHIS, National Animal Health Monitoring System, April 2014
Age

Age is usually the primary reason for culling ewes. According to the 2011 NAHMS study, almost 70% of sheep operations cited age as the primary reason for culling ewes. In 2011, 55.6% of ewes culled were culled due to age. In 2011, the average age of culled ewes was 6.3 years, compared to 5.9 in 2001.

Ewes tend to be most productive between the ages of 3 and 6. After 6 years of age, their productivity tends to decline. On average, they give birth to fewer lambs and produce less milk for their offspring, resulting in lower pounds weaned. For these reasons, it is customary to cull ewes when they reach 5 or 6 years of age, especially in range flocks where ewes cannot receive individual attention and/or nutritional resources are limited. In many of these extensive operations, productivity falls off after 5 to 6 years of age.

On the other hand, small flocks and/or farms with good feeding conditions, may keep ewes in flocks for much longer. Some ewes are productive well beyond 6 years of age. In fact, ewes that can maintain productivity for a longer period of time should be favored in selection and culling decisions. In many instances, their offspring are some of the most productive ewes in the flock. For some flocks, keeping older, productive ewes could be a way to increase productivity, while simultaneously reducing replacement costs.

Health

According to the NAHMS study, health issues are the other major reason why ewes are culled. In fact, they are the major reason for involuntary or premature culling of ewes before they reach their productive life spans.

Udder health - In the NAHMS study, hard bag and mastitis were identified as primary reasons for culling ewes. In 2011, 7.1% of ewes were culled due to hard bag syndrome. Another 6.7% were culled as a result of mastitis. Hard bag, which affects both udder halves, can be caused by ovine progressive pneumonia (OPP) or mastitis. Mastitis is an infection of the udder. Both conditions result in limited or no milk being produced by the affected gland(s), causing lambs to starve, or grow poorly.

Only ewes with healthy, sound udders should be kept in flocks. Udders should be palpated to make sure there are not any lumps, hardness, or fibrinous material. Udder halves should be relatively equal. Both teats should be functional and of normal size, as newborn lambs may have difficulty nursing oversized teats. Ewes with long, pendulous udders should be culled, as lambs may have difficulty finding the teats. Such udders are also more prone to injury. Ewes that have lost all or part of their udder function should be culled.

Prolapses - A prolapse is when structures fall out of their normal positions. Ewes that prolapse their vaginas should be culled, as they may repeat the problem in subsequent years. Their offspring should not be kept for breeding, as vaginal prolapses are believed to be an inherited problem. Ewes that experience a uterine prolapse, may be retained for breeding, depending upon the circumstances; however, most producers wisely cull these ewes.

Hoof health - Footrot, a bacterial infection of the hooves, is one of the more difficult diseases to control and eradicate from sheep flocks. It has caused many sheep producers to liquidate their flocks. Footrot is costly to treat, especially in terms of labor. It can also be an animal welfare issue and negatively impact productivity.

Culling is one of the most powerful tools for dealing with footrot. Ewes that are chronically infected with footrot or scald, or fail to respond to treatment, should be removed from the flock. Ewes that have abnormal and/or excessive hoof growth should be culled. It is possible to select for footrot resistance in a flock.

Internal parasites - In situations in which internal parasites (worms) are a major obstacle to profitable production, parasite resistance should be a selection and culling criterion. Ewes which require frequent or regular deworming should be culled. If fecal samples are not obtained from ewes, the FAMACHA© system can be used to identify susceptible ewes, as there is a correlation between FAMACHA© scores and fecal egg counts.
Internal parasites (cont.) – It is possible to select for parasite resistance in sheep, as 20% to 30% of the flock is usually responsible for 70% to 80% of the output of worm eggs. Parasite resistance (faecal egg counts) is a moderately heritable trait. The National Sheep Improvement Program (NSIP) currently provides estimated breeding values (EBVs) for parasite resistance in Katahdin sheep. The same can be done for other breeds once data are submitted.

Other health issues – There are numerous other physical problems for which ewes should be culled. Ewes should be evaluated for soundness on a yearly basis, preferably at the time of lambing, marking or breeding. Ewes with unidentified weight loss or ill thrift should be culled. Old, thin ewes that cannot maintain their body condition should be culled. Teeth or other problems may interfere with chewing. Only ewes with sound mouths should be kept. All of the ewe’s incisors should be present. Ewes with genetic defects or predisposition to disease should be culled.

Performance

Performance is another important criteria that should guide selection and culling decisions. Many of the factors already discussed account for the differences in performance among ewes. For example, sub-clinical mastitis may be the reason that a ewe weans lambs with below-average weights.

Fertility

It is generally recommended that the breeding season be limited to two or three heat cycles, preferably only two (34 days). Mature ewes which fail to breed and maintain pregnancy should be culled. Pregnancy scanning can be used to determine which ewes are open. Pregnancy testing is especially useful for ewe lambs, as open ewe lambs, can be sold for higher prices than yearling ewes that fail to lamb.

Ewes that lamb late in the season may be another target for culling, as ewes that lamb early in the lambing season are usually the most productive. If out-of-season or accelerated lambing is the goal, ewes which fail to breed out-of-season and/or miss one or more breeding opportunities should be culled.

Lambing

While dystocia (difficult birthing) is complex, research has shown that producers can reduce the incidence of dystocia by culling ewes that require assistance at lambing. Some producers will even cull lambs from assisted deliveries. Ewes that reject or harm their lamb(s) should be culled. Ewes whose lambs are small, weak, and/or slow to suckle should be discriminated against.

Ewes that fail to raise a lamb should be culled. No ewe can return a profit if she fails to produce a lamb. It is easy to identify a dry maiden ewe, as she will not have any udder development. In older ewes, it is harder to pick out dry ewes; however, they are usually in better body condition and have smaller udders.

In some production systems, ewes that raise single lambs should be candidates for culling, as more costly production systems require higher lambing percentages. Two single births in a row may be the culling standard for some sheep operations. If the single lamb is of poor quality or weight, this compounds the reason for culling.

When lamb losses are beyond the ewe’s control, such as predation or accidental death, exceptions can be made for keeping a ewe that fails to raise a lamb or fails to raise twin lambs. However, if a producer makes too many excuses for a ewe, this should be sign that the ewe is better off being put in the cull pen.

The importance of animal ID and records

Identification and record keeping are tools that assist in identifying culled ewes. Ideally, all ewes are identified with ear tags or similar identification. If this is not the case, ewes can be ear tagged or ear notched at the time of lambing, marking, weaning, or whenever something is noticed that is a reason for culling.

Ear notching can be an especially useful system for identifying culled ewes. Ewes that fail to breed or produce a lamb (or a good quality lamb) can be ear notched. Ewes that require assistance at lambing, reject their lambs, or give birth to small, weak lambs that are slow to suckle can be notched. Ewes that have mastitis, vaginal prolapses, or other health problems can be ear notched. Ewes that require extra work, such as routine hoof trimming or deworming, can be notched. One standard of culling would be to cull any ewe with two ear notches. Culling ewes with one ear notch would result in a stricter culling standard.

If ewes are individually identified and individual records are kept, it is much easier to identify ewes for culling. Records can be used to rank ewes for productivity and identify those which are underperforming. Litter weight at weaning is a good composite trait that can be used to evaluate productivity. At the same time, it is important to combine records with visual appraisal, as records may not document poor udder conformation, chronic hoof disease, or other problems that should be eliminated from the flock.
Other reasons for culling ewes

Various other criteria may be used to make culling decisions.

In hair sheep flocks, failure to adequately shed may be a reason for culling. Similarly, woole sheep flocks should cull ewes with fleece defects or wool quality issues.

Temperament can be another reason for culling. Fence jumpers should be culled. Flighty ewes are more difficult to handle and can get the entire flock excited. Calm ewes should be favored over nervous ewes, as their behavior has been associated with lower lamb mortality.

Author & reviewers

Author: Susan Schoenian, M.S., University of Maryland Extension, Keedysville, Maryland

Reviewers: Reid Redden, Ph.D., Texas A&M AgriLife Extension, San Angelo, Texas; Dan Morrill, Ph.D., Iowa State University, Ames, Iowa; and Rodney Kott, Ph.D., Former Montana State University Extension Sheep Specialist, Fredericksburg, Texas

More information

U.S. Lamb Resource Center
http://lambresourcecenter.com/production-resources/productivity/

National Sheep Improvement Program
http://www.nsip.org

U.S. Sheep Industry Roadmap
http://lambresourcecenter.com/reports-studies/roadmap/

Literature cited

Introduction

Sheep are seasonal breeders with the highest ovulation rates occurring during the middle portion of the breeding season. Successful reproduction of the ewe requires that she has a normal estrous cycle, ovulates one to four eggs, is mated by a fertile ram, and then maintains the fertilized embryos until she delivers healthy, vigorous lambs. This is a very complex reproductive process that becomes more challenging once flocks begin to push the level of productivity to higher and higher levels. Nutrition plays a critical role in the successful reproductive rates that are accomplished in ewe flocks. Figure 1 shows protein and energy changes through the various production phases. Ewes cannot make these nutrient modifications on their own; it is up to the manager to provide rations that meet animals’ needs.

Energy and protein requirements by stage and level of production for 150-pound ewes

Sheep are seasonal breeders with the highest ovulation rates occurring during the middle portion of the breeding season. Successful reproduction of the ewe requires that she has a normal estrous cycle, ovulates one to four eggs, is mated by a fertile ram, and then maintains the fertilized embryos until she delivers healthy, vigorous lambs.

Energy and protein requirements by stage and level of production for 150-pound ewes

Sheep are seasonal breeders with the highest ovulation rates occurring during the middle portion of the breeding season. Successful reproduction of the ewe requires that she has a normal estrous cycle, ovulates one to four eggs, is mated by a fertile ram, and then maintains the fertilized embryos until she delivers healthy, vigorous lambs.

Energy and protein requirements by stage and level of production for 150-pound ewes

Sheep are seasonal breeders with the highest ovulation rates occurring during the middle portion of the breeding season. Successful reproduction of the ewe requires that she has a normal estrous cycle, ovulates one to four eggs, is mated by a fertile ram, and then maintains the fertilized embryos until she delivers healthy, vigorous lambs.

Energy and protein requirements by stage and level of production for 150-pound ewes

Sheep are seasonal breeders with the highest ovulation rates occurring during the middle portion of the breeding season. Successful reproduction of the ewe requires that she has a normal estrous cycle, ovulates one to four eggs, is mated by a fertile ram, and then maintains the fertilized embryos until she delivers healthy, vigorous lambs.

Energy and protein requirements by stage and level of production for 150-pound ewes

Sheep are seasonal breeders with the highest ovulation rates occurring during the middle portion of the breeding season. Successful reproduction of the ewe requires that she has a normal estrous cycle, ovulates one to four eggs, is mated by a fertile ram, and then maintains the fertilized embryos until she delivers healthy, vigorous lambs.

Energy and protein requirements by stage and level of production for 150-pound ewes

Sheep are seasonal breeders with the highest ovulation rates occurring during the middle portion of the breeding season. Successful reproduction of the ewe requires that she has a normal estrous cycle, ovulates one to four eggs, is mated by a fertile ram, and then maintains the fertilized embryos until she delivers healthy, vigorous lambs.

Increasing weight, improving body condition

The most common nutrient required by the ewe is energy. Sheep with a shortage of energy intake will lose weight. This may happen with un-supplemented ewes grazing native range. The ewes cannot consume adequate amounts of forage due to low availability of forage or the slow rate of digestion by poor quality forage. Ewes will respond to improved nutrition by gaining weight and/or body condition. The process of providing this improved nutrition prior to and through breeding season is commonly referred to as flushing.

Flushing works best on ewes that are slightly under conditioned (CS<3) or early in the normal breeding season. Flushing can increase the lambs born by 10 to 30%. Ewes that are already in above average body condition (CS>3.5) do not respond to flushing. Figure 2 demonstrates the response in terms of number born with improved ewe body condition.

Flushing can be accomplished by supplemental feeding of concentrates, which is the standard practice for most farm flock operations. The amount of supplemental grain is dependent on the size of the ewes and the quantity and quality of the forage portion of the diet. The National Research Council (NRC) suggests at least a 10% increase in energy intake. This can be accomplished with .5 to 1.0 pound of grain per day.

The other means of improving the flock’s overall body condition prior to breeding is to allow more forage availability to achieve maximum voluntary intake. With more forage available, ewes can increase selective grazing to consume a higher energy and protein diet. Improved nutrition is normally continued through the first three weeks of breeding. Supplemental feeding may need to continue if the breeding season coincides with decreasing forage quality at the end of the growing season.
Lambs born per ewe exposed

![Bar chart showing lambs born per ewe exposed for Mules and Merinos.](chart)

**Figure 2.** Impact of condition score and lambs born (lifetimewool.com.au and MLC 1983)

Supplementing to meet needs

Ewes bred on dormant range may need protein and/or energy supplementation to meet their nutrient requirements. The quality of dormant range is dependent on the amount of weathering and the quality stage when growth stopped. Active, vegetative growth would be much higher in both energy and protein content compared to plants that were mature at the end of the growing season. The other critical nutrients are minerals and vitamins. Specifically, phosphorous and selenium deficiencies can reduce reproductive rates. Ewes should have access to free choice minerals throughout all stages of production. The mineral source should be formulated to meet the needs of the animals based on the local feed provided. Producers should contact their extension specialist or consulting nutritionist for input regarding a mineral supplementation program.

Vitamins A and E are both associated with reproduction. In general, if ewes have access to green feed during breeding, then supplementation of A and/or E is probably not required. Ewes bred in a dry lot system or on dormant range probably need supplemental E at 200 IU per day. This level would require the mineral source to contain 3200 IU of E, with a one-ounce daily consumption level. The majority of sheep minerals available are formulated with much lower levels of vitamin E.

Monitoring gestational condition

During mid-gestation the placenta is developing and inadequate feeding can retard development resulting in smaller birthweights. Research has shown that younger ewes are more prone to fetal loss during mid-gestation (Raasch 1997). Since most ewes will be in full fleece during this stage of production, it is critical that they are closely monitored to prevent excess losses in body condition. Condition score changes should be held to less than one half condition score. For example, a ewe in BCS of 3 should not lose more than 0.5 BCS during gestation, as this increases the risk of twin lamb disease. Ewes in light condition at birth do not lactate well, regardless of nutrition. One condition score is approximately 11% change in bodyweight. For 150 pound ewes, a half a condition score would be equivalent to losing eight pounds, which is not very much weight loss. And, be aware that ewes can lose BCS and still gain weight during gestation.

It is likely that there will be more ewes carrying twins and triplets. This requires better feeding in late gestation to ensure ewes are in good body condition (CS>3) for lactation and adequate birthweight of the multiples. Fetal counting can be used to subdivide the flock into high and low feeding groups depending on multiples or singles.

Flocks that are really pushing their reproductive capacity may see an improvement with the inclusion of omega-3 fatty acids in the flushing ration. This work was conducted in the United Kingdom and found providing omega-3 fatty acids, such as flax oil, increased both embryo quality and survival (Smith 2013).

Late gestational needs

Late gestation nutrition requires increased energy intake to allow for the rapid fetal growth. Fetal scanning and aging can be used to allot increased nutrients to ewes carrying multiples. If sorting the flock into drop groups by fetal count is not possible, then they should be phased in to a late-gestation ration. Ewes carrying triplets could be fed the late gestation ration starting 6 to 8 weeks ahead of lambing; ewes carrying twins, 4 to 6 weeks ahead; and singles, 2 to 3 weeks ahead of lambing. Nutrient intake in late gestation requires grain feeding for winter lambing flocks. Pasture or range lambing flocks can generally meet the nutrient demand with lush spring growth.

Demand increases during lactation

The greatest nutrient demand for the ewe is during lactation. Twin-rearing ewes require 50% more energy and protein to ensure adequate milk production for growth and survival of the lambs. Peak milk yield occurs around week four of lactation and begins declining after week eight of lactation. Nutrient requirements are drastically reduced in late lactation. Underfed lactating ewes will wean lambs with 10% lighter weaning weights. Ewes should not lose more than one half condition score during lactation. During the drying off period, the last week before weaning, additional weight loss can occur without lamb weaning weights.
Crossbred ewes in the Midwest appear in good body condition at the end of breeding season.

**Author & reviewers**

**Author:** Dan Morrical, Ph.D., Iowa State University, Ames, Iowa

**Reviewers:** Reid Redden, Ph.D., Texas A&M AgriLife Extension, San Angelo, Texas; Dan Morrical, Ph.D., Iowa State University, Ames, Iowa; Susan Schoenian, M.S., University of Maryland Extension, Keedysville, Maryland; and Rodney Kott, Ph.D., Former Montana State University Extension Sheep Specialist, Fredericksburg, Texas

### More information

**U.S. Lamb Resource Center**  
http://lambresourcecenter.com/production-resources/productivity/

**National Sheep Improvement Program**  
http://www.nsip.org

**U.S. Sheep Industry Roadmap**  
http://lambresourcecenter.com/reports-studies/roadmap/

### Literature cited

Lifetimewool. Ewes in better condition at joining conceive more lambs, lifetimewool.com.au


Raaech, G., B. Morrical and C. Youngs, 1988, Effect of supplemental vitamin E and a reproductive performance and scrotal profiles of ewes managed in dry lot. ASL R1468

Smith, M. 2013, Omega 3 for sheep – boost embryo survival to boost margins, "Farmers Guardian." August 2013
Introduction

Accelerated lamb production is a proven system that provides a consistent, year-round supply of lamb while increasing ewe productivity and production efficiency of the lamb production enterprise. This system of production has evolved from efforts in both Northern Europe (1,2) and America (3,4,5) that have sought to overcome the seasonal constraint in lamb production occurring with traditional, annual lambing systems. These systems differ in birth interval but are defined by the birth interval of an individual ewe of less than 12 months, with the majority of systems striving for ewes to lamb every 7 to 10 months. Therefore, ewes on these systems give birth at different periods from year to year thereby creating a year-round supply of lamb. This also creates an even cash flow for the farm, which is not possible with traditional, annual production, and allows for opportunities to borrow capital for expansion efforts.

Marketing flexibility and year-round supply

Accelerated systems allow more opportunistic marketing possibilities, which is advantageous in reducing risk. As markets fluctuate within and between years, accelerated production units are able to adapt and change target markets quickly as this system allows diverse marketing options. Lambs can be sold as market-ready, light lambs for the non-traditional market (35 to 80 pound lambs), as heavier, older lambs for the traditional market (>125 pound lambs), or for weights in between, depending on market conditions (Figure 1). Perhaps the greatest selling point for accelerated production is that the creation of a consistent, year-round supply allows a producer to build markets that would not be possible for traditional, annual, seasonal production systems. These markets pay premiums for this consistent, year-round supply of young, lean quality product.

Perhaps the greatest selling point for accelerated production is that the creation of a consistent, year-round supply allows a producer to build markets that would not be possible for traditional, annual, seasonal production systems. These markets pay premiums for this consistent, year-round supply of young, lean quality product.
Types of accelerated systems

Several types of accelerated systems exist with the two most common known as the “8-month” system (three lambings per ewe in two years, ref. 2,3) and the “STAR®” system (five lambings in three years, ref. 5). Important system differences include birth interval, time to re-breeding, and system flexibility.

Table 1. Comparison of two popular accelerated lamb production systems.

<table>
<thead>
<tr>
<th></th>
<th>STAR®</th>
<th>8-month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum birth interval</td>
<td>7.2 months</td>
<td>7-9 months</td>
</tr>
<tr>
<td>Lactation length</td>
<td>42-72 days</td>
<td>~42-100 days</td>
</tr>
<tr>
<td>Breeding period</td>
<td>&lt;30 days</td>
<td>&lt;51 days</td>
</tr>
<tr>
<td>Time to re-breeding</td>
<td>72 days</td>
<td>~120/601 days</td>
</tr>
<tr>
<td>Lambing periods/year</td>
<td>5</td>
<td>3/61</td>
</tr>
<tr>
<td>Breeding periods/year</td>
<td>5</td>
<td>3/61</td>
</tr>
<tr>
<td>Maximum births/ewe/year</td>
<td>1.67</td>
<td>1.5</td>
</tr>
</tbody>
</table>

1 Lambing periods can be doubled to six if two 8-month systems are used within an operation and offset by 2 months. This would also reduce the time to re-breeding to as little as 60 days if non-pregnant ewes are identified early and placed in the next breeding period of the opposite schedule.

- The 8-month system excels in providing:
  - more time for recovery following lactation,
  - long pre-weaning periods,
  - potentially larger lamb weaning weights, and
  - a less rigid schedule.

- The STAR® allows for:
  - faster re-breeding opportunities and
  - greater overall flock productivity.

Other variations include two overlapping 8-month systems in which the systems are offset by two months. This allows for six lambing periods within a year with the advantages of shorter re-breeding periods and even greater consistency in lamb supply. This overlapping system also allows heightened labor efficiencies as employees can be trained for more specialized tasks.

Genetics resources for accelerated production

Sheep with extended breeding seasons are required for accelerated production (short to no anestrous period). These breeds that are less seasonal include many breeds common in North America (Figure 2). There is likely variation within breeds, as well as it is common to find some ewes and rams within even highly seasonal breeds that are capable of breeding out-of-season. Sheep breeds that are less seasonal include those that have evolved closer to the equator and those specifically selected for out-of-season breeding in higher latitudes. There is also evidence suggesting that crossbreeding (heterosis) improves out-of-season reproduction just as it does other reproductive traits (4). Therefore, producers interested in accelerated production are encouraged to maximize the use of crossbreeding to improve both out-of-season breeding and lambing rate.

Figure 2. Sheep breeds commonly available in the US that are more capable of conceiving year-round:

- Rambouillet
- Merino
- Horned and Polled Dorset
- Finnsheep
- Romanov
- Katahdin
- Dorper
- Hair sheep of west African descent
- Ile de France
- Polypay

Nutrition

In general, the nutritional requirements of accelerated production are higher as animals are in a more productive state for a greater proportion of the time. The precise nutritional requirements of sheep in accelerated systems are not clearly defined, however, there is evidence (6,7) indicating that the plane of energy nutrition of both rams and ewes is more important for fertility during the less optimal breeding season (February through July in the northern hemisphere) than during the optimal breeding season. The extent, timing, and duration of improved plane of nutrition are not established, but producers are advised to improve energy intake of the ewe during late lactation and during the period just prior to breeding as is commonly done in pre-breeding flushing protocols to improve ovulation rate during the normal breeding season. During the less optimal, spring breeding season, improved energy intake may boost conception rates in ewes and improve libido in rams.

A challenge in the nutritional management of accelerated ewes is balancing the need to decrease energy intake just prior to and after weaning to minimize incidence of mastitis with the need to replenish energy reserves to improve out-of-season fertility. Producers with accelerated flocks typically decrease both energy

Continued on next page.
and protein intake for 3 to 5 days pre-weaning and then begin to increase energy intake 3 days post-weaning improving it to a flushing level of energy intake by 2 weeks post-weaning.

Table 2. Proposed energy requirements of sheep in accelerated systems based on National Research Council (NRC) requirements for ewes raising, carrying and rearing twins (8), but altered to allow for greater energy intake during late lactation.

<table>
<thead>
<tr>
<th>Period</th>
<th>Annual system*</th>
<th>Accelerated system*</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 weeks prior to breeding</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Day 0-40 post conception (PC)</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Day 40-115 PC</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Day 115 to term</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Day 0-30 of lactation</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Day 30-60 of lactation</td>
<td>1.9</td>
<td>2.2</td>
</tr>
</tbody>
</table>

* Energy intake is expressed relative to maintenance energy requirements of non-pregnant adult ewes.

Reproductive management

Reproductive technologies such as intravaginal controlled internal drug releasing devices (CIDRs) that provide a sustained source of progesterone supplementation to ewes, may be used to synchronize breeding and improve conception rates during the spring breeding season. CIDRs have been demonstrated to be effective in improving breeding synchronization, but their ability to improve conception rates above that observed using vasectomized "teaser" rams is less certain (9,10). The use of teaser rams to enhance reproductive management of sheep is commonly known as the "ram effect" (11). This form of bio-stimulation of reproduction is especially effective in improving conception in ewes on the "edge" of the normal breeding season, but it is not as effective in improving conception in sheep that may be in the depth of the non-breeding season.

The use of artificial light to enhance sheep reproduction is an effective means of improving both ram and ewe fertility. Lighting protocols can greatly improve out-of-season fertility and ovulation rate in accelerated systems (12). Some of these protocols require conditions that are not feasible on many farms, including the use of a barn that must be kept dark along with proportionally more feeding of stored feed. Both of these conditions increase the cost of production and must be considered when evaluating the economics of improved productivity of these systems.

Infrastructure

In cold climates, an indoor lambing facility is needed for accelerated production as at least one of the lambing periods will take place in winter. (Figure 3) Although not an absolute requirement, insulated birth facilities heated by supplemental heat or by capture of animal heat, allow for improved operator and animal comfort during winter birth periods. The size of these facilities can be smaller than for traditional, annual lambing programs using indoor facilities for a single birth period as less than 60% of the ewe flock typically gives birth in a given period.

Efficient feeding systems are critical for any sheep production system, whether it be a grazing program, one using machine harvested feeds, or a combination of both. This especially applies to accelerated production due to the greater nutritional needs of the sheep. Grazing programs can easily meet the nutritional needs of highly productive sheep for at least part of the production cycle but must be carefully managed to meet the higher requirements of the pre-breeding period, late pregnancy and lactation that collectively constitutes about half of the cycle. This may require greater investment in subdivision fencing and other grazing infrastructure. In most accelerated systems, investments in efficient forage feeding programs are also needed to reduce feeding labor and to meet the relatively higher nutritional needs of the flock. Larger operations commonly employ a total mixed ration feeding program to reduce labor and cost of feed, and to more effectively meet animal requirements during late pregnancy and lactation.

Barriers and challenges

The chief barrier to accelerated success is poor and variable out-of-season breeding success. Producers may struggle to achieve consistent breeding success during the spring. Particular emphasis must be placed on:

- Ram fertility and libido: screen with breeding soundness exams and monitor mating activity.
- Nutrition: ensure an adequate plane of nutrition prior to and during the breeding season.
- Genetics: source genetics with the capacity to breed out-of-season.
### Pros and cons of accelerated production

<table>
<thead>
<tr>
<th>Pro</th>
<th>Con</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year-round supply: create new and build existing markets</td>
<td>Precise management: nutrition, reproduction, health</td>
</tr>
<tr>
<td>Consistent cash flow</td>
<td>Requires a winter lambing period</td>
</tr>
<tr>
<td>Reduced market risk</td>
<td>Requires high-quality forage</td>
</tr>
<tr>
<td>Greater net income (per ewe, lamb, enterprise)</td>
<td>Requires steady labor</td>
</tr>
<tr>
<td>Even distribution of labor</td>
<td></td>
</tr>
</tbody>
</table>

### Choosing accelerated lambing
- Accelerated production systems are well suited for higher value, more productive land.
- Aseasonal genetics are key: light control protocols reduce risk.
- Accelerated production requires high-quality forages.
- Accelerated production requires a greater initial investment (indoor lambing facility, feeding, infrastructure); however, the higher productivity may create lower fixed cost per lamb produced when depreciated over time.
- Accelerated production means labor over the year, but it is a steady requirement.
- Accelerated production is a profitable option if the current annual program can attain greater than 1.3 lambs marketed per ewe.

### Author & reviewers
**Author:** Richard Ehrhardt, Ph.D., Michigan State University, East Lansing, Michigan

**Reviewers:** Reid Redden, Ph.D., Texas A&M AgriLife Extension, San Angelo, Texas; Dan Morrical, Ph.D., Iowa State University, Ames, Iowa; Susan Schoenian, M.S., University of Maryland Extension, Kearneysville, Maryland; and Rodney Kott, Ph.D., Former Montana State University Extension Sheep Specialist, Fredericksburg, Texas

### Literature cited

### More information
**U.S. Lamb Resource Center**
http://lambresourcecenter.com/production-resources/productivity/

**National Sheep Improvement Program**
http://www.rsip.org

**U.S. Sheep Industry Roadmap**
http://lambresourcecenter.com/reports-studies/roadmap/
Efficiency of CIDR-Based Protocols Including GnRH Instead of eCG for Estrus Synchronization in Sheep

Paula Martinez-Ros 1,* and Antonio Gonzalez-Bulnes 2,3,©

1 Dpto. Produccion y Sanidad Animal, Facultad de Veterinaria, Universidad Cardenal Herrera-CEU, CEU Universities, C/Tirant lo Blanch, 7,46115 Alfa del Patriarca, Valencia, Spain
2 Dpto. Reproduccion Animal, INIA, Avda. Puerta de Hierro s/n, 28040 Madrid, Spain; bulnes@inia.es
3 Dpto. Toxicologia y Farmacologia, Facultad de Veterinaria, UCM, Ciudad Universitaria s/n, 28040 Madrid, Spain
* Correspondence: paula.martinez@uchceu.es; Tel.: +34-961-369-000

Received: 7 March 2019; Accepted: 1 April 2019; Published: 3 April 2019

Simple Summary: This study examines the preovulatory and ovulatory events (in terms of the timing of onset of estrus behavior, preovulatory LH surge, and ovulation) and the yields obtained (in terms of ovulation rate, progesterone secretion, and fertility) after insertion of controlled internal drug release (CIDR) devices for 5 days and treatment with equine chorionic gonadotrophin (eCG) or gonadotrophin-releasing hormone (GnRH).

Abstract: The present study examined, for meat sheep (Segureña breed; 2-5 years old, mean body score of 3.5 ± 0.5), the timings of onset of estrus behavior, preovulatory luteinizing hormone (LH) surge and ovulation, and the ovulation rate and fertility obtained after insertion of controlled internal drug release (CIDR) devices for 5 days plus treatment with equine chorionic gonadotrophin (eCG; single dose at CIDR removal, n = 19 ewes) or gonadotrophin-releasing hormone (GnRH, either in a single dose at 56 h after CIDR removal, group CIDR-GnRH, n = 19 ewes; or in one dose at CIDR insertion and another dose 56 h after CIDR removal, group GnRH-CIDR-GnRH, n = 19 ewes). In all the ewes, the appearance of estrus behavior ranged between 84% and 90% and all females showing estrus signs had subsequent preovulatory LH peaks and ovulations. Onset of these events was earlier in the CIDR-eCG group than in the CIDR-GnRH and GnRH-CIDR-GnRH groups (p < 0.05). These differences were mainly determined by the onset of estrus behavior, since timing and intervals of LH peak and ovulation were similar among treatments. In fact, the range of ovulations was narrower in the GnRH-CIDR-GnRH group, which suggests better synchronization of follicular growth (p < 0.05). In conclusion, protocols with two doses of GnRH offer similar yields to eCG protocols.

Keywords: CIDR; eCG; estrus synchronization; fertility; GnRH; ovulation; sheep

1. Introduction

Reproductive management of sheep, like in other domestic species, is commonly based on the induction and synchronization of estrus and ovulation, either in reproductive or nonreproductive season and either for natural mating or artificial insemination, by the use of pharmacological treatments [1]. Such treatments, from seminal studies in the 1950s [2], are mostly based on the administration of progesterone or its analogues for mimicking the activity of the corpus luteum. Usually, a single intramuscular dose of equine chorionic gonadotrophin (eCG) is injected at progesterone withdrawal since, from very early studies [3], eCG proved to be effective at inducing estrus and ovulation during seasonal anestrous in order to increase the percentage of twin pregnancies throughout the year.
and to adjust the interval between ovulation and insemination in protocols for fixed-time artificial insemination (FTAI).

The future use and availability of eCG, despite being an essential component of protocols for induction and synchronization of estrus and ovulation, has been, however, strongly compromised by a highly active animal-rights movement because the hormone is obtained from pregnant mares. Hence, there is a need for alternative protocols without eCG.

We have recently evaluated the usefulness of different short-term (5–7 days) protocols using controlled internal drug release (CIDR) inserts without eCG administration at device removal [4]. Our objective was to prove the hypothesis that such protocols would induce estrus and fertile ovulations without the need for eCG. CIDR insertion causes atresia of any large follicle present in the ovaries and therefore promotes the appearance of new follicles that reach their maximum diameter 5–7 days later [5]. Our results indicated that, without eCG, preovulatory events and fertility after 5 days are better than after 6 or 7 days of CIDR insertion and similar to those obtained by the use of classical treatments with 14 days of CIDR insertion plus eCG at device removal. These findings may indicate that the dominant follicle induced by CIDR insertion would be at the height of its growing phase 5 days later and, in case of CIDR withdrawal, would be able to ovulate without eCG stimulation. However, 1 or 2 days after, it would be in the static or regressing phase and, therefore, its ability to ovulate without eCG stimulation would be compromised.

The proposed protocol of 5 days of CIDR insertion may be useful for natural mating, but its use in FTAI requires the precise synchronization of ovulations obtained by the use of eCG. In fact, our previous study indicates that fertility under field conditions was similar between treatments based on 14 days of CIDR plus eCG and 5 days of CIDR without eCG but increased around 20% when using 5 days of CIDR plus eCG. These results highlight the benefits of using eCG regardless of the duration of CIDR insertion and encourage the search for an alternative.

A possible option would be other luteinizing hormone (LH)-active hormones, but early studies evaluating the usefulness of gonadotrophin-releasing hormone (GnRH), human chorionic gonadotrophin (hCG) and even a eCG-hCG mixture (PG600) indicated that only GnRH would constitute a potential substitute [6]. In fact, later studies trying to replace eCG with hCG, at least partly if using PG600, showed poorer fertility yields [7,8]. The most promising results have been found when using GnRH to stimulate ovulation [9], although this hormone has been more frequently associated with prostaglandin-based protocols [10–12]. It is important to note that GnRH must be applied at least 24–36 h after progestagen removal or luteolysis [13], since its earlier application (e.g., at progestagen removal) causes luteinization of the preovulatory follicle and anovulation [14].

The first hypothesis to be tested in the current work was that GnRH may synchronize ovulations after 5 days of CIDR treatment in a similar way to eCG, giving similar reproductive yields. The second hypothesis was that the administration of GnRH at CIDR insertion would facilitate a more precise synchronization of the follicular wave; such a protocol including a first GnRH dose at CIDR insertion and a second dose concomitantly with artificial insemination would be similar to protocols using a Cosynch protocol [15] supplemented with progesterone [16] and, therefore, would contribute to a more precise synchronization of the ovulatory events, thus improving fertility.

Hence, the objective of the present study was to characterize the preovulatory and ovulatory events (in terms of timing of onset of estrus behavior, preovulatory LH surge, and subsequent ovulation) and the yields obtained (in terms of ovulation rate, progesterone secretion, and fertility) after the insertion of a CIDR device for 5 days combined with either the administration of eCG at sponge removal or the administration of two different schemes of GnRH treatment. These results would have direct implications for evaluating the effectiveness of the proposed practice of using short-term CIDR protocols without eCG.
2. Material and Methods

2.1. Animals and Experimental Design

The trial was carried out during the breeding season (December) and involved 57 multiparous meat ewes (Segureña breed; 2-5-years old, with a mean body score of 3.5 ± 0.5 on a scale of 1–5), maintained outdoors with access to indoor facilities at the experimental farm of the CEU Cardenal Herrera University in Naquera (Valencia, Spain; latitude 39° N). The experiment was assessed and approved by the University Committee of Ethics in Animal Research (report CEEA17/019) according to the Spanish Policy for Animal Protection (RD53/2013), which meets the European Union Directive 2010/63/UE.

Ovarian cyclic activity and ovulation were synchronized in all the animals by the insertion of one intravaginal progesterone-loaded CIDR (CIDR® Ovis, Zoetis, Madrid, Spain) for 5 days and an intramuscular (i.m.) injection of 5 mg of prostaglandin F₂α (dinoprost tromethamine, Dinolytic®, Zoetis, Madrid, Spain) at CIDR withdrawal, in agreement with previous studies of our group [4], as depicted in Figure 1. The first group of ewes (group CIDR-eCG, n = 19) was treated with a single i.m. dose of 400 IU of eCG at CIDR removal (Foligon®, MSD Animal Health, Madrid, Spain), while the other two groups were not treated with eCG. In one of them (group CIDR-GnRH, n = 19), a single dose of 50 µg of GnRH was administered 56 h after CIDR removal (gonadorelin acetate, Acegon®, Lab. Syva, Leon, Spain). The third group (group GnRH-CIDR-GnRH, n = 19) received the same treatment as the CIDR-GnRH group but with the addition of a 50-µg GnRH dose at CIDR insertion.

![Figure 1. Schematic representation of the three treatment groups compared in the study. All the groups were treated with controlled internal drug release (CIDR) devices for 5 days and a prostaglandin F₂α injection at CIDR removal. The CIDR-equine chorionic gonadotrophin (eCG) group was treated with a single intramuscular (i.m.) dose of 400 IU of eCG at CIDR removal, the CIDR-gonadotrophin-releasing hormone (GnRH) group was treated with a single dose of GnRH at 56 h after CIDR removal, and the GnRH-CIDR-GnRH group was treated with two single GnRH doses—one at CIDR insertion and one 56 h after CIDR removal.](image)

The variables evaluated during the induced follicular phase and the subsequent luteal phase were the percentage and timing of onset of estrus behavior, preovulatory LH surge and ovulation, the number and functionality (in terms of plasma progesterone concentrations) of the induced corpora lutea, and the fertility rate.
2.2. Occurrence and Timing of Estrus Behavior Onset

Occurrence and timing of onset of estrus behavior (defined as acceptance of the first mating and time elapsed from CIDR withdrawal) were determined by individual detection of estrus signs by trained rams every 4 h from 20 to 60 h after CIDR withdrawal.

2.3. Occurrence and Timing of Preovulatory LH Surge

Occurrence and timing of onset of the preovulatory LH surge (defined as the point before LH concentration increased more than 10% over basal concentrations [17]) were determined by enzimimunnoassay (LH Detect®, INRA, Tours, France) in jugular blood plasma. Plasma samples were collected every 4 h from 32 to 84 h after CIDR removal in heparinized 4-mL vacuum tubes (Vacutainer™ Systems Europe, Meylan, France) and immediately centrifuged at 1500x g for 15 min. The plasma was separated and biobanked into polypropylene vials at −80 °C until assayed. The assay had a sensitivity of 0.01 ng/mL and inter- and intra-assay variation coefficients of 7.4% and 8.5%, respectively; variation coefficients were calculated using controls ranging from 0.05 to 40 ng/mL.

2.4. Occurrence and Timing of Ovulation

Occurrence and timing of ovulation were determined by transrectal ultrasonography (7.5 MHz; Aloka SSD500, Aloka Co., Ltd., Tokyo, Japan) by assessing the disappearance of large anechoic structures (i.e., ovulatory follicles) recorded in a previous ultrasonography, as previously described [18,19].

2.5. Ovulation Rate and Corpora Lutea Functionality

Ovulation rate was determined by transrectal ultrasonography at Day 10 of the induced estrous cycle. Concomitantly, jugular blood plasma samples, obtained as previously described, were used to determine plasma progesterone concentrations with a direct solid-phase RIA kit (PROG-CTRIA, IBA Molecular, Madrid, Spain). The assay had a sensitivity of 0.05 ng/mL and inter- and intra-assay variation coefficients of 4.5% and 3.5%, respectively; variation coefficients were calculated using controls ranging from 0.5 to 20 ng/mL.

2.6. Fertility Rate

The fertility rate, in terms of number of pregnant females with regards to treated and mated ewes, was assessed by transrectal ultrasonography at Day 35 after CIDR withdrawal.

2.7. Statistical Analysis

Statistical analysis was performed using SPSS® 22.0 (IBM Corporation, Armonk, NY, USA). The effects of treatment (eCG, single GnRH injection, or double GnRH injection) on the onset of estrus behavior; preovulatory LH surge and ovulation and, afterwards, on ovulation rate; and progesterone secretion were assessed by analyses of variance (ANOVA). Ranges in the timing of these variables were analyzed after comparing the 95% credible interval of the mean with the range. Statistical analysis of occurrence of estrus, LH surge, ovulation, and fertility was performed by a chi-squared test after arcsine transformation of the values. All results are expressed as mean ± SEM and the statistical significance was accepted at p < 0.05.

3. Results

3.1. Occurrence and Timing of Estrus Behavior

The percentage of animals showing estrus behavior after CIDR withdrawal ranged between 84% and 90% in all groups, without significant differences among them (Table 1). There were, on the other hand, significant differences in the timing of estrus onset, and the group treated with eCG had a significantly earlier appearance of estrus signs than the groups treated with GnRH (p < 0.05). The
range of appearance of estrus behavior was similar for the CIDR-eCG and CIDR-GnRH groups (20 and 24 h, respectively) and longer (36 h; \( p < 0.05 \)) for the GnRH-CIDR-GnRH group (Figure 2).

Table 1. Percentage and timing of occurrence (hours \( \pm \) SEM) of estrus behavior, preovulatory luteinizing hormone (LH) surge, and ovulation in ewes treated with a single i.m. dose of 400 IU of eCG at CIDR removal (group CIDR-eCG), with a single dose of GnRH at 56 h after CIDR removal (group CIDR-GnRH), and with two GnRH doses—one at CIDR insertion and one 56 h after CIDR removal (group GnRH-CIDR-GnRH).

<table>
<thead>
<tr>
<th>Event</th>
<th>CIDR-eCG (n = 19)</th>
<th>CIDR-GnRH (n = 19)</th>
<th>GnRH-CIDR-GnRH (n = 19)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occurrence of estrus behavior (%)</td>
<td>17/19 (89.5)</td>
<td>17/19 (89.5)</td>
<td>16/19 (84.2)</td>
</tr>
<tr>
<td>Timing of estrus behavior after CIDR removal (range)</td>
<td>34.1 ± 2.0 a (24–44)</td>
<td>39.3 ± 2.0 b (28–52)</td>
<td>39.8 ± 2.2 b (24–52)</td>
</tr>
<tr>
<td>Occurrence of preovulatory LH surge (%)</td>
<td>17/17 (100)</td>
<td>17/17 (100)</td>
<td>16/16 (100)</td>
</tr>
<tr>
<td>Timing of preovulatory LH surge after CIDR removal (range)</td>
<td>42.2 ± 3.0 a (28–56)</td>
<td>44.4 ± 2.3 a,b (32–52)</td>
<td>50.7 ± 1.9 b (44–56)</td>
</tr>
<tr>
<td>Timing of preovulatory LH surge after onset of estrus behavior (range)</td>
<td>8.0 ± 1.0 (4–12)</td>
<td>6.7 ± 1.6 (4–16)</td>
<td>7.5 ± 1.6 (4–16)</td>
</tr>
<tr>
<td>Occurrence of ovulation (%)</td>
<td>17/17 (100)</td>
<td>17/17 (100)</td>
<td>16/16 (100)</td>
</tr>
<tr>
<td>Timing of ovulation after CIDR removal (range)</td>
<td>65.8 ± 2.3 a (52–76)</td>
<td>68.4 ± 2.5 a,b (60–80)</td>
<td>73.8 ± 2.1 b (68–84)</td>
</tr>
<tr>
<td>Timing of ovulation after onset of estrus behavior (range)</td>
<td>31.6 ± 0.8 (28–36)</td>
<td>30.7 ± 0.9 (28–36)</td>
<td>30.2 ± 1.0 (28–36)</td>
</tr>
<tr>
<td>Timing of ovulation after onset of preovulatory LH surge (range)</td>
<td>24.0 ± 1.1 (16–28)</td>
<td>24.0 ± 1.4 (16–28)</td>
<td>22.5 ± 1.3 (16–28)</td>
</tr>
</tbody>
</table>

Different superscripts indicate significant differences among treatments (\( a \neq b; p < 0.05 \)).

Figure 2. Distribution (percentage of animals) of time of onset of estrus behavior, in hours after CIDR withdrawal, in ewes treated with a single i.m. dose of 400 IU of eCG at CIDR removal (group CIDR-eCG, white bars), with a single dose of GnRH at 56 h after CIDR removal (group CIDR-GnRH, grey bars), and with two GnRH doses—one at CIDR insertion and one 56 h after CIDR removal (group GnRH-CIDR-GnRH, black bars).
3.2. Occurrence and Timing of Preovulatory LH Surge

All the animals showing signs of estrus behavior in response to the hormonal treatment, independently of the group, showed a preovulatory LH surge afterwards (Table 1). The timing of the preovulatory surge was earlier in the group treated with eCG than in the GnRH-CIDR-GnRH group ($p < 0.05$), and the CIDR-GnRH group had in-between values. The same was found when analyzing the range of appearance and intervals (Figure 3). These differences were determined by the timing of onset of estrus behavior, since both the mean interval and the range between the onsets of estrus behavior and LH surge were similar between treatments.

![Figure 3. Distribution (percentage of animals) of time of onset of the preovulatory LH surge, in hours after estrus behavior (left hand) and after CIDR withdrawal (right hand), in ewes treated with a single i.m. dose of 400 IU of eCG at CIDR removal (group CIDR-eCG, white bars), with a single dose of GnRH at 56 h after CIDR removal (group CIDR-GnRH, grey bars), and with two GnRH doses—one at CIDR insertion and one 56 h after CIDR removal (group GnRH-CIDR-GnRH, black bars).]

3.3. Occurrence and Timing of Ovulation

The results on occurrence and timing of ovulation were very similar to the previous data on occurrence and timing of preovulatory LH surge. All the animals showing estrus signs and a preovulatory LH surge afterwards ovulated in response to the hormonal treatment independently of the group (Table 1). The timing of ovulation after CIDR withdrawal was again earlier in the group treated with eCG than in the GnRH-CIDR-GnRH group ($p < 0.05$), and the CIDR-GnRH group again had intermediate values. However, again, these findings were determined by the timing of onset of estrus behavior (Figure 4), since the mean intervals and the range between the occurrences of the preovulatory LH surge and ovulation were similar among treatments.

Finally, grouping of preovulatory LH surges and ovulations in the GnRH groups caused the range of ovulations after CIDR removal to be narrower in the GnRH-CIDR-GnRH group (16 h) than in the CIDR-GnRH and CIDR-eCG groups (20 and 24 h, respectively).
Figure 4. Distribution (percentage of animals) of time of occurrence of ovulation, in hours after onset of the preovulatory LH surge (left hand) and after CIDR withdrawal (right hand), in ewes treated with a single i.m. dose of 400 IU of eCG at CIDR removal (group CIDR-eCG, white bars), with a single dose of GnRH at 56 h after CIDR removal (group CIDR-GnRH, grey bars), and with two GnRH doses—one at CIDR insertion and one 56 h after CIDR removal (group GnRH-CIDR-GnRH, black bars).

3.4. Ovulation Rate and Corpora Lutea Functionality

There were no significant differences in the mean number of corpora lutea between the groups treated with GnRH (Table 2); however, the ovulation rate was numerically higher in the CIDR-eCG group than in the GnRH-CIDR-GnRH group ($p = 0.08$) and significantly higher in both groups than in the CIDR-GnRH group ($p < 0.05$). Assessment of plasma progesterone did not show significant differences among groups (Table 2).

Table 2. Mean (± SEM) number of corpora lutea and plasma progesterone concentrations (ng/mL) and fertility rate in ewes treated with a single i.m. dose of 400 IU of eCG at CIDR removal (group CIDR-eCG), with a single dose of GnRH at 56 h after CIDR removal (group CIDR-GnRH), and with two GnRH doses—one at CIDR insertion and one 56 h after CIDR removal (group GnRH-CIDR-GnRH).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of corpora lutea (range)</td>
<td>$2.1 \pm 0.2^a$</td>
<td>$1.3 \pm 0.2^b$</td>
<td>$1.6 \pm 0.2^a$</td>
</tr>
<tr>
<td>(1-4)</td>
<td>(1-2)</td>
<td>(1-2)</td>
<td></td>
</tr>
<tr>
<td>Plasma progesterone concentrations (range)</td>
<td>$5.9 \pm 1.0$</td>
<td>$5.1 \pm 0.6$</td>
<td>$4.9 \pm 0.7$</td>
</tr>
<tr>
<td>(2.3-7.8)</td>
<td>(2.9-7.1)</td>
<td>(1.5-7.0)</td>
<td></td>
</tr>
<tr>
<td>Fertility rate with regards to ewes ovulating (%)</td>
<td>$13/17 (76.5)$</td>
<td>$11/17 (64.7)$</td>
<td>$13/16 (81.3)$</td>
</tr>
<tr>
<td>Fertility rate with regards to treated ewes (%)</td>
<td>$13/19 (68.4)$</td>
<td>$11/19 (57.9)$</td>
<td>$13/19 (68.4)$</td>
</tr>
</tbody>
</table>

Different superscripts indicate significant differences among treatments ($a \neq b; p < 0.05$).

3.5. Fertility Rate

The fertility rate of ewes ovulating in response to the treatment was higher than 60% in all the groups (Table 2), with a trend of being higher in the GnRH-CIDR-GnRH group than in the CIDR-GnRH group ($p = 0.06$). Hence, finally, the fertility rate considering treated ewes was similar in the CIDR-eCG and GnRH-CIDR-GnRH groups and numerically higher in both groups than in the CIDR-GnRH group.
4. Discussion

The results of the present study indicate that the administration of GnRH after 5 days of CIDR-based protocols gives reproductive responses (in terms of ewes responding to the treatment with the appearance of estrus, preovulatory LH surge, and ovulation) that are similar to the classical protocols based on the use of eCG. Overall, the onset of these events was earlier in the group treated with eCG at CIDR removal (CIDR-eCG) than in the groups treated with GnRH at 56 h after CIDR removal (CIDR-GnRH and GnRH-CIDR-GnRH) and especially in the group treated with a first GnRH dose at CIDR insertion (GnRH-CIDR-GnRH).

The administration of GnRH after CIDR withdrawal was performed at 56 h to mimic the timing of FTAI. Administration of GnRH at timing of FTAI, instead of 24–36 h after: CIDR removal [13], diminishes the handling of the animals, which is always important in practice. However, under the conditions of the current study, there was no influence of the GnRH injection on the timing of onset of estrus behavior and even in the beginning of the preovulatory surge, which had occurred previously in all the animals. If using our proposed protocol for FTAI, administration of GnRH at 56 h would be important for avoiding animals with later preovulatory LH surges, which may negatively affect fertility, since GnRH treatment induces the LH surge within 1–4 h post-administration [20]. A possible advance of the timing of GnRH administration, weighing handling costs and the possible benefits of inducing an earlier and more synchronous LH peak, should be tested under field conditions since the design of the present study was mainly focused on studying the characteristics of estrus, preovulatory LH surge, and ovulation (which requires a high number of successive samples from a small number of animals) rather than the fertility yields (which requires a large number of animals).

The scenario in the CIDR-eCG and CIDR-GnRH groups, bearing in mind that the endogenous LH peak occurred prior to the GnRH injection, was therefore equivalent to our previous study comparing 5 days of CIDR treatment with or without eCG [4]. The comparison of results shows that differences in the timings of occurrence of estrus behavior and ovulation between animals with or without eCG are similar between the previous and the current study, confirming that the appearance of estrus is earlier when applying eCG. However, there are some differences in these features between studies, which may be related to the different time of the year since the occurrence of these events was earlier in the present trial (performed in mid-breeding season, December) than in the previous one (performed in late-breeding season, April). These results suggest the need for further studies to determine the influence of seasonality but, at the same time, support the use of the GnRH injection at 56 h for counteracting possible delays in the endogenous LH surge, when eCG is not used, at the beginning or the end of the reproductive season. A further step would be to study the usefulness of this protocol for inducing synchronized and fertile ovulations during the anestrous season, which is the main limiting factor in case of eCG shortage, since gonadotrophin secretion and therefore ovulation are depressed in anestrous [21].

In the present trial, the timing of appearance of estrus, preovulatory LH surge, and ovulation after CIDR withdrawal were even more delayed after administration of the first GnRH dose at CIDR insertion (group GnRH-CIDR-GnRH). The differences were statistically significant when compared with the group treated with eCG, which may be an effect of the follicle-stimulating hormone (FSH) and LH activities of this hormone and the earlier timing of eCG administration, as well as numerically when compared with the CIDR-GnRH group. The delay in the preovulatory events found in the GnRH-CIDR-GnRH group is possibly related to the effect of the exogenous GnRH surge on follicular dynamics at the beginning of the follicular wave induced by the CIDR treatment. The CIDR insertion causes an abrupt increase in progesterone and a subsequent decrease in pituitary LH secretion, which induce atresia of all the large follicles present at the ovaries and the appearance of a new follicular wave [5]. The administration of GnRH causes the opposite effect, since it induces an endogenous LH surge, but has the same final result: the dominant follicle cannot ovulate and therefore undergoes luteinization, so a new follicular wave is initiated [10]. However, the GnRH injection not only acts on LH secretion but also on FSH secretion, which increases in response to GnRH stimulation in the
absence of the negative feedback of estradiol and inhibit [22,23]. The best example is the FSH peak occurring immediately after the preovulatory LH peak and at about the time of ovulation, which is identified as being responsible for the development of the first follicular wave of the following estrous cycle [24]. In sheep, inhibit is secreted by follicles that are ≥3 mm in size [25,26], so we can hypothesize that the preovulatory follicle growing after GnRH synchronization of the wave would emerge from the pool of gonadotropin-responsive follicles around 3 mm in size, which is the optimal follicular population for assisted reproductive techniques in sheep [27]. Hence, by injecting GnRH, we are inducing a similar scenario to Day 0 of the estrous cycle—the best scenario for applying assisted reproductive techniques (the so-called Day 0 Protocol in sheep MOET programs [28]). Afterwards, the CIDR assures high serum plasma progesterone concentrations which are necessary during follicular development to ensure adequate oocyte health at ovulation [29].

The differences among the GnRH-CIDR-GnRH group and the CIDR-GnRH and CIDR-eCG groups were mainly determined by the timing of onset of estrus behavior (i.e., the time needed by the preovulatory follicle to reach its maximal estradiol secretion and therefore to induce estrus signs), since timing and intervals of preovulatory LH surge and ovulation were similar among the three treatments. In fact, the ranges of appearance of preovulatory LH surge and ovulation were narrower in the GnRH-CIDR-GnRH group than in the CIDR-GnRH and CIDR-eCG groups, which reinforces evidence of a better synchronization of the follicular growth in such a group.

On the other hand, we have to highlight that the CIDR-eCG group had the widest range of occurrence of ovulations, from 52 to 76 h after CIDR withdrawal, after a wide range of occurrence of the preovulatory LH surge, from 28 to 56 h after CIDR withdrawal, and three peaks of onset of estrus behavior (with two groups of around 26%–27% of the sheep, each one having estrus signs at 24 and 44 h, and a third group of around 30% of the animals showing estrus behavior at 32−36 h after CIDR withdrawal). Such patterns of appearance of estrus, preovulatory LH surge, and ovulation suggest a heterogeneous follicle population stimulated to ovulate by the use of eCG. Hence, these results suggest that eCG may be the best option, and has been for around 70 years, but not a good one for managing the follicular phase after progesterone-based estrus synchronization, bearing in mind its long half-life and prolonged effect on follicular growth [30].

5. Conclusions

Protocols based on short-term (5 days) CIDR treatments and a double administration of GnRH (one at device insertion and one around the timing of fixed-time artificial insemination) assure the occurrence of fertile and synchronized ovulations for protocols based on the use of short-term CIDR treatments and eCG at device withdrawal.

Author Contributions: P.M.-R. and A.G.-B. designed and performed the study and wrote the article.

Acknowledgments: The authors thank the CEU-Cardenal Herrera farm staff, especially Amparo Galvez, for their assistance with animal care and handling and Zoetis España for the kind donation of the CIDRs used in the study.

Conflicts of Interest: The authors declare no conflict of interests.

References


© 2019 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).
Introduction
A breeding soundness examination (BSE) is an overall assessment of a male’s potential ability to service and impregnate a given number of females during a given period of time. It is a picture-in-time of the male’s reproductive potential. The evaluation includes:

- A thorough physical exam
- A body condition score (BCS)
- A scrotal circumference (SC)
- A thorough microscopic semen evaluation

Rams contribute up to 75% of the genetic change in a flock, therefore, it is very important to not short cut the selection or care of the ram. A breeding soundness exam prior to purchase should be part of buying criteria. Producers must also remember that things change, a ram can acquire a disease, such as bluetongue, pneumonia, or get injured. Additionally, any major stressor may cause a change in breeding ability and semen quality.

A BSE should be performed annually on all rams six months of age or older in a flock, allowing producers to cull less productive rams, provide adequate feed to increase or decrease body condition, provide any care or treatment as needed and purchase any replacement(s) prior to mating.

The First Steps
As a BSE is performed, the ram should be bright, alert, walk with a sound gait and have no physical lesions or signs of illness. Each individual ram must have a unique identification. All information pertaining to that ram should be recorded on a breeding soundness form.

Body condition score (BCS)
A BCS is assessed by feeling along the ribs and lumbar spine. It is based on a scale of 1 to 5. A score of 1 means a ram is very thin and under conditioned. A BCS of 5 is a very fat, over-conditioned ram that is unable to be palpated on the individual lumbar spine or dips along the vertebrae. Both a score of 1 or 5 are unsatisfactory and require feeding changes to modify the score prior to the breeding season. A BCS in between these is considered satisfactory, with a 3 or 4 ideal going into the breeding season.

Rams have a job to do and often will forego eating enough to maintain their physical condition, thus thin rams may not make it through the breeding season. Meanwhile, an over-conditioned ram will often have very poor semen quality, cause interference with other rams while they are breeding ewes, and be lazy and not perform — these are referred to as the “couch potatoes.”

Scrotal circumference (SC)
The genitalia are examined next.

The scrotal exam includes palpation of the testes and epididymis. These should be firm, with no lumps, lesions, swellings, hard or soft spots, no difference in size and no atrophy. Out of breeding season, they may be slightly flaccid.

Scrotal circumference relates to the capacity to service more ewes per breeding cycle, earlier maturing female offspring and the increase in number of multiple births produced. The heritability of SC is estimated at 35% (SID 2002). A SC is measured in centimeters.

Acceptable scrotal circumference

<table>
<thead>
<tr>
<th></th>
<th>Rams 6 to 14 months</th>
<th>Rams &gt; 14 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsatisfactory</td>
<td>&lt; 26cm</td>
<td>&lt; 29cm</td>
</tr>
<tr>
<td>Questionable</td>
<td>27 to 29cm</td>
<td>30 to 32cm</td>
</tr>
<tr>
<td>Satisfactory</td>
<td>30 to 36cm</td>
<td>33 to 40cm</td>
</tr>
<tr>
<td>Exceptional</td>
<td>&gt;36cm</td>
<td>&gt;40cm</td>
</tr>
</tbody>
</table>

Source: Guidelines for Ovine Breeding Soundness Examination
Scrotal circumference (SC) (cont.)

Seed stock producers should set higher SC standards for their own flock. As part of the genitalia exam, the penis is extended fully. The penis and prepuce are examined to ensure there are no lesions, e.g., pizzle rot, injury, strictures or adhesions. Having the penis extended also allows for a clean semen collection.

Semen evaluation

A semen sample is collected via artificial vagina (AV) or electro-ejaculation (EE). The use of AVs requires a ewe being in heat at time of semen collection and is often used when collecting for artificial insemination (AI) and/or freezing as a larger volume of semen is often collected.

EE is more often used when time is a constraint, such as with the annual breeding soundness exam, especially with multi-sire flocks. A modified cail table may be used to hold the ram during this procedure. The semen motility, or sperm showing forward progressive movement, is evaluated. The sample is diluted to show individual cell motility and the non-diluted sample should be scanned for swirling. Motility is easily influenced by poor technique, improper diluent and temperature; therefore, it has a lower threshold of 30% and above normal motility for a satisfactory rating.

The size and shape of the individual cells - the morphology - is evaluated using a phase contrast microscope, as some defects are undetectable with a regular light microscope. Any defects should be noted on the BSE form. Above 50% normal morphology is satisfactory and above 80% normal morphology is exceptional. The presence and volume of white blood cells (WBC), if found on the microscope, will be noted as it may indicate disease. This may warrant an ELISA blood test or semen PCR test for Brucella ovis (B. ovis), or other treatment and breeding soundness retest.

The overall results and other considerations

The overall breeding soundness rating for a ram is based upon the parameters measured above. The ram will be rated as:

- E = Excellent
- S = Satisfactory
- Q = Questionable
- U = Unsatisfactory

The libido or sexual drive of the ram is not part of the BSE; therefore, it is essential to observe the sexual activity of each ram. A mature ram rated as excellent should be able to service 75 to 100 ewes in a 17-day breeding cycle under most range and semi-confine ment conditions. Similarly, one rated as satisfactory should be able to breed 50 to 75 ewes in that time period (Kimberling et al., 2007). Depending on what makes a ram rate as questionable, or unsatisfactory, along with its age and prior history, will effect whether the ram warrants a retest in 30, 45, or 60 days, if at all.

Other testing may be incorporated at the same time as a breeding soundness examination but is not limited to:

- Blood testing for B. ovis (the most common cause of epididymitis in mature rams)
- Codon testing (scrapie or spider lamb)
- Ovine progressive pneumonia (OPP)

Most states require a B. ovis negative test within the past 30 days or that a ram be from a B. ovis free certified flock for any change in ownership. Buyers should always require this, as well as all rams over six months of age and owned by the seller, be tested and B. ovis negative — and get this in writing!
Why do breeding soundness examinations?

Incorporating ram BSEs as part of production management can increase profits by $20 to $27 per ewe. A study in south central Wyoming was conducted in the late 1980s using a range flock of 2,800 ewes divided equally into two groups.

Group 1 was exposed to rams having a BSE of satisfactory or better. Group 2 was exposed to non-tested rams selected by traditional ranch selection criteria. At weaning, the Group 1 ewes produced an average of 17 more pounds of weaned lamb per ewe than those in Group 2 (Colorado State University, 1983-1993). Assuming a low market price of $120/cwt and a high market price of $160/cwt, this equates to a $20 to $27 increase in revenue per ewe. This increased revenue was realized with a cost of $0.60 per ewe for the BSE. The assumptions being the cost of the BSE is $18 per ram and the exposure rate is 30 ewes per one ram.

Healthy rams with excellent semen can service more ewes in a given year and produce more lambs. In one case, a western U.S. range flock of 1,410 ewes utilizing BSE tested rams with satisfactory or better semen was able to run one ram per 85 ewes. Only 50 (3.55%) ewes turned up not pregnant. More impressively, 1,050 (74.47%) of the ewes had twins, while only 310 (21.99%) had singles and a total of 90% of the lambs were born in the first 18 days of lambing ( Kimberling et al., 1999-2008). A shorter lambing season decreases labor costs and provides the producer with better feeding and marketing options with a more uniform lamb crop.

Increasing the number of ewes served per ram in an operation can have a significant impact on lowering costs per lamb produced. Assuming a 150% lamb crop and $400 annual ram costs, using one ram per 30 ewes translates into a ram cost of $8.89 per lamb produced. Increasing the number of ewes per ram to 50 head would lower the ram cost to $5.33 per lamb produced. A ratio of one ram per 85 ewes would lower the ram cost to $3.15 per lamb.

BSEs are inexpensive insurance

Producers often think if ewes are getting pregnant, they do not have a problem or need to semen test rams. If rams are not tested, they will not know if there is a problem. A BSE will:

- Identify less productive rams so they can be culled, therefore improving overall flock reproductive efficiency.
- Set the stage for a more uniform lamb crop by producing more lambs in a shorter period of time.
- Maximize ram breeding potential (higher ewe-to-ram ratio), thus allowing for fewer rams to keep, manage and replace.

Decrease the number of open ewes. In single ram operations, a BSE can save the producer from the disaster of no lamb crop. These attributes add to the bottom line in the production scheme. Producers who have adopted BSEs, and utilize the information, look at the testing as an inexpensive insurance policy. The ram breeding soundness examination provides much needed information, allowing producers the ability to make better management decisions.

What are you paying to keep a ram for just one year?

<table>
<thead>
<tr>
<th>Ram Cost/Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase Price: $1,000 per Ram*</td>
</tr>
<tr>
<td>Salvage (Cull) Value: $170</td>
</tr>
<tr>
<td>Depreciation (4 years)</td>
</tr>
<tr>
<td>Interest (6%)**</td>
</tr>
<tr>
<td>Death Loss (5%)</td>
</tr>
<tr>
<td>Feed &amp; Maintenance</td>
</tr>
<tr>
<td>Cost/Year</td>
</tr>
</tbody>
</table>

Annual ram costs of around $400 are common when fully accounting for investment value, depreciation, feed and maintenance.

* Average sale price at 2015 Wyoming Ram Sale
** Based on $585 average investment value in rams on a per head basis in any given year
Author & reviewers

Authors: Geri Parsons, Optimal Livestock Services, Fort Collins, Colorado, and Cleon Kimberling, D.V.M., Optimal Livestock Services and Colorado State University Professor Emeritus, Fort Collins, Colorado

Contributors: Jay Parsons, University of Nebraska – Lincoln, Lincoln, Nebraska; Bill DeMoss, Mountain Vet Supply, Fort Collins, Colorado, and the awesome sheep producers we work with.

Reviewers: Reid Redden, Ph.D., Texas A&M AgriLife Extension, San Angelo, Texas; Dan Morrical, Ph.D., Iowa State University, Ames, Iowa; Susan Schoenian, M.S., University of Maryland Extension, Kedeyville, Maryland; and Rodney Kott, Ph.D., Former Montana State University Extension Sheep Specialist, Fredericksburg, Texas

More information

U.S. Lamb Resource Center
http://lambresourcecenter.com/production-resources/productivity/

National Sheep Improvement Program
http://www.nsip.org

U.S. Sheep Industry Roadmap
http://lambresourcecenter.com/reports-studies/roadmap/

Literature cited

Guidelines for Ovine Breeding Soundness Examination, Society for Theriogenology.


Introduction

Pregnancy detection in the ewe provides the opportunity to adjust nutritional and lambing management to save on feed and labor costs. The old rule of thumb that "one open ewe takes the profits of five producing ewes" may be true when all costs are calculated. Early determination of fetal numbers and gestational stage gives the option of sorting for nutritional demands in late pregnancy and early lactation. Without this information, the single-bearing ewe is being fed too much, or the twin-bearing ewe too little. Open ewes are robbing the pregnant ewes of necessary nutrition. Grouping according to gestational stage will also save on labor and allow for better utilization of facilities and biosecurity.

The key in any type of business is producing an end product, or more simply put, production. The economic benefit of pregnancy testing in cattle, whether it be beef or dairy, has been proven time and time again. The product at the farm or ranch level from a cow is the calf and milk. Individual production must be taken into account in those businesses and boils down to pounds of meat or milk produced per cow. This is not only looked at annually, but also over the lifetime of the cow. The earlier one can tell if there is a viable pregnancy the more potential for higher profit. So why is this so different in sheep? Or is it?

Pregnancy diagnosis in cattle is conducted via rectal palpation by a veterinarian palpating the uterine tract for the presence of a fetus and determining age based on the size of the fetus. Due to the size of the ewe, this has not been an option. This left ewes being pregnancy tested, often referred to as bagging, to some degree at shearing, with questionable accuracy. Or ewes that have not lambed with group 1 get put in with group 2, and so on, until the end of lambing season. This was the case until ultrasound technology became more affordable, making it more beneficial to utilize.

Pregnancy testing methods

Marker paint – For a smaller, more intensively managed breeding system, the use of marker paint, or a harness on a ram, can provide limited information on the pregnancy status of a ewe. It is not fool proof as not all ewes marked will become pregnant and remain pregnant. Recording each marked ewe is required on a daily basis and grease or chalk must be reapplied as needed, changing the color at 14-day intervals. A ewe may continue to be re-marked, even though she may already be pregnant. This is common with an aggressive ram, certain ewes and/or tight quarters. A noted benefit of using markers is the potential to see a ram breeding problem earlier if all ewes continue to re-mark.

Blood testing – Blood testing is another method for pregnancy checking ewes. Measuring blood progesterone concentration has been trialed several times. A pregnancy-specific protein B (PSPB) may also be tested for in the blood after 30 days of pregnancy with relative success. This will provide an idea of pregnancy status, but does not indicate fetal numbers or stage of the pregnancy. Some false negatives may occur if the ewe is around 30 days pregnant.

Ultrasound – Ultrasound imagery is the most reliable form of pregnancy checking the ewe. More information will be gained by the producer, giving him or her the tools to make better management decisions.

Ultrasound technologies were developed through the scientific study of sound waves. The older, A-mode ultrasound technology does not produce an image. It is widely available and, in recent years, has made a comeback in sales due to marketing. It has a beep and/or light that goes on when the pregnancy is detected. What actually is being detected is fluid, therefore, accuracy is quite variable. The B-mode ultrasound technology has the capability of producing an image. Waves are transmitted from crystals in the handheld ultrasound probe to and from the specific body tissue forming the ultrasound image in gray scale on the screen. The denser the tissue the lighter or whiter the tissue appears, such as bone, whereas liquid appears black on the image. Although ultrasound equipment was initially developed and used in human medicine, the development of equipment for use on animals has been slow because of high cost, portability and durability.
Ultrasound provides information

Pregnancy checking the ewe with an ultrasound can provide very beneficial information. The following will help producers know what can be identified and some of the ways to use this information.

- **Pregnant or open** – Save feed for the pregnant ewes; they are the ones that need it. Cull all open ewes as soon as possible to save on feed, labor and medicine costs.

  - Ewes that are consistently open should not be retained. Without a lot of medical intervention, testing or hormonal therapy, these ewes will not get pregnant. Get rid of those barren ewes now.

  - Healthy animals are less labor intensive, saving time, medicine and money. When a ewe has aborted, or is a poor doer, they often have chronic problems preventing them from getting pregnant. An ultrasound image may detect the problem, depending on the severity of inflammation and damage. Producers are encouraged to cull those ewes to clean up the herd.

  - Stop the spread of disease and cut your costs. When debilitating or recurring problems, such as footrot, are present, it is a great time to pregnancy test and cull open ewes.

    - **Example:** The medicine needed to treat footrot in a 170-pound ewe could be LA200, at $1.10/injection with multiple treatments often necessary (average 4X). The generic version of Oxytetr 200 is $.50/injection. Using Draxxin is $3.00/dose; Zactran is $6.00/dose.

- If producers incorporate unseasonal breeding, it is advantageous to know the pregnancy status as early as possible allowing open ewes to be put back into the breeding group sooner.

- **Fetal counts** – Efficiently manage the proper care and nutrition of the pregnant ewe depending on the number of lambs she is carrying. A ewe carrying multiple lambs requires 25% higher nutritional energy than ewes carrying a single. Proper nutrition can prevent fetal loss and/or prevent difficult lambing, poor colostrum, poor milk production, poor mothering and pregnancy toxemia.

  - Single bearing ewes can be lambed out on the field or pasture – with or without the use of a dog or donkey - with little oversight or labor.

  - Ewes with multiple lambs can lamb in a shed, getting the added care for higher lamb survival.

  - Some ewes with single lambs can be utilized for grafting of a triplet.

- **Gestational dates** – The diameter of the fetal thorax or head can be used to estimate the number of days pregnant.

  - Use this information to group animals according to when they will lamb when space is limited in the shed or corral for the close up group.

  - Use the estimate to group according to nutritional needs.

  - It is useful to have estimated day pregnant when a ewe gets marked multiple times by a ram.

  - This is important information, as well, for 4-H or FFA shows and the purchase of a bred ewe.

  - The estimate will also help you to simply get a full night of sleep when you know that no ewes will be lambing until the following weekend.
Testing early

The earlier producers are able to pregnancy check the ewe, the earlier she can be managed correctly. Whether to cull, feed accordingly or put into a different breeding group, the advantages of ultrasound will save time and money.

The best time to schedule a flock’s ultrasound is when the ram is turned out with the ewes. Timing is very important when counts and dates are needed. There are, however, limitations to the information an individual ultrasound technician can provide based on the technician’s experience, the ultrasound machine used, the facility, the amount of help provided and the timing of the scanning after mating.

Producers should be prepared to follow any requests of the ultrasound technician prior to pregnancy checking ewes to ensure scanning accuracy. Fetal death loss does occur and will vary greatly between producers, which can be the result of poor nutrition. Producers should be observant and notice what and how much animals are eating. They should also watch for signs of illness, injury and stress. Helpers on the farm or ranch should also know what is going on and why.

Ultrasound technology is the most useful and practical method for pregnancy checking the ewe. The earlier in the pregnancy the ewe can be scanned, the earlier she can be properly managed to avoid problems. Pregnancy checking will save time, medicine and labor all adding to the bottom line. It will provide valuable information to help producers determine which animals to retain and which animals to cull based on lack of productivity or the presence of disease.

One producer benefits from early ultrasound

In 2002, the producer of a small farm flock in Colorado came across a “great deal” – free pasture for the late summer and fall. The grass was good quality and water was nearby.

Late that fall, the 48 head of black face ewes were ultrasound. The ewes were in good body condition with no visible signs of illness. There was a difference in the appearance of the pregnancy on a couple of ewes noted by the sonographer. Upon a closer look, it was described as floating cotswolds; several of the fetuses were showing movement with visible heartbeats. Randomly, a ewe would come through the chute with the skeleton of the fetus appearing normal. The amniotic fluid was clear with the proper amount in proportion to the fetus. The fetuses were still, lying on the floor of the uterus and no heartbeats were detected.

The differences between this and a normal, healthy pregnancy were shown to the producer and several questions were asked regarding flock health, any early abortions, vaginal discharge, loss of wool, etc. No signs of illness were noted, nothing that alerted the producer. Only eight of the tested ewes showed completely healthy, normal-appearing pregnancies, and three others were open. The timing of scanning was early enough that the ram was turned back in with ewes that day.

Two weeks later, the producer remembered when he had removed the ram. The ram appeared more ragged than normal at the end of the breeding season with a slight respiratory problem and had some wool break. Something, potentially a bluetongue virus, had gone through the flock. No abortions or vaginal discharges were ever seen during the next month. The ewes, being in good health and on a good nutritional plan, absorbed the fetuses.

Out of the original 48 ewes, the 8 showing normal pregnancies lambed on time with healthy lambs. Luckily, the producer had ultrasound pregnancy checks and was able to cut his losses. With reintroduction of the ram, the remaining 40 ewes did go on to produce lambs in May.

Ewes with multiple lambs can lamb in a shed, getting the added care for higher lamb survival.
Authors, contributors & reviewers

Authors: Geri Parsons, Optimal Livestock Services, Fort Collins, Colorado, and Cleon Kimberling, Ph.D., Optimal Livestock Services, Fort Collins, Colorado, and Colorado State University Professor Emeritus, Fort Collins, Colorado

Contributors: Jay Parsons, Ph.D., University of Nebraska – Lincoln, Lincoln, Nebraska; Bill DeMoss, Mountain Vet Supply, Fort Collins, Colorado, and the awesome sheep producers we work with

Reviewers: Reid Redden, Ph.D., Texas A&M Agrilife Extension, San Angelo, Texas; Dan Morrical, Ph.D., Iowa State University, Ames, Iowa; Susan Schoenian, M.S., University of Maryland Extension, Keedysville, Maryland; and Rodney Kott, Ph.D., Former Montana State University Extension Sheep Specialist, Fredericksburg, Texas

Literature cited


More information

U.S. Lamb Resource Center
http://lambresourcecenter.com/production-resources/productivity/

National Sheep Improvement Program
http://www.nsip.org

U.S. Sheep Industry Roadmap
http://lambresourcecenter.com/reports-studies/roadmap/
Introduction

Most sheep producers strive to reduce lamb crop mortality associated with late gestation and newborn lambs. Some consistently keep losses between 5 to 10%, while others in a similar production system are 15% or greater year after year. Sheep respond to management more than any other domestic specie, which is apparent during the critical periods that effect lamb mortality. Keeping detailed flock records during lambing season can document the sources of lamb mortality.

The most important step to reduce lamb mortality is to evaluate key production records from current and past lambing seasons. The key benchmarks to monitor are:

Pre-Lambing to Late Gestation (last 6 weeks)
- Percent abortion rate
- Percent pregnant ewe death loss
- Percent pre-term stillborn lambs

Post-Lambing to Newborn Lambs (0-2 weeks)
- Percent lamb crop born per ewe lambing
- Percent full-term stillborn
- Percent newborn lamb mortality

Pre-lambing to late gestation (last 6 weeks)

Preventative flock health care and a sound nutrition management plan promote higher lamb vigor and increased lamb survivability, and reduce pregnant ewe death. Based on data collected on lamb mortality, stillborn births often account for 25% of losses that occur at or near the time of lambing. Stillborn mortality can be divided into two categories: pre-term and full-term delivery.

Pre-term stillborn: In many flocks, the majority of pre-term losses are associated with abortion diseases. The top three abortion diseases include: Campylobacter, Chlamydia, and Toxoplasmosis. In most flocks, the incidence of pre-term delivery associated with natural causes, non-bacterial, is expected to be 2 to 4%. When exceeding this threshold, producers are advised to contact a veterinarian to submit fetal and placental tissues to a diagnostic laboratory in order to identify the cause of the abortions. Preventing abortions is a high priority in sheep flocks. If diagnostic results identify infectious agents, then appropriate management steps can be adopted to reduce lamb mortality.

Pregnancy toxemia (ketosis) is a common nutritional disorder in sheep, generally associated with undernourished and over-conditioned ewes carrying multiple lambs, resulting in stillborn lambs and potentially ewe death. For a gestating ewe with adequate body condition carrying twin lambs, her nutritional needs can be met with good quality forage and supplemental energy (grain) equivalent to 3% of her body weight. Plane of nutrition during this period is very important to maintain a healthy pregnancy and result in sufficient fat reserves to support lactation.

Full-term stillborn: For full-term stillborn mortality, both nutrition and health are important, along with lamb delivery abnormalities. A full-term stillborn delivered in a litter of triplets or resulting from a backward presentation at birth are common. However, if entire lamb litters arrive stillborn, or there is a stillborn along with low vigor litter mates, contact a veterinarian for a diagnosis.

Successful sheep operations develop and follow a lambing management plan focused on reduced lamb mortality.
Post-lambing to newborn lambs (0-2 weeks)

The majority (up to 80%) of all lamb crop mortality (including full-term stillborn) occurs in newborn lambs under 2 weeks of age. For live newborn lambs, the primary causes of mortality can differ by the type of production system. In production systems using a shed lambing facility, the primary challenges to newborn lambs are starvation and hypothermia, as well as respiratory diseases, scours and injury. Lambs born in pasture or range lambing systems are threatened by weather conditions and predators.

The most successful sheep operations develop and follow a lambing management plan focused on reducing lamb mortality. Whether lambing occurs in a building or on pasture, management can make a difference on the percent lamb crop reared. For pasture lambing, choosing a lambing time that has more favorable weather and utilizing predator management tools could be the key steps in reducing lamb mortality. For shed lambing, management has a greater opportunity to evaluate and take action on newborn lambs at risk of starvation and experiencing hypothermia.

However, for all types of sheep production systems, the key to reducing newborn lamb mortality starts with proper nutrition and health management of the ewe flock during gestation.

Lambs born with low vigor are especially susceptible to hypothermia, more prone to injury, and eventually starvation. Lambs born with a special source of high-energy fat called “brown fat” deposited on the heart and kidneys. The energy boost from brown fat is expected to last for at least 6 hours following birth. Those born with low vigor likely have poor brown fat stores. Low vigor lambs fall into the hypothermia classification quickly after birth even in an optimal lambing environment.

Causes of newborn lamb mortality

Starvation: Ewe milk is the sole source of nutrients for a newborn lamb, and if not available in adequate quantities to maintain and promote weight gain, the lamb will rely on its limited body reserves. Identifying whether a lamb is receiving adequate mother’s milk is important to limit lamb mortality. The ewe’s ability to feed lambs should be evaluated. Lambs should be full and ample capacity should remain in the udder. If lambs are constantly suckling, it is a clear sign that milk capacity is limited.

Predation: Wildlife, especially coyotes, prey on sheep flocks in any type of management system and geographical location in the United States. However, young suckling lambs in grazing systems with extensively managed operations are the most vulnerable. Many resources are employed to protect lambs and adult ewes from predation including state or federal animal damage control professionals, improved fencing, and the use of guard animals. Guard dogs, donkeys or llamas are often used to ward off predators.

The opportunity to intervene and rear lambs artificially with milk replacer is limited in a pasture and range lambing system. The ewe’s ability to supply newborns with colostrum and milk without human intervention is paramount. Selecting flock replacements with excellent maternal traits, including milk production, are critical to reducing newborn loss due to starvation.

A common challenge in the U.S. sheep industry is “hard bag,” a non-mastitis condition that severely limits or renders the udder completely nonfunctional. Hard bag associated with ovine progressive pneumonia (OPP) has been a chronic problem in the industry; it is common to find a 10% to 15% incidence in flocks. Genetic screening technology for OPP resistance has been developed and adoption of this technology is expected to sharply reduce the incidence of the hard bag condition in ewes.

Hypothermia: Hypothermia can occur in any lambing system when the thermal regulatory capacity of the wet newborn lamb is overwhelmed. To determine whether a lamb is hypothermic, its temperature must be checked with an animal thermometer; normal body temperature is 102.5°F. Too often producers rush to supplement colostrum to hypothermic lambs resulting in death due to anaphylactic shock. Many techniques can be used to recover a hypothermic lamb; the use of artificial heat and the inter-peritoneal administration of a warm dextrane solution into the abdominal cavity to supply an immediate energy boost. To provide artificial heat, a warming barrel can be installed in a lambing pen. When the lamb’s mouth is warm, it is safe to administer 4 ounces of colostrum.

A lamb warming barrel provides artificial heat and can be installed in a lambing jug. Learn how to make your own by viewing South Dakota State University’s iGrow YouTube channel: https://www.youtube.com/watch?v=8e9Rqg1DpwT0

Lamb Resource Center

The Lamb Resource Center is your one-stop shop for industry resources and information. Visit www.LambResourceCenter.com to learn more.
Reduce lamb loss in a lambing facility

RECOMMENDATIONS FOR IMPROVEMENT

Well-designed facilities and attentive management during lambing time can improve newborn lamb survival. The following recommendations should be considered to improve the care and well-being of newborn lambs.

**Temperature and ventilation:** The location of the receiving pen and lambing jugs/pens should be temperature controlled at 35 to 40° F. Natural or mechanically supported ventilation is important to maintain temperature and reduce the moisture in the facility housing the newborns. These actions reduce the incidence of common causes of newborn lamb mortality including hypothermia, respiratory diseases and scours.

**Drop pen:** Allowing ewes to deliver lamb(s) in designated receiving pens with familiar surroundings will reduce stress. Ewes should be moved to the lambing process before moving to a lambing jug/pen, unless environmental conditions require sooner action. Teats should be stripped at this time to remove the wax plug and to evaluate milk production. Afterbirth material should be properly disposed to minimize disease transfer.

**Lambing jugs:** Jugs/pens should be a minimum of 5’ x 5’ or 6’ x 6’ for larger framed ewes. Immediately after the ewe is brought into the lambing jug, the lamb’s navel is clipped to about one inch and dipped with strong iodine (7%). Teats should be stripped to ensure the lamb can suckle colostrum and that no udder dysfunction exists. Supplemental Vitamin E can be given to newborn lambs using an oral or injectable product.

Colostrum shortage is common. Supplements have been shown to be helpful but the source from a ewe is preferred. At least 4 to 6 ounces of ewe colostrum should be given to newborns before relying on milk replacer or other milk based supplements. Hypothermic lambs must be warmed to normal body temperature (102.5° F) before delivery of colostrum to avoid anaphylactic shock.

**Lamb saver tube competency:** Using this device will save more newborn lambs and valuable time than any other consideration or investment during lambing season.

**Daily health observation routine:** Lambs must be observed every 2 to 3 hours for general health, vigor, and to evaluate ability to suckle. Lambs may require assistance with suckling. The use of a lamb saver tube can be implemented and repeated every 4 hours until lambs succeed without shepherd intervention. If lambs show signs of scouring or dehydration, e.g., hunched up, gaunt, loss of vigor, a veterinarian should be consulted. Ewes should be offered good quality forage and an increasing amount of supplemental grain. A good appetite and observed cud-chewing are positive signals on her health status.

**Wet grafting adoption:** Grafting, or fostering, is the transfer of a lamb from one ewe to another ewe that is not its mother. Adoption to a ewe with adequate milk is most successful at delivery. This practice is implemented with triplet born lamb transferred to a ewe without a lamb or a fresh born single.

**Colostrum intake:** Nothing is more important following lambing than a lamb’s consumption of the ewe’s colostrum or “first milk.” This liquid is extremely nutritious with high levels of fat, but most importantly, it contains critical antibodies that enable lambs’ immune systems to function properly. Absorption of antibodies by the lamb gut declines to less than 50% capacity at 12 hours. If administered using a lamb saver tube, it is recommended to deliver 0.5 ounces per pound of body weight, generally 4 to 8 ounces per feeding, and repeated every 4 to 6 hours until the lamb suckles voluntarily. By 24 hours, a 10-pound lamb should have consumed 20 to 30 ounces of colostrum.

**Artificial rearing:** Evaluation of the ewes’ ability to supply adequate milk is important. Decisions on artificial rearing lambs using lamb milk replacer should be done in the first 24 hours. The automated commercial lamb milk replacer delivery technology (for example, Lac-Tek or Nursotek) have made artificial rearing an easy choice resulting in lower lamb loss.

**Bonding time:** The ewe and lamb(s) should remain in a jug for a minimum of 48 hours, if space allows, to create a necessary bond. Once the

Nothing is more important following lambing than a lamb’s consumption of the ewe’s colostrum or “first milk.”

Continued on next page
Reduce lamb loss in a lambing facility (cont.)

Pair has bonded, they can be moved to a community pen with no more than 10 ewe-lamb pairs. Gradually, the number of pairs can increase until a lactating group reaches 25 to 35 ewes, while ensuring at least 25 square feet per pair. Lambs showing weakness or illness should be held back.

Identification: Individual identification ear tagging and paint-branding (optional) for the ewe and her offspring is an important component in reducing lamb mortality especially in the case of starvation. Paint branding both the ewe and her offspring is a common practice to aid in health observations especially when the ewe and her lamb(s) reach the community pens. The entire family gets the same paint brand number on both sides of their bodies. Industry adoption of electronic identification based on radio frequency identification (RFID) technology offers an upgrade in tracking ewe and lamb pairs.

Recording lambing data: A lambing notebook is a permanent treasure of information on the lambing season and serves as the template to make improvements in future lambing seasons. It is always better to have too much written information than not enough. Recommendations of record information to collect:

- Ewe and lamb(s) paint brand or ear tag numbers
- Date and time of birth
- Any assistance given
- Any problems with the lamb(s) or the ewe
- Any treatment given
- Any special needs
- Mothering ability score
- Lamb vigor score
- Lamb losses with any information available, include a suspected cause of death

Author & reviewers

Author: Jeffrey Held, Ph.D., South Dakota State University, Brookings, South Dakota

Contributors: Heidi Carroll, M.S., South Dakota State University, Brookings, South Dakota; Jessica Reiners, South Dakota State University, Brookings, SD

Reviewers: Reid Redden, Ph.D., Texas A&M Agrilife Extension, San Angelo, Texas; Dan Morrical, Ph.D., Iowa State University, Ames, Iowa; Susan Schoenian M.S., University of Maryland Extension, Kearneysville, Maryland; and Rodney Kott, Ph.D., Former Montana State University Extension Sheep Specialist, Fredericksburg, Texas

More information

U.S. Lamb Resource Center
http://lambresourcecenter.com/production-resources/productivity/

National Sheep Improvement Program
http://www.nsip.org

U.S. Sheep Industry Roadmap
http://lambresourcecenter.com/reports-studies/roadmap/
This publication gives a complete overview of the topic of tube feeding neonatal lambs and kids. Relevant anatomy, indications, and techniques are presented. Photographs illustrate the techniques discussed. Information about colostrum, biosecurity, sanitation, and passive transfer of immunity is included as well.

Introduction

It is essential that sheep and goat producers learn how to feed young animals with a stomach tube. This simple procedure can often save a young animal’s life, thereby increasing lambing and kidding crop rates and enhancing profitability. With a brief amount of instruction and a little practice, anyone can perform this crucial task quickly, safely, and effectively.

Indications

When is tube feeding necessary? If an animal is too weak or otherwise unable to nurse, it needs to be tube fed. Other situations include maternal factors (lack of milk production, lack of mothering, mastitis, death) and management decisions to control various diseases (C.A.E., O.P.P., Johne’s Disease, etc.). Neonates with diarrhea may need to be tube fed with electrolytes.

Importance of Colostrum

Colostrum is the first milk of a mother’s lactation period. It is produced by the udder in the last weeks of pregnancy and lasts for a few days after delivery. It is darker and thicker than milk. It contains high levels of fat, protein, vitamins, and special proteins called antibodies. These antibodies are produced by the dam’s immune system in response to vaccination or disease exposure. Antibodies protect animals against various diseases such as tetanus, enterotoxemia, and E. coli. Giving dams a booster vaccination two to three weeks before kidding or lambing helps ensure high levels of antibodies in colostrum.

Newborn animals must ingest colostrum within a few hours of birth. A newborn’s intestinal tract is not very selective in the first hours
of life; antibodies can be absorbed whole, which is essential for their function. After twelve hours, antibodies and other proteins are digested into amino acids and then absorbed; they can be used as a source of nutrition but they no longer have any disease-fighting ability. Producers should strive to ensure adequate colostral intake as soon as possible after birth.

Sources of colostrum, in decreasing preference, include the neonate's own dam, another dam of the same species in the herd, frozen colostrum from the same herd, fresh or frozen colostrum from a neighbor's dam of the same species, fresh or frozen colostrum from another species, and commercial colostrum supplements. Commercial preparations should be considered supplements for poor quality or quantity of colostrum, not as colostrum substitutes. Each year, producers should harvest extra colostrum from high-producing animals and freeze it in case of emergency; update frozen colostrum reserves every year. Freezing colostrum in two-ounce portions simplifies future use and reduces waste.

Laboratory tests can confirm the quality of a sample of colostrum by measuring its antibody concentration. Blood tests in neonates over 24 hours old can confirm whether or not they have absorbed sufficient levels of antibodies. The lack of a protective level of circulating antibodies is called failure of passive transfer (FPT). FPT makes a young animal very susceptible to disease; many animals with FPT die of scours or pneumonia within two weeks of birth. After the first 12 to 24 hours of life, the gut is “closed” and can no longer absorb intact antibodies, so the only treatment for FPT is a costly intravenous transfusion of plasma antibodies.

**Anatomy**

The diagrams below depict simplified cross sections of an animal's head. The swallowing diagram shows the structures of the throat area during swallowing. The breathing diagram shows the same structures during breathing. During swallowing, food and liquids are funneled down the esophagus instead of into the airway by the automatic function of protective flaps of tissue (the soft palate and epiglottis).

**Steps to Tube Feeding**

1. Determine that tube feeding is necessary. If a newborn lamb or kid has not nursed within two hours of birth, it should be tube fed. If an animal is nursing or can take a bottle, there is no need to tube feed.

2. If the animal is hypothermic (cold), warm it before administering colostrum. Neonates must
be warmed before colostrum can be absorbed properly. Stick your finger in the animal’s mouth—if it seems cool, the animal needs to be warmed up. Take it indoors, fashion a wool sweater for it, put it under a safe heat lamp, place it near a wood stove or do whatever it takes to warm it. A moribund animal may need to be immersed in warm water for rapid warming. Dry all neonates thoroughly before putting them outdoors.

3. Warm the fluid to be administered to about 104°F. There is no need to feed colostrum if the animal is older than 24 hours old—milk will do. Electrolytes should be administered if the animal is weak due to dehydration from diarrhea. Frozen colostrum should be thawed in a warm water bath, not a microwave; microwaving will destroy the antibodies in the colostrum.

4. Assemble sanitized equipment, including a feeding tube and a 60-cc dose syringe. Tube feeding kits are available through livestock catalogs and farm supply stores. An open-ended, 20-inch long piece of soft, flexible tubing, six millimeters in diameter, with a smooth end is a safe and effective stomach tube.

5. Place the tube alongside the neonate’s body, with the mouth of the tube at the animal’s mouth and the end at its last rib, where the stomach is located (Figures 1 and 2). Note how far the tube will have to be inserted to reach the last rib.

6. Sit in a chair or on a hay bale and restrain the animal by facing it away from you, gently holding it by its shoulders between your knees; the animal’s body will dangle down between your legs (Figure 3). Never tube feed an animal on its side or it may inhale the fluid you are administering.

7. Hold the animal so its head is in a normal position. Dip the tip of the tube in clean water and slowly insert the tube in the animal’s mouth (Figure 4). There is no need to use pressure or force, just gently advance the tube toward the back of the animal’s mouth (Figure 5). The animal should swallow the tube readily (Figure 6). You can see the swallowing motion if you watch carefully.

---

**Figures 1 and 2.** Feeding tube will be inserted to the depth of the last rib. Note length of remaining tube on baby lamb (top) and kid (bottom).

**Figure 3.** Restrain the animal by holding it gently by the shoulders between your knees facing away from you.
The goal is to insert the tube into the esophagus, not the trachea. If the tube enters the trachea (windpipe), the animal should cough, gag, and react violently, but a moribund animal may not react. An animal that has swallowed the tube can still bleat and cry; an animal that has inhaled the tube can not make these noises. Actually, it is unusual for the tube to enter the trachea.

8. Correct placement of the tube can be checked by several methods, but the first method is the most reliable and effective.

- **Best Method**: Attach a 60-cc dose syringe to the mouth of the feeding tube after it has been fully inserted into the animal; pull the plunger back. As shown in the photo (Figure 7), it should be very difficult to get the plunger to move past a few cc marks if the tube is placed properly. The pressure created by the plunger causes the thin muscular walls of the esophagus and stomach to be pulled against the hole in the end of the tube. If the tube is improperly placed and is in the trachea, it will be very easy to pull the syringe’s plunger. This is because the trachea and lung airways have sturdy cartilage rings and can withstand the negative pressure created when the plunger is pulled back. The air naturally present in the trachea and lungs is pulled back into the syringe very easily. If you understand, master, and perform this check every time you pass a
feeding tube, you will never accidentally drown an animal while tube feeding.

- The animal should swallow as the tube is introduced and advanced.

- Watch the tip of the tube advance in the esophagus on left side of the animal’s neck.

- The tube should be inserted to the previously-noted length. (A tube inserted into the trachea cannot be advanced this far.)

- Feel the tube in the esophagus on the left side of the animal’s neck. (The tube cannot be felt if it is in the trachea.)

- The animal shouldn’t gag or cough.

9. Detach the syringe from the feeding tube and remove the plunger. Firmly re-attach the empty syringe to the mouth of the feeding tube. Fill the syringe with the warmed fluid (Figure 8). Let the fluid trickle in via gravity (Figure 9). Do not force it with the plunger, as the pressure could rupture the stomach or cause fluid to enter the lungs. Thick colostrum may not flow freely; it may need to be diluted with thinner colostrum. Try to keep air from entering the tube and stomach.

10. After the fluid has been administered, detach the syringe and crimp off or plug the end of the tube as it is withdrawn from the animal as shown in the photo (Figure 10). This prevents the animal from inhaling any fluid as the tube is withdrawn across the pharynx.

Figure 8. Attach the empty syringe to the feeding tube and fill with the warmed fluid.

Figure 9. Let the fluid trickle into the neonate’s stomach via gravity.
How Much and How Often?

An animal should receive at least 10 percent of its body weight in colostrum in the first 24 hours of life. For example, a 10-pound lamb should receive one pound (16 ounces) of colostrum during its first day. Frequent small meals of two or three ounces are better than one or two huge meals. If all goes well, the animal will only need to be tubed once, then returned to its dam to nurse free choice. Animals that do not respond well or do not get stronger within a few hours should have a thorough physical examination.

Biosecurity and Sanitation Concerns

Johne’s Disease, Brucellosis, mycoplasmosis, O.P.P., C.A.E., and other diseases can spread to your herd through infected colostrum. If you are using colostrum from another herd, be sure the source is disease-free or pasteurize the colostrum. In order to pasteurize colostrum without destroying its beneficial antibodies, heat it and maintain a temperature of 133°F to 134°F for 60 minutes. To disinfect tube feeding equipment, rinse well immediately after use. Wash thoroughly with warm, soapy water to remove all debris. Dilute one ounce of bleach with 21 ounces of water and submerge all equipment in this solution for two minutes. Remove, rinse well, air dry, and store in a clean place. Wash your hands well before and after tube feeding.

Conclusion

This publication teaches producers how they can easily learn to tube feed neonatal small ruminants with confidence. Every sheep and goat producer should master this skill and have sanitized equipment and frozen colostrum ready during lambing and kidding season. For assistance with this technique or locating tube-feeding equipment, contact your veterinarian or county extension educator.

The information herein is supplied for educational or reference purposes only, and with the understanding that no discrimination is intended. Listing of commercial products implies no endorsement by WSU Extension. Criticism of products or equipment not listed is neither implied nor intended.

Supplies

- 60 cc dose syringe
- Stomach tube feeder (available from feed stores, veterinarians, and livestock supply stores and catalogs)
- Container with warm milk, colostrum, or electrolytes
- Disinfectant
About the Author

Dr. Susan Kerr, WSU-Klickitat County Extension Educator, Washington State University-Klickitat County Extension, 228 W. Main St., MS-CH-12, Goldendale, WA 98620
Phone: 509-773-5817  E-mail:kerrs@wsu.edu
Keeping newborn lambs alive and healthy is the greatest management challenge facing sheep producers. An important strategy for meeting this challenge is making sure that lambs receive adequate colostrum during the first two to three hours of life. The effect of colostrum on the health, survival, and performance of newborn lambs cannot be overrated.

The Importance of Colostrum

Colostrum is the "first milk" that ewes produce after lambing. Colostrum has a high level of several nutrients that are important for lamb health and performance. Colostrum also contains a high concentration of antibodies against a variety of infectious agents. Immediately after birth, the lamb is exposed to a variety of infectious agents present in the environment, the dam, and other ewes and lambs. Without any protection from these infectious organisms, the lamb may become diseased or die.

At birth, the lamb does not carry any antibodies against these organisms because antibodies in the ewe's bloodstream do not cross the placenta. However, these antibodies are concentrated in the colostrum and provide a natural and efficient source of protection against many intestinal, respiratory, and other diseases. Vaccinating ewes for diseases such as enterotoxemia and tetanus prior to lambing is important, since antibodies against these diseases will then be contained in the colostrum. Additionally, colostrum provides needed energy to help lambs stay warm and acts as a laxative to ensure excretion of meconium.

Recent research from Great Britain has found that ewes vary greatly in the quantity and quality of colostrum they produce. Younger ewes generally will produce less colostrum because they also produce less milk. At lambing, check ewes (by stripping the teats) for the quantity and quality of colostrum. Ewes with excessively thick colostrum should be milked out and their lambs supplemented with frozen colostrum. Ewes that have small udders and slow colostrum flow at stripping may not have adequate colostrum, especially for multiple lambs. Lambs from these ewes should be closely monitored to make sure they are acquiring adequate colostrum to keep growing.

Which Lambs Need Colostrum?

All newborn lambs need colostrum. It is possible for lambs to survive without colostrum in a reasonably disease-free environment, but the likelihood of disease and death is higher in lambs that do not receive colostrum. This increased susceptibility to infection continues until at least 6 or 8 weeks of age. Thus, ensuring adequate colostrum intake is important for all lambs. Lambs should be allowed to nurse the ewe as soon as possible, because lambs have an extremely strong suckling reflex immediately after birth. Many times lambs can be helped to nurse even before the ewe gets up. This practice is a more efficient use of shepherd labor than thawing colostrum and tube feeding.

It is critical that lambs receive colostrum during the first 24 hours of life in order to ensure adequate absorption of colostral antibodies. Antibodies are large protein molecules that can cross the intestinal wall and enter the bloodstream of the lamb only during the first 24 to 36 hours of life. Absorption of these antibodies is most efficient the first few hours after birth. It is recommended that lambs receive 10 percent of their weight in colostrum by 24 hours after birth. This means that a 10 pound lamb should receive one pound (16 ounces) of colostrum by 24 hours of age. Ideally, they should receive half of this within 4 to 8 hours of birth.

Colostrum should be fed with a nipple bottle if lambs are capable of nursing. They should be given 2 to 4 ounces of colostrum at 3- to 4-hour intervals. Weakened or chilled lambs, if handled properly, will require only one supplemental feeding in most cases. Lambs that have lost their mothers or are born to ewes that have inadequate colostrum should be fed the entire 16 ounces of colostrum within the first 24 hours.
Weak lambs that will not nurse should be fed colostrum through a stomach tube. A small catheter, obtainable from a veterinarian, attached to a 60 cc syringe makes an ideal stomach tube. Colostrum is allowed to free-flow into the lamb’s stomach after the catheter has been passed down the esophagus. Lubricate the catheter with colostrum prior to its passage and gently push it to the back of the lamb’s mouth. Most lambs will readily swallow the catheter. Insert the catheter so that the tip would be at the rear of the lamb’s rib cage. This is slightly more than half the length of the lamb. It is a good idea to mark the catheter prior to passage so that you know how far you have inserted it into the lamb. A 60 cc syringe will hold two ounces of colostrum.

**Colostrum Sources**
The ideal colostrum source for supplemental feeding of lambs is from a healthy ewe in one’s own flock. Older ewes have had greater exposure to infectious agents and usually have a higher concentration of antibodies against a wider variety of diseases than young ewes. Colostrum can be harvested from early lambing ewes, frozen, and stored until it is needed during the lambing season. Colostrum must be thawed carefully so that the antibodies are not destroyed. Rapid thawing with excess heat will reduce antibody activity and effectiveness. It is best to let colostrum thaw at room temperature. If using a microwave oven, set the microwave on a low (defrost) setting and stir frequently. Colostrum can be stored in small milk cartons, cellophane plastic bags, or in ice cube trays. Keep in mind that small amounts thaw much more quickly at room temperature than do large amounts.

Colostrum from dairy cows or dairy goats may be used if ewe’s colostrum is not available. The desired breeds of dairy cattle produce milk with a higher fat content, which is desirable for lambs. Commercially-available colostrum substitute products (of bovine origin) have not been adequately tested for efficacy in lambs. In emergencies, these products may be used to supplement natural colostrum, but should not be relied upon to entirely replace natural colostrum.

**Precautions**
Producers who are attempting to develop an Ovine Progressive Pneumonia (OPP) free flock must be concerned with the source of colostrum used, since OPP can be transmitted from infected ewes to their offspring via colostrum. The surest way to prevent this transmission is by isolating all newborn lambs at birth and not allowing them to consume any ewe’s milk. They should be fed lamb milk replacer. These lambs must have colostrum, however. Cow colostrum is the best, least risky source to ensure that efforts to eradicate OPP are not being wasted by contaminated colostrum.

**Summary**
Colostrum is vital for lamb viability and survival. Passive immunity against several infectious diseases is transmitted from the ewe to the lamb via colostrum. Producers should monitor the number of lambs that require colostrum supplementation. If more than 10 percent of lambs require supplementation, producers should evaluate their genetic, nutritional, and health management programs. Lambs that require colostrum supplementation or help in nursing should not be retained as breeding stock. Unless producers carefully evaluate records, they may increase the percentage of lambs that require labor-intensive tube feeding during the lambing season. This is not an economically sound trend for sheep producers or for the sheep industry.
Ensuring lambs receive adequate colostrum provides antibodies, energy and essential nutrients that benefit the new-born lamb.

**Importance of colostrum**

- Colostrum provides passive immunity to lambs as it contains antibodies. It is also a nutritious energy source which helps the lambs to maintain body temperature that can reduce losses from both hypothermia and disease. Healthy lambs that receive adequate colostrum should also lead to a reduction in antibiotic usage.

- If the ewes have been vaccinated against clostridial diseases at the correct time pre-lambing, they will pass these antibodies down to the lamb through the colostrum which offer some protection for up to 12 weeks.

- Managing ewe nutrition and body condition score (BCS) in pregnancy is key to the 3 Qs of colostrum.

**The 3 ‘Q’s of colostrum – Quality, Quantity and Quickly**

- **QUALITY** – The quality of colostrum will depend on the ewe’s health, the ewe’s BCS and the ewe’s pre-lambing diet. A refractometer can be used to test the quality of colostrum

- **QUANTITY** – Lambs must receive 50ml/kg of colostrum in the first 2 hours of life and 200ml/kg during their first 24 hours of life. For lambs reared outdoors, the colostrum allowance should be increased by 15% to 20%.

- **QUICKLY** – Lambs must receive colostrum as soon as possible after birth, and certainly within the first six hours of life.

**Testing colostrum quality:**

**Using a refractometer**

A refractometer will measure the volume of Immunoglobulin-G (IgG) in the colostrum.

1. Collect a sample from the ewe and place a few drops of colostrum onto the prism of the refractometer.

2. This should be carried out at room temperature (take inside in very cold weather)

3. Close the cover plate over it (ensure there are no bubbles).

4. Hold the refractometer up to the light and look into the eyepiece to see the scale.

5. Colostrum quality of above 25% is considered a good quality colostrum.
Testing colostrum quality through blood tests

The ZST test is an indirect measurement of the passive transfer of immunoglobulins via the colostrum from the dam to the neonate. The lambs' blood can be tested between 2 and 7 days old. If the 'ZST units' is 14 then colostrum absorption is acceptable, 5-14 units means there has been some failure of colostrum absorption and <5 means no colostrum has been absorbed.

Poor refractometer and ZST results may reflect inadequate pre-lambing nutrition. Ensuring ewes are at key BCS throughout the year will ensure the ewes are at their fittest at lambing time. Please discuss this further with your vet.

Alternative options when colostrum quality or quantity is poor:

- Take colostrum from another ewe who has a lot of milk, is in good BCS and rearing a single.
- Cows’ colostrum – ensure it’s mixed from a number of different cows to avoid anaemia, that it comes from a herd with a high health status and preferably that they’re vaccinated against clostridia. Cows’ colostrum is also not as concentrated as sheep’s colostrum so the feeding rate should be increased by 10-15%.
- Goat colostrum – ideally from a high health status which are vaccinated against clostridial diseases.
- Powdered colostrum – this can be used as a replacer or as a supplement. Energy and protein levels vary significantly between brands and all are lower than fresh ewe colostrum. If using as a replacer, it is important to remember that it is favourable to use another ewes’ milk over using powdered colostrum. Supplement feeding of colostrum can be given to triplets, poor-doing lambs or the lambs of ewes who do not have enough milk.

The Red Meat Development Programme has been funded through the Welsh Government Rural Communities – Rural Development Programme 2014 – 2020, which is funded by the European Agricultural Fund for Rural Development and the Welsh Government.
Saving Hypothermic Lambs

By Bill Fosher

In winter lambing flocks, hypothermia and starvation of newborn lambs can account for nearly all of the pre-weaning death loss of lambs. It’s a serious problem that can often be minimized through management of the ewe flock and its environment.

Even under the best management in the best environment, there will still be some cases of hypothermia and starvation in most winter lambing flocks. With attention to detail, hypothermia and starvation can be reduced to very low rates even in flocks that lamb in the dead of winter in very cold climates. In most sheep production systems, the majority of the cost of producing a lamb is already spent when the lamb is born (in the form of feed and keep), so saving chilled lambs is an important way to protect your investment. Preventing it from happening in the first place is even more important.

When it does happen, it’s important for shepherds to know how to recognize, treat, and, most importantly, learn from each case. In most cases, the problems that lead to hypothermia and starvation are difficult to fix during lambing. They can go back months to the level of nutrition in early gestation, or to barn design, or the availability of bedding. That’s why it’s important to keep records about the causes of any hypothermia cases. Once lambing is over, it’s easy to put those problems out of your mind and forget to fix them for next time. Make a habit of keeping good lambing records and reviewing them well before the next breeding season so that you have time to make any changes or cull any ewes to reduce problems in the next lambing season.

In the meantime, you need to try to save as many cold lambs as possible. Here’s a step-by-step guide to the process. The goal of this guide is to help you make sound decisions about how to treat a lamb when you’re tired, busy, and probably a little upset. All the steps are aimed at getting the lamb back with its mother as soon as possible, and are based on the assumption that the mother has adequate milk and has not rejected the lamb. If that is not the case, the lamb will need to be grafted or raised as an orphan, but the initial intervention steps are the same.

Understanding hypothermia and starvation

In newborn lambs, hypothermia and starvation go hand in hand, and left unchecked they fuel one another leading to the death of the lamb. When a lamb is born, it has a reserve of brown fat that releases a tremendous amount of energy during the first few hours of life, keeping its blood sugar high and providing it with enough food to jump start its metabolism.

During these first few hours, the lamb must start to take in the ewe’s colostrum in order to sustain its metabolism and keep itself warm. But digesting food takes energy, and that’s another role that the brown fat plays. If the lamb doesn’t have enough brown fat, or if it doesn’t get colostrum before the brown fat’s energy is all used up, its metabolism can slow down to the point where it can’t digest colostrum. It starts to get cold, and loses more energy. The cycle starts to
fuel itself — the lamb lacks energy because it’s chilled, so it doesn’t get the energy it needs to get warm. The shepherd must intervene, or the lamb will die.

**Recognizing a chilled lamb**

As with most interventions, the earlier the shepherd spots the problem and responds to it, the more likely he is to be successful, and the less time and effort will be required to achieve success. Spotting a lamb that is just starting to have trouble is a key skill. Things to watch for include a hunched posture, hollowed out sides, excessive calling, lethargy, and dehydration. If you pinch a lamb’s skin over the spine, it should snap back almost instantly. If it stays in place like a tent, the lamb is dehydrated and probably needs attention.

In many cases where hypothermia-starvation is in its early stages, all that’s required is to make sure that the lamb gets a good suck from the ewe. The ewe’s teat may be plugged too tightly for the lamb to start the milk flow, or the lamb may have had difficulty finding the teat. If the lamb starts to suckle with assistance, you can often postpone any further intervention and monitor the situation closely to ensure that the lamb and ewe are getting on smoothly.

Any lamb that is unresponsive or laying flat out on its side requires immediate attention.

Perhaps the best way to learn to recognize a chilled lamb is to watch the behavior of lambs that are doing just fine. There’s an indescribable look to a well-fed and happy lamb, and once you know it you will have little trouble spotting the ones that lack it.

**Caring for the ewe and other lambs during intervention**

If a lamb needs to be removed from its mother, the dam should be left penned by herself where she cannot try to claim other lambs. If a ewe has more than one lamb, consider removing not just the chilled lamb, but all of them. The process of warming a lamb can take several hours, and during that time, a ewe may forget about one of her lambs. She will not forget about all of them. However, you must return the non-chilled lamb or lambs to the dam to suckle regularly — probably every 20 minutes to half hour.

When the chilled lamb has recovered and can be returned to its mother, it will still need to be watched closely for a day or longer. It’s often easiest to pen the ewe in a location that will be convenient for these frequent checks at the beginning of the intervention.

**Necessary skills**

There are also two techniques discussed here that require some training and skill: feeding by stomach tube and administering glucose by intraperitoneal injection. Done incorrectly, either procedure can kill a lamb. I recommend stomach tube feeding of chilled lambs for several reasons. First, it’s a much surer method of getting the required amount of milk into a lamb than attempting to feed it from a bottle with an artificial nipple. Second, it will take less of the shepherd’s time (which is always in short supply when these things happen), and third it can be accomplished even on a lamb that is totally unwilling to suck. Perhaps most importantly, it
doesn’t interfere with the lamb’s understanding that food comes from its mother’s udder. A lamb trained to an artificial nipple will stop seeking its mother’s teat at some point.

Most shepherds who have tried both prefer rigid catheters to flexible ones for stomach feeding. A 60 or 120 cc catheter-tipped syringe is also essential. Remove the plunger and catheter from the syringe. Have the milk on hand and warmed to body temperature. Work the catheter down the lamb’s throat and into the stomach, then attach the syringe and pour the milk in. Allow the milk to flow by gravity — do not force the milk in. If you’re using colostrum and it’s too thick to flow, add just enough warm water to get it flowing. Do not use hot water, or the immunoglobulins in the colostrum will be destroyed.

IP dextrose injection is a bit more complicated. The most straightforward explanation I’ve seen can be found at the Alberta Lamb Producer’s Association website: [http://ablamb.ca/documents/factsheets/intradex.pdf](http://ablamb.ca/documents/factsheets/intradex.pdf), which adapts its procedure from David Henderson’s excellent, but very British, Veterinary Book for Sheep Farmers.

The Alberta site makes reference to a typical 4.5 kg lamb, which is about 10 pounds. Adjust the dosage so that your lamb gets 5 ml per pound of the 2:3 solution of dextrose and freshly boiled water (see chart). In the interest of sanitation and sharp needles, I like to use two brand new needles: one for drawing up the solution, and one for the injection.

**Dosage chart for mixing IP dextrose injection for various lamb weights**

<table>
<thead>
<tr>
<th>Lamb weight</th>
<th>Total injection</th>
<th>50 percent dextrose</th>
<th>freshly boiled water</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 lbs</td>
<td>25 ml</td>
<td>10 ml</td>
<td>15 ml</td>
</tr>
<tr>
<td>7 lbs</td>
<td>35 ml</td>
<td>14 ml</td>
<td>21 ml</td>
</tr>
<tr>
<td>10 lbs</td>
<td>50 ml</td>
<td>20 ml</td>
<td>30 ml</td>
</tr>
<tr>
<td>13 lbs</td>
<td>65 ml</td>
<td>26 ml</td>
<td>39 ml</td>
</tr>
<tr>
<td>15 lbs</td>
<td>75 ml</td>
<td>30 ml</td>
<td>45 ml</td>
</tr>
</tbody>
</table>

**Necessary equipment**

The key to this whole procedure is a warming box. The warming box is a contraption that can be simple or complicated, as long as it provides a constant, gentle heat to the lamb. I have rigged up hair dryers blowing into dog crates. Some pasture lambing operations use insulated coolers with hot water bottles. The main thing is that you don’t want to heat the lamb directly; just keep it in a very warm and dry environment. Heating a lamb too fast can be just as lethal as leaving it cold.

**Things not to do**
Don’t submerge a lamb in warm water. This common trick may work sometimes, but it will wash the scent off the lamb making it less likely that the ewe will reclaim it, and it will generally heat the lamb too quickly. Don’t warm a lamb with low blood sugar. This can send the lamb into convulsions and kill it. Don’t overheat a lamb. Warming a lamb too quickly or to too high a temperature can also kill it. Don’t feed a cold lamb. A hypothermic lamb can’t digest milk or milk replacer, and the food will cause digestive problems as it sits in the stomach.

**Step 1. Evaluate**

Determine lamb’s age: is it more or less than five hours old?

Determine lamb’s body temperature – ideally with a thermometer, but with your index finger if no thermometer is immediately at hand. If you’re using your finger, err on the side of caution: if the lamb’s mouth feels anything less than very warm, at least go to the next step of finding the thermometer.

Determine lamb’s general condition: able to stand, suck and swallow? Unable to swallow? Unable to stand?

Rub [MB1] the lamb dry if it’s wet.

**Step 2. Act**

*If the lamb’s temperature is over 99 degrees F., regardless of age:*

- Collect milk or colostrum from the mother if possible to use in feeding the lamb.
- Feed by stomach tube.
- Return to warming box until it reaches 101 degrees F.
- Return to mother.

*For lambs with temperatures lower than 99 degrees F.*

**More than five hours old, unable to hold up head or swallow**

- Give IP injection of dextrose.
- Move to warming box.
- Collect milk or colostrum from the mother if possible to use in feeding the lamb.
- Check temperature every 20 minutes until it reaches 99 degrees F.
- Feed by stomach tube.
- Return to warming box until it reaches 101 degrees F.
- Return to mother.

**More than five hours old, able to hold head up and swallow**
- Move to warming box.
- Collect milk or colostrum from the mother if possible to use in feeding the lamb.
- Check temperature every 20 minutes until it reaches 99 degrees F.
- Feed by stomach tube.
- Return to warming box until it reaches 101 degrees F.
- Return to mother.

**Less than five hours old, able to hold up head and swallow**

- Move to warming box.
- Collect colostrum from the mother if possible to use in feeding the lamb.
- Check temperature every 20 minutes until it reaches 99 degrees F.
- Feed by stomach tube.
- Return to warming box until it reaches 101 degrees F.
- Return to mother.

**Step 3. Follow up**

If the lamb remains weak, it may need to be kept in draft-free, gently heated environment and fed by stomach tube regularly until it is strong enough to return to its mother. If at all possible, use milk or colostrum from the lamb’s own mother for all feedings, as this will increase the likelihood that the lamb will be accepted when returned to her.

Keep the ewe penned up with her lambs in a lambing jug or other easily monitored area where other ewes won’t interfere with bonding, and the chilled lamb will have as few distractions as possible. Watch the lambs for signs of starvation or dehydration until they’re solid and ready to rejoin the flock.

**Step 4. Find the cause**

Hypothermia and starvation cause a great deal of death loss and their treatment greatly increases labor requirements at lambing time. Shepherds should set a goal both for economic and animal welfare reasons to reduce hypothermia and starvation as much as possible. Each case should be noted in the lambing records of the dam, and the shepherd should attempt to pin down the cause of each case. After the crush of lambing is over, these records can be reviewed to look for patterns that might suggest management changes or culling of individual ewes.

Well-fed and -conditioned ewes can deliver and keep lambs fed and warm under fairly extreme temperatures, provided they are sheltered from wind, drafts, and moisture. Temperature alone should not cause hypothermia-starvation in shed lambed ewes unless the air temperature is below 0 degrees F.

Some management-related causes of hypothermia-starvation in shed-lambed ewes would include:
1. Poor maternal nutrition in early gestation when placental development takes place, leading to low birth weights and low milk production.
2. Poor maternal nutrition in late gestation, reducing fetal development and resulting in low birth weight and weakness in newborn lambs.
3. Inadequate bedding; ewes lambing on wet or frozen pen floors.
4. Drafts at floor level.
5. Overcrowding of ewes leading to mismothering, grannying, or lost and wandering lambs.
6. Inadequate pen construction allowing lambs to wander away from their mothers.
7. Some disease-related causes of hypothermia-starvation would include:
   1. Ovine progressive pneumonia, which can cause reduced (or absent) colostrum.
   2. Any of the several abortion diseases, leading to weak newborn lambs.
   3. Mastitis, causing the ewe to refuse to allow the lambs to suckle, or past mastitis causing one or both sides of the bag to fail completely or partially.

If causes related to management and disease are ruled out, the most common cause of hypothermia and starvation in lambs is maternal inattention. Good mothering ability includes the skill of keeping track of your lambs and not allowing them to starve. In some rare cases, teat size and placement on the ewe can also be a factor. Be particularly attentive for ewes with excessively large, low, or high teats. Sometimes there can be plenty of milk that the lambs simply can't get to.

Each operation needs to review its death loss totals and determine where it can improve, as death loss is one of the largest drags on profitability in most sheep operations. The overall goal should be to reduce death loss to the lowest practical point, and it makes sense to start with keeping newborn lambs alive and kicking.

Topics
hypothermia, Lamb, Sheep

Grafting: A Lamb Saving Management Tool.
by A. Richard Cobb

Grafting (Fostering) is an alternative for producers who do not enjoy raising lambs on artificial milk. The ability to graft, or switch, a lamb from one ewe to another is a management tool that can save many lambs during a lambing season.

Grafting works best when you have a number of ewes lambing at the same time. When grafting, we are asking one ewe to adopt or accept another ewe’s lamb or lambs. Grafting can be done for many reasons. Examples of situations where removal of one or more lambs will benefit the lambs and the ewe are:

1. A ewe has more lambs than she can successfully care for.
2. A ewe becomes sick or dies, leaving orphan lambs.
3. A ewe does not have enough milk to adequately feed the lambs she has.
4. A ewe lambs with multiple lambs but she is young, or old, or is very thin.
5. A ewe has only a half udder and has twins or triplets.

First let’s establish names for the various animals we will be discussing.

Foster ewe. This is the ewe we are grafting the lamb onto.

Mother. The birth mother of the lamb we are grafting.

Alien. The lamb we will be grafting onto the foster ewe.

The selection of a foster ewe can make or break the adoption. A good foster ewe should:

1. Be above average in Body condition score. A thin ewe will have problems producing enough milk for two lambs.
2. Be calm by nature. A nervous or crazy ewe will not work.
3. Have a good milk supply.
4. Have teats suitable for nursing. Teats should not be too large and their location and angle from the body should make it easy for the lamb to find them.

**Slime Grafting.**

The slime method can be used only while the foster ewe is lambing. Due to the high maternal instinct of most ewes, they can be fooled into thinking they have given birth to two lambs instead of just one. To accomplish this graft, the shepherd must have in mind a lamb that will benefit from being grafted. Shepherds should make each lamb stand twice a day and observe their reaction. A healthy, lamb that has enough milk will stretch when it stands. A lamb that is not getting enough milk will not stretch but will immediately look for milk. A lamb that is obviously not thriving is also a good choice for an alien lamb. The alien lamb must be able to stand and move about for any graft to be successful. If the lamb is down, it needs immediate intensive care.

When a potential foster ewe lambs, with a single, the shepherd should check to make sure. This is done by inserting your hand into the body cavity of the ewe and feeling for another lamb. Be as sanitary as possible doing this. Wear a plastic glove or breeding sleeve and lubricate it for ease of entry. If there is no second lamb then prepare the alien lamb for grafting. If possible, match the size of the alien with the size of the foster ewe's own lamb. If one is much larger than the other this can lead to problems with one lamb consuming most of the milk. Color does not seem to be a problem when grafting. A black lamb can be grafted onto a white-faced ewe that has a brockle or white lamb.

A ewe identifies its lambs by smell at first. Therefore, your plan is to make the alien smell like the foster ewe's lamb. Smear the alien lamb with the birthing fluids of the foster ewe. Hold the alien up behind the ewe and cover it with the fluid. Be sure to smear the underside and crotch area of the alien as well.

A very important part of the grafting process is to tie the legs of the alien lamb together so that it cannot just get up and walk away. A newborn lamb does not suddenly stand up and run off. It lies there for a period of time before struggling up. Alien lambs, if they are just a day old are probably pretty quick on their feet and will need to be restrained. I sometime tie all four legs together and sometime tie three.

You are now ready to simulate the birth of another lamb. The foster ewe is probably licking off her own lamb. We try to keep the foster ewe from seeing or hearing the alien lamb until it is "born". This is not always easy, as aliens tend to be quite verbal.

Place your hand in the birth canal of the foster ewe and make a fist. She should begin to strain as she thinks that she is having another lamb, which is what you want her to think! Let her strain against your hand for 2-3 minutes and the remove the hand. Produce the alien lamb and place it below her own lamb and wrap both lambs together as much as possible without hurting them. This will help to hold an active alien lamb down even more. Add more birthing fluids to both lambs if possible. Then, stand back and observe what happens.
If the foster ewe starts to lick both lambs and make mothering sounds, this is excellent. Do not rush her into making any decisions. Let her mother the lambs at her own speed. The longer that she licks and "talks" to the lambs the greater is the chance that she will accept the alien.

Keep the alien tied for at least a half-hour. Perhaps it is best to move everyone to a lambing pen. If you choose to leave them in the birthing area, be sure that it is escape proof. Remember that the alien may be very independent and may seek to leave when you untie its legs. Do not allow it to run away. If it is in an escape proof area and realizes that this ewe will allow it to nurse freely, it will stay around.

Continue to observe what is happening when you do untie the alien. The sign of a successful graft is that the foster ewe allows the alien lamb to nurse. Sometimes the alien has to be convinced that this is where he now lives. An escape proof pen and a foster ewe that "talks" to the lamb and allows it to nurse best accomplish this.

Watch to see that the alien, if a day or so older, does not dominate and drink all the Colostrum. It is best to allow the foster ewe's lamb to nurse first, or to milk the foster ewe and tube feed her lamb.

Keep the foster ewe confined in the escape proof pen for three to five days. Continue to observe how they interact. Be sure to identify that the ewe and the lambs belong together. Place a stripe on the backs of all three or paint brand each with the same number. Do something so you realize that the ewe has multiple lambs at her side, so they are not mistakenly separated at some time.

When you feel fine about the graft, move the foster ewe and her lambs to a mixing pen. This is a pen with a few other ewes and lambs. This will allow the foster ewe and her lambs to interact in a larger population. Continue to observe how they interact. Does the alien lamb "stay at home"? If not, then return them to the smaller, escape proof pen. If everything goes right in the mixing pen, then move the whole group to the main flock.

After a few successful grafts, the producer develops a feel for lambs that need to be grafted if they are to thrive. Always be on the lookout for such lambs.

A producer should also be on the lookout for ewes that are potential foster ewes. Slime grafting works very well most of the time. The problem with it is that you have a very small window of time that you can attempt this type of graft. You need a ewe that is actually lambing, and one that produces a single. You also need to be present when she is lambing. Slime grafting is not the most commonly used method of grafting.

Stocking or Scent Grafting

Work at the University of Illinois and the University of California Hopland Research Center looked at the idea of transferring the scent of a ewe's single live (or dead) lamb to another to aid in the grafting process. To facilitate the scent transfer stockinette jackets made of elastic knitted fabric. A large sock (wool or other) with cutouts for the head and four legs can be substituted. were placed on a ewe's own live (or dead) lamb at birth. The stockinette jacket acquired the
natural odor of the ewe's own lamb, and when the jacket was transferred to an alien, the alien was accepted about 85% of the time. In addition, about 40% of the ewes immediately accepted the alien upon first introduction. I suggest keeping her haltered and restrained so she cannot move her head a great distance for a day or so and then turn her free and observe her reaction. If she still rejects the alien, she needs to go through the Stanchion graft program.

A second study was done in which researchers used an artificial odor to facilitate grafting. Neatsfoot Oil (a natural animal product used to preserve leather) was smeared on an ewe's own lamb shortly after birth. An alien, smeared with the same material was introduced to ewe as well. Only 50% of the ewes accepted the alien with this treatment, however, 80% of those adopting the alien did so immediately.

Because of the high percentage of immediate adoptions, another experiment was performed using both the stockinet's and the Neatsfoot Oil. In this study, 80% of the foster ewes accepted the alien as well as their own lamb and, of those adopting aliens, 83% did so immediately. Because of the success using a strong odor, other strong smells may be able to be substituted for the Neatsfoot Oil.

To successfully use this system of grafting producers should identify each prospective foster ewe and place a stockinet or sock on her single lamb soon after birth. The sock should remain on the lamb until an alien lamb is identified. Then the foster ewe should be isolated in an escape proof lambing pen. I would suggest keeping both the alien and the ewe's own lamb away from her until they are ready to be presented to her. The sock would be taken off the foster ewe's lamb and inverted and placed on the alien. By inverting the sock the smell of the foster ewe's lamb will be intensified. The neatsfoot oil should be rubbed all over each lamb and then both are presented to the ewe at the same time. Observe for any reaction by the ewe. If she licks the alien and allows it to nurse, she will accept it. If she rejects it she will butt it. The sock should remain on the alien lamb for a few days before removal. Then the producer will need to observe again to make sure the ewe still accepts it.

If the producer places a sock on a lamb and the mother of the lamb is not used as a foster ewe, the producer should observe the lamb daily and remove the sock if it gets too tight on the lamb.

The above described methods of grafting are encouraging but it must be remembered that any ewe having lambs grafted onto her MUST have special treatment. She needs to be isolated in a lambing pen with her new lambs and observed for 2-3 days. The lambs grafted onto her MUST be identified as being on her and she needs to have some identification on her body that shows she has an alien lamb on her.

**Stanchion Grafting**

This method calls for preparation before lambing. Stanchions need to be built that foster ewes can be restrained in. They can be permanent or portable. The most important thing to remember is to build them to be very sturdy. They will receive a good deal of stress from ewes that do not wish to be secured. Most ewes readily adapt to the restraint however and become very calm.
A ewe that has lost her lamb from injury or disease that has a good milk supply as well as good teat placement and a better than average body condition score is an excellent candidate to be a foster mother. So is a ewe with a single lamb and the above credentials. Ideally she is well mannered and calm. For me a ewe is an excellent candidate for grafting for three days after she lambs. After that her desirability decreases every day. This is not to say that you cannot form a graft with a ewe that has a five-day-old lamb but they seem to be able to count higher after three days. Perhaps they just become less maternal. Ewes with pendulous udders, large teats or poor teat placement are not good candidates. They may be good mothers but it is more difficult to teach a lamb to nurse a big fat teat that is in an unusual position. Watch a lamb try to nurse and they stick their heads under the flank of the ewe and reach up, not down. Lambs nurse by instinct and do not "look" for the teat and go to it. Lambs can be taught to nurse from just about any position but it will take a commitment by the producer to do so.

There is usually a question as to which lamb should be chosen to graft. I suggest that you choose the strongest. If the mother of the lambs accepts both lambs then the smaller lamb (s) is able to nurse without trouble. It (they) should start to thrive as soon as the larger lamb is removed. The larger lamb is also stronger and better able to stand the stress of grafting.

Another trick that seems to help a great deal is not to let the foster ewe see the alien lamb. Keep her in a stanchion constructed so that she cannot see behind herself. Don't ever just tie her in a corner and drop the alien in the pen with her. I feel it is best that she not see the alien until she is released after 3-5 days.

Sometimes real disasters can occur. A ewe with twins or triplets dies unexpectedly. You will need to find mothers for all lambs. This is a situation that it may be best to call a person in the area that has expressed an interest in raising bottle lambs. It is also possible to graft two lambs onto a ewe with a single if she meets the criteria as described above. It is also possible to graft lambs onto ewes for a day or a few days, keeping the ewe in a stanchion for that time until another foster ewe comes along.

An ideal stanchion graft would go as follows. A needy lamb is identified and a foster ewe as described above is located. The ewe and her natural lamb, if she has one, are placed in the adoption pen with the ewe's head secured by the stanchion. The alien lamb is placed in the pen behind the ewe and with her own lamb. The alien lamb is given aid, if needed; in nursing from the foster ewe. Both lambs are observed often to see that they are nursing. They will exhibit fullness to their stomachs, stretch when they stand up and their mouths will be warm when you insert your finger. The foster ewe stands and lies down quietly. After three to five days, the ewe's head is released from the stanchion. She turns and nuzzles and licks both lambs. (The lambs may show fear of the ewe when she is released, but remember, that she has been standing or lying quietly for a long time, and suddenly she pulls back and spins around, anything will be frightened). She allows both lambs to nurse. If this is the case, leave the new family in the adoption pen or move them to another small, escape proof pen. Continue to observe their interaction for two or three days and then move them to a mixing pen and then if everything goes right to the large flock pen.
Sometimes a foster ewe will be nervous and "dance" when a lamb tries to nurse while she is in a stanchion. Sometimes a hand on her rump and a loud voice when she moves is enough to make her stop moving and relax. Sometimes this is not enough. It may become necessary to hit the ewe on her back or side when she moves. Do this as gently as possible. If a ewe is determined to not let a lamb nurse then stronger "coaching" may be necessary. In this situation, I am 100% on the side of the lamb. I do not wish to hurt the ewe but I will do whatever is necessary to help the lamb be successful in its quest to be adopted. Over the years I have promised ewes that they will stand in that pen forever if they don't accept the lamb. Sometimes they listen and once in a while they refuse to. In that case you just have to start over. When another possible foster ewe is identified, release the uncooperative ewe and her lamb, making sure she still claims it, and start over. I feel that we can make successful grafts over 90% of the time using the stanchion method. You can save yourself and the ewes a lot of aggravation if you develop an ability to recognize ewes that will not accept an alien lamb and replace them as quickly as possible.

**Skin Graft**

I actually believe the Skin Graft is the best method of grafting to attempt if you do not have the opportunity to do a Skin Graft.

This involves skinning a dead lamb and attaching the skin to the alien lamb you wish to graft onto the mother of the skinned lamb. This either works right away or the lamb is rejected and you can then use the Stanchion Graft if necessary. I believe it is the most commonly used method in large commercial flocks because if it works, it is fast. The problem, for most producers, is the actual skinning of the dead lamb. Producers often feel they are unable to skin a lamb, even a dead one, an so if is usually not attempted.

**Important Thoughts on Grafting**

After reviewing the above grafting methods, it is suggested that producers be alert to the possibility of grafting alien lambs as soon as possible after they have been identified.

While the first choice would be to use either the slime or the Skin Graft, but both of these methods have drawbacks. First, a producer must be present at lambing to accomplish a slime graft. That by itself can be a problem. The drawback for the Skin graft is that many producers do not feel, for a number of reasons, that they can actually skin a dead lamb.

The next preferred method would be to use the stockinette/odor graft. The advantage of this, if the research is correct, is that you will know quickly if the alien lamb is accepted or not. If it is accepted you have saved time and effort. If the foster ewe rejects it, you can still use the Stanchion Graft to get that foster ewe to accept that alien.

Producers should realize that none of the described methods are miracle cures for the grafting problem. They cannot be accomplished with a minimum of effort. In each case, the ewes and lambs need time to bond and to be observed to make sure the graft succeeds.
Grafting lambs: an opportunity to increase flock productivity

Richard Ehrhardt, Small Ruminant Specialist, Michigan State University - January 28, 2020

This article discusses how to successfully graft lambs unto another ewe.

Milking a ewe who has just lambed and putting the new grafted lamb in top of the other biological
Introduction

Grafting is the process of assessing milk/colostrum production in ewes and matching lambs to supply. Grafting lambs is an effective means of efficiently raising “extra” or “bonus” lambs and maximizing flock productivity. It is also a vastly underutilized technique for many reasons. One is simply lack of know-how. Another is lack of milk/colostrum in ewes due to chronic disease such as ovine progressive pneumonia (OPP) and/or because of undernutrition. In addition, the opportunities for matching graftee lambs to surrogate ewes can be few and far between unless the birth period is concentrated. In well-managed flocks that are free of OPP, it is possible to eliminate artificial rearing by grafting and still produce a 200% weaned lamb crop. The concept is simple, but execution of this matching process is an acquired skill. Critical aspects to focus on are assessment of milk, lamb demand, lamb vigor and maternal bond.

Predicting milk yield

Future milk yield can be estimated by colostrum yield at birth. This can often be approximated by palpating an udder, but it is best to milk a potential surrogate udder at least partially to estimate yield. This must be done quickly after birth, so it may be better to guess rather than obtain an accurate assessment, as bonding success is time-dependent. A crude estimate is that 120 cc (approximately ½ cup) of colostrum at each milking will support an average size lamb (10 lb). Milk production, especially in early lactation, is a function of litter size. The underlying explanation for this phenomenon is that the total placental mass of larger litters will always be greater than smaller litters, and it is the mass of the placenta that determines mammary development in late gestation. The placenta produces hormones that support mammary growth, hence the larger the placental mass the greater the extent of mammary growth. This is in effect mother nature’s way of matching maternal milk production to litter size, so use this information when predicting milk yield. For example, a ewe carrying triplets that had two large lambs die at birth and one large live lamb will likely have tons of milk to spare and may well be able to support two graftees.

Assessing lamb milk demand

Lamb demand is assessed by lamb size. A large lamb will have proportionally higher demands than a small lamb. For example in my own flock, a small Romanov or Florida native-sired lamb will have lower nutrient needs than a large Dorset or Ile de France lamb. Breed is likely of little importance; it is just that certain breeds tend to have larger
Lamb vigor and its assessment

Lamb vigor can be quite variable. I try to match vigor when possible within a litter. Lamb vigor is highly related to lamb temperature, and chilled lambs quickly lose vigor and become lethargic. Vigor will usually improve by feeding and warming lambs and often increases as the lamb recovers from the birth process. Grafting will not work if the grafter lacks suckling drive, so it is necessary to warm and feed a weak lamb to increase its vigor before attempting to graft the lamb on a surrogate. Placing a lethargic chilled lamb and a vigorous, strong lamb together will never work, as the mother will only take an active interest in the active lamb and will commonly ignore the lethargic lamb. If your only opportunity is to graft into an established litter, you should choose an especially vigorous lamb with a strong suckling drive.

Assessing and enhancing maternal bond

Maternal bond strength is a function of time after birth. You can usually mix/match entire litters within 10 minutes of birth. Bonding becomes established in as little as 10 minutes, but this timing is not precise and can be elastic, extending up to an hour or longer in some cases. After establishment, bonding is very difficult to disrupt. However ewes vary greatly in their receptivity, some may be receptive for 2 h following birth while others know how to count and smell their lambs very quickly (10 min or less).

If bonding is constantly being disrupted by several ewes lambing together at the same time and lambs and moms constantly mixing, the receptive period will be longer. If a ewe lambs in isolation, bonding will establish quickly. A receptive ewe will quickly lick the new lambs. Bonding can be enhanced by milking the ewe, which stimulates the release of oxytocin, a hormone that strengthens maternal bonding. The colostrum can also be used as a bonding agent, as ewes will recognize the smell of their own colostrum. Ewes will also recognize the smell of their fetal fluids (amniotic and allantoic fluid) from their own offspring, so rubbing a grafter with the newborn of a surrogate mom will help.

Ewe restraint techniques to prevent lamb rejection

In cases where ewe receptivity is weak, providing some degree of ewe restraint can allow for a successful bond. These techniques can be applied to grafting or any time bonding is weak, which can occur any time a lamb becomes separated from its mom.
Grafting lambs: an opportunity to increase flock productivity - Sheep &... https://www.canr.msu.edu/news/grafting-lambs-an-opportunity-to-increas...

during the first few hours following birth. Securing a ewe with a halter and enough lead to prevent her from turning around can often be enough to encourage bonding. It is imperative to use a halter with no risk of choking, along with use of a lead that can be tied to the top rail of a lambing pen panel. The lead should be tied to the top rail near the water source. The concept is to provide enough lead to allow drinking and feeding but not enough to allow the ewe to butt lambs or run in circles in the pen. The amount of lead may need to be decreased in cases in which the ewe is showing more intense rejection behavior. The lead can then be lengthened as rejection behavior subsides. The lead should be removed a few hours after it is clear that all lambs are able to nurse successfully. The time needed to accomplish this may be as short as 2 h or as long as 2 days.

As discussed below, lambs may need to be supported nutritionally during this period by tube feeding to maintain suckling drive. In cases in which rejection behavior is strong, watch for opportunities to graft onto a new, more receptive surrogate. Also, if the period is long, it may be prudent to consider use of a “ewe stanchion”. These devices can be placed within a lamb pen or can be used to replace a panel of a lambing pen. This author rarely finds them necessary, but others report success using stanchions. My recommendation is to reserve their use for situations when rejection behavior is more intense (when a halter is needed for more than 24 h). Finally, it is wise to keep grafted lambs in the lambing pen at least 24 h after lead removal to continue to provide the tight quarters necessary to ensure and strengthen bonding.

**Grafting process**

When creating a new litter, the process starts when a ewe or several ewes give birth. You quickly assess how many lambs are born, how much milk is present and then quickly mix/match lambs from the other litters or bring in grafteres that you have been holding in anticipation of a matching opportunity. I take foreign lambs and rub them with the ewe’s own lambs (dead or alive lambs) or apply afterbirth. Another biological fluid that works wonders to stimulate bonding is colostrum from the surrogate ewe. The concept here is to try to make all of the litter smell the same, so apply bonding fluids to all of the litter you are introducing to a surrogate ewe. Colostrum is often a precious fluid, so I use it sparingly (perhaps 20 mL to drip on a lamb’s head and back). If the surrogate ewe has given birth within 30 minutes of the grafting process these techniques work well. But if the surrogate lambed more than 30 min ago or even up to 2 hours perhaps, it is possible to trick a ewe into thinking that she has given birth again, thus making it easier to introduce a grafter. Birth can be simulated simply by performing a vaginal exam using an OB glove. Do not attempt this much beyond a 2 hour period post-birth.
because the cervix will have closed and the vagina will have lost its elasticity.

Grafting into an established litter is less successful than when creating a new litter near the time of birth. There are times when this might be the only option, however, and it is worth attempting if the graftee has a strong sucking drive. An example might be when a ewe has triplets when no other ewes have lambed within several hours, only ½ of the ewe’s udder is functional, and all the lambs are very strong and vigorous. Let’s assume you have two or three ewes that had single lambs within 12-16 h earlier. If two of the ewes have lots of milk, then graft the 2 stronger triplets onto those ewes. Typically I would put a secure halter on the recipient ewes (see restraint section above for details), milk them, tube the graftee with the surrogate ewe’s milk and apply some of the milk to the lamb as well. It helps to feed the ewe at this time to distract her.

Ewes will vary in how much they protest the new lamb. Some ewes will accept the new lamb within 6 h, others may take 48 h. You may need to support the lamb by stomach tube feeding during this period or hold the ewe temporarily to allow suckling. Bonding success indicated by successful feeding which in turn is evident by monitoring gut fill of the lamb. It is easy to tell if a lamb has fed successfully as it will have a distended belly full of milk. A newborn lamb requires 10% of its weight in colostrum over a 24 hour period but never give more than an 8 h dose at one time. Stomach tube feeding may seem daunting at first, but it is a simple procedure. The first thing to be certain of is that the lamb is fully warm (above 102.5° F) as cold lambs will not have a normal swallow/suckle reflex and it is possible to place the tube into the trachea instead of into the esophagus under these conditions which can be fatal if milk enters the lungs. This risk is virtually eliminated if the lamb is warm and the tube applied slowly yet firmly to that back of the mouth allowing the lamb to effectively swallow the tip of the tube.

If the bonding is not working, it is common for another opportunity to come up during the process and you can move to the new opportunity. Perhaps the new opportunity would be a ewe that just lambed with one stillborn lamb. It is quite possible that the new ewe may accept the older lamb after anointing the lamb with uterine fluids and colostrum. I have had success placing the graftee under the older living lamb of the surrogate ewe to hold it down momentarily while I remove the stillborn lamb. It is not uncommon for this trick to work as the ewe comes over and licks the new lamb and then, voila!, the graftee suddenly pops up from underneath and the ewe thinks the graftee is the stillborn lamb risen from the dead. The ewe commonly associates the older graftee with her own lamb and forgets about the dead lamb.
Grafting has many advantages to artificial rearing, but it is a learned skill and not always feasible. Grafting is preferred to artificial rearing, as it allows the lamb to grow on mother’s milk and keeps a productive ewe from getting too fat in the event that she loses one or more lambs. Artificial rearing is necessary if no grafting options exist. Generally speaking, you can support graffees in a warmed area and feed them colostrum for approx. 36-48 h before it becomes necessary to resort to artificial rearing. During this holding period, the graffees should be fed via stomach tube and not a via a rubber nipple, as it is very difficult to retrain a lamb to suckle on a ewe if it has already learned how to suckle on a rubber nipple.

Summary

Grafting is a great way to increase flock productivity by reducing or eliminating the need to artificially rear lambs. Artificial rearing is expensive in terms of milk replacer and management time. Large flocks may gain some efficiencies in artificial rearing if they have a large volume of lambs to rear, but the training necessary for artificial rearing is often less than that required for grafting. So it makes sense to graft as much as possible and to reserve artificial rearing for cases when matching opportunities do not exist. Grafting opportunities will increase dramatically if the flock is well fed in late pregnancy, allowing abundant colostrum production. In addition, elimination of ovine progressive pneumonia (OPP) in a flock will increase maternal milk significantly, allowing for more grafting opportunities and reducing the need for artificial rearing.

This article was published by Michigan State University Extension. For more information, visit https://extension.msu.edu. To have a digest of information delivered straight to your email inbox, visit https://extension.msu.edu/newsletters. To contact an expert in your area, visit https://extension.msu.edu/experts, or call 888-MSUE4MI (888-678-3464).
disability, political beliefs, sexual orientation, marital status, family status or veteran status. Issued in furtherance of MSU Extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Quentin Tyler, Director, MSU Extension, East Lansing, MI 48824. This information is for educational purposes only. Reference to commercial products or trade names does not imply endorsement by MSU Extension or bias against those not mentioned.

The 4-H Name and Emblem have special protections from Congress, protected by code 18 USC 707.

CARE OF ORPHAN LAMBS

NEW PLYMOUTH VET GROUP

Looking after an orphaned lamb can be a very rewarding experience providing everything goes well. Here are a few guide lines to help make rearing your lamb easier.

**Management**

**Feeding**
At birth, lambs have no immunity as the ewes placenta does not allow for the transfer of antibodies to the lamb during pregnancy. Therefore the only source of antibodies to the lamb is through the ewes first milk known as colostrum. The antibodies in the colostrum help the lamb fight off infections and disease early in life. Colostrum is thick, yellow in colour and very high in protein and fat, providing important source of nutrition to the new born lamb. It is essential that the lamb gets this within 6-12 hours of birth as after this the lambs gut can no longer absorb the antibodies. Lambs require at least 200ml in the first 6-12 hrs.

If you are unsure if your new born lamb has had any colostrum, a ewe that has recently lambed can be milked and the colostrum fed straight to the lamb. There are also some artificial colostrum products available such as Jumpstart™ or Halen New Born™. Be aware that homemade colostrum recipes do not contain antibodies for the lamb and should not be used. Lambs can be fed colostrum for the first 24 hours before weaning onto lambs milk powder.

In order to prevent abomasal bloat it is best to feed little and often with never more than 250 ml per feed. Milk should be fed at room temperature and a yogurt culture can be added to it. Lambs should be fed based on their weight. A lamb requires 10-15% of their body weight in milk. For example a newborn 4kg lamb needs 400 ml-600 ml total of milk, split into 6 feeds of 75-100 ml. As the lamb grows, the amount of milk can be gradually increased. 1 litre daily split into 3-4 feeds should suit most lambs over 3 weeks old. Never feed a lamb until its stomach starts to bulge or does not want any more to drink.

In an emergency calf milk powder can be used but mix at 200 gm per litre (rather than 125 g/litre for calves) and do not water it down.

Some lambs need to be taught how to suckle from a bottle. Place the teat in the lambs mouth to encourage it to drink. This may require some patience but the lamb will eventually learn.

**Weaning**
Weaning is the gradual transition of the lambs diet from milk onto solid feed. Lambs require access to grass and hay to allow for development of the digestive system. Lambs will begin to nibble on solid food soon after birth and will be fully eating grass by 4-6 weeks old. Hard feed such as Sheep Nuts™ or Multifeed™ nuts can also be fed. Weaning can begin as early as 6 weeks of age but most lambs benefit from milk feeding up to 12-14 weeks of age. At weaning the lamb should be eating solid food for a minimum of 10 days and drinking water freely. Weaned lambs should be given access to high quality pasture to ensure continued growth rates. It is important that the lambs are not grazing in an area where they can come in contact with any poisonous plants as they will nibble on anything given the chance. They should have access to fresh water at all times.

**Housing**
Lambs require a warm, dry and draught free shelter with access to pasture. Sheep are social animals so are happiest if reared in a group. This will also help the lamb to learn that it is a sheep rather than a human! Woolovers™ lamb covers can provide extra warmth and insulation if needed. Old woolen jerseys with leg holes cut out also work well.
**COMMON HEALTH ISSUES**

**Vaccinations**

It is recommended that all lambs are vaccinated to protect against a number of diseases caused by Clostridia bacteria. These bacteria live in the soil and cause diseases such as Tetcнос, Pulpy kidney, Black leg, Malignant Oedema and Blacks disease.

Generally animals are only at risk to infection after an injury. Risk factors include lambing, docking and yarning injuries. Rapidly growing animals that are eating a lot of supplementary feed are also at risk. Once there is bruised tissue present, the bacteria multiply and produce toxins which can cause sudden death with few clinical signs. There is nothing more disheartening than finding a healthy strong lamb suddenly dead.

Once a lamb has been given its initial vaccinations, a booster will be required annually.

The type and timing of vaccine used will depend on a few factors:

Ewe is vaccinated 2-6 weeks prior to lambing and lamb has received adequate colostrum from ewe:

<table>
<thead>
<tr>
<th>Age of lamb</th>
<th>Type of vaccine</th>
<th>Lamb is protected by antibodies in the ewe's colostrum. Protection lasts for up to 12 weeks.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 weeks/ Docking</td>
<td>No vaccine required.</td>
<td></td>
</tr>
<tr>
<td>Sensitizer: Weaning</td>
<td>5 in 1/Covexin 10 in 1</td>
<td></td>
</tr>
<tr>
<td>Booster: 4-6 weeks later</td>
<td>5 in 1/Covexin 10 in 1</td>
<td></td>
</tr>
</tbody>
</table>

Ewe is not vaccinated or lamb did not receive colostrum from ewe:

<table>
<thead>
<tr>
<th>Age of lamb</th>
<th>Type of vaccine</th>
<th>Provides immediate short term protection for 2-3 weeks against tetanus and pulpy kidney.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 weeks/Docking</td>
<td>Lamb Vaccino</td>
<td></td>
</tr>
<tr>
<td>Sensitizer: Weaning</td>
<td>5 in 1/Covexin 10 in 1</td>
<td></td>
</tr>
<tr>
<td>Booster: 4-6 weeks later</td>
<td>5 in 1/Covexin 10 in 1</td>
<td></td>
</tr>
</tbody>
</table>

Correct vaccination technique:

The recommended vaccination site: The anterior half of the neck.

The vaccine should be placed under the skin. ‘Tent’ the skin prior to injection.
Docking
The docking of the tails and removal of testicles in ram lambs should ideally be done before 2 weeks old and no older than 6 weeks old. If you are not intending to breed from your ram lamb then it is wise to castrate him as pet rams can become dangerous. The docking of tails reduces the risk of fly strike by preventing the buildup of faeces around the bottom. The easiest way to dock a lamb is to use rubber rings and an elastrator. A veterinarian can do this procedure if you have any concerns. Docking lambs over 6 months old requires pain relief.

Correct docking technique:

Abomasal bloat
One of the most common causes of death in orphan lambs is due to bloat. Orphan lambs are fed higher volumes of milk in fewer feeds than they would when feeding from the ewe. This makes them prone to getting bloat. The bloat is caused by an overgrowth of bad bacteria in the fore stomach (abomasum). These bacteria feed on the lactose found in the milk, converting it to lactic acid which leads to gas production and bloating of the abomasum. Bloat can cause death either through compression of other body organs or through rupture of the abomasum.
Symptoms of bloat are a distended tummy and signs of discomfort such as kicking the stomach and constant sitting and standing up. Massaging the tummy and getting the lamb to walk around can help relieve some gas, however if symptoms persist contact a veterinarian.
The best way to prevent bloat is not to over feed your lamb. Never feed a lamb until its stomach starts to bulge or does not want any more to drink. The milk should also be fed at room temperature rather than feeding warm. It is also important to prevent overload of milk by making sure the teat hole is the correct size. If the milk is free flowing from the teat when the bottle is tipped upside down then the hole is too big. Another prevention method is to add a yogurt culture to the milk powder mixture.

Method for feeding cultured milk powder (Amount for 1 lamb, makes 1 litre of milk).

- Mix 200 g of milk powder with 500 ml of warm water.
- Add 25 ml of acidophilus yogurt and mix thoroughly.
- Place in a warm area and allow to thicken over night.
- Top up with 500 ml water and mix thoroughly the next morning.
- Feed milk at room temperature.
- For future use, save 25 ml of the thickened mixture as a replacement to Acidophilus yogurt.
- The mixture will keep for 5 days in the fridge.
Scours
The most common cause of diarrhea in lambs is related to change in nutrition rather than an infection. However whatever the cause, the general treatment principals are the same. The most important factor is to prevent dehydration which is done by feeding plenty of electrolytes. Depending on the size of the lamb 100-200 ml doses 3-5 times a day is recommended. Milk feeds can be introduced slowly as the diarrhea resolves. Electrolytes can be purchased from the clinic or your local farm store. If symptoms persist or the lambs condition is deteriorating, consult a veterinarian.

Navel III/Joint Infections
This occurs in the newborn lamb where bacteria travel up through the umbilical cord and become lodged in the joints, leading to an infection. Affected lambs will become lame and have putty inflamed joints. Consult a veterinarian with regards to antibiotic treatment. Prevention involves ensuring that newborn lambs get adequate amounts of colostrum, are kept in a clean environment and spraying fresh umbilical cords with iodine.

Worms
Once lambs are eating grass they become susceptible to picking up worm larvae from the pasture. Signs of worms include scouring, weight loss and poor growth rates. Lambs will require drenching from around 4 weeks from the start of grazing and will need to be drenched every 28 days until the lambs first winter. The worm burden in the pasture can be reduced by cross grazing with older sheep or other species such as cattle.

Entropian
This is an inherited disorder where the lamb is born with eyelids that turn inside out. It may affect one or both eyes, causing the eye to weep and leads to damage of the cornea due to irritation of the eyelashes. If left untreated, it can cause ulceration of the cornea and blindness. In some cases only manual correction is needed. The eyelids can be rolled down after every feed and bathed in warm saline. However others may require surgical correction by a veterinarian.
Raising Lambs and Kids Artificially

Susan Schoenian, Sheep & Goat Specialist, University of Maryland Small Ruminant Extension Program
(Previously published on the Maryland Small Ruminant Page)

One of the outcomes of having a high lambing/kidding percentage (greater than 200%) is that you may end up with some lambs/kids that you have to raise artificially. While some ewes/does will be able to raise triplets (even quads), sometimes it may be necessary (or wise) to remove lambs/kids from large litters in order to obtain more satisfactory weight gains.

There are different opinions as to which offspring should be removed for
artificial rearing. Traditionally, it was recommended that the bigger, stronger lambs/kids be removed for artificial rearing; however, experience has shown that these lambs do better on their dams, and the smaller weaker lambs do better if they are artificially reared [7].

Of course, before initiating artificial feeding, you should first try to cross-foster the “extra” lambs/kids onto another ewe/doe that has sufficient milk to raise another offspring. The best way to graft newly born lambs/kids is to rub the fetal membranes and fluids from the foster ewe’s lamb(s) onto the lamb (or kid) you wish to graft. You can also skin a dead lamb and place the skin on the lamb you wish to graft.

For older lambs/kids, you can try putting the foster ewe/doe into a head stanchion for several days. In a head stanchion, the ewe/doe will be able to stand, lie down, and eat and drink, but she will not be able to push the lambs/kids away and prevent nursing. You can also hold the ewe or doe until she allows the lambs/kids to nurse. Unfortunately, grafting is not always successful.

**Colostrum**

As with any baby, it is important that newborn lambs/kids consume adequate amounts of colostrum during their first 24 hours of life. Research has indicated that a newborn lamb should receive 3 ounces of colostrum per pound of body weight, divided into several feedings [2]. It may be necessary to tube feed [11] some newborn lambs/kids. If colostrum is not available from the dam or another ewe/doe on the farm, cow or goat colostrum can be used. When cow colostrum is used, 30% more should be fed to lambs, due to differences in nutritional content. You need to pay close attention to the source of colostrum, as CAE, OPP, and Johne’s disease can be transmitted via infected colostrum.

Artificial colostrum can also be used. Land O’Lakes makes a colostrum substitute for lambs and kids that contains protective antibodies (IgG). Other colostrum products are intended to supplement natural colostrum; they do not contain any antibodies. While not the “real,” they are preferable to no colostrum.

Frozen colostrum should be thawed at room temperature or in a hot water bath. High heat or microwaves should not be used to thaw colostrum because they will destroy the antibodies in the milk. The best way to thaw colostrum is at room temperature [2].

After colostrum feeding, lambs should be fed milk replacer that has been formulated for lambs, due to the differences in milk composition. It is best to feed kids milk replacer that has been formulated for them. Lambs and kids may do all right on other milk replacers or milk, but will do best if they are a fed species-specific milk replacer.

<table>
<thead>
<tr>
<th>Species</th>
<th>DM</th>
<th>Protein</th>
<th>Fat</th>
<th>Lactose</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow</td>
<td>12.8</td>
<td>27.3</td>
<td>28.9</td>
<td>38.3</td>
<td>5.5</td>
</tr>
<tr>
<td>Goat</td>
<td>13.5</td>
<td>26.7</td>
<td>29.6</td>
<td>37.8</td>
<td>5.9</td>
</tr>
<tr>
<td>Ewe</td>
<td>18.2</td>
<td>24.7</td>
<td>39.0</td>
<td>26.5</td>
<td>4.7</td>
</tr>
</tbody>
</table>
Milk replacer powder should be reconstituted (mixed) according to the manufacturer’s instructions. It should never be diluted. Because of the high fat content of lamb milk replacer, it should be mixed in warm water, then cooled and stored at 35 – 40° F. It is essential that milk be mixed properly. Lumps can contribute to abomasal bloat [1]. The addition of yogurt to the milk may help to prevent bloat [9].

**Feeding recommendations**

It is recommended that milk be fed cold, about 40°F (4°C). With cold milk, there is less tendency for lambs/kids to overeat, thus helping to prevent bloat, diarrhea, and other digestive upsets. Feeding cold milk is essential if milk will be offered free choice. Small numbers of lambs/kids can be fed using individual bottles fitted with rubber teats. A nipple bucket can also be used to feed a few lambs or kids.

For the first few days of life, lambs/kids should be fed frequently. After lambs/kids are a few days old, the frequency of feedings can be reduced. There are numerous protocols for feeding, as shown in the tables [available in the original article]. Lambs/kids generally need to consume 10% – 15% of their body weight per day. More frequent feedings will help to prevent overeating.

For larger numbers of lambs/kids, an automatic feeding station can be set up. A few lambs/kids can be fed from a bucket or bar. On large farms, an automatic milk feeder can be used. Biotic markets several automatic feeders (e.g. Lak-Tek) for lambs and kids. Lambs/kids will drink cold milk from a lamb bar at frequent intervals, much like they would if they were nursing a ewe/ewe. An open vessel (bucket or trough) can also be used to feed fresh milk.

**Weaning**

Because milk replacer is expensive and artificial rearing can be labor intensive, lambs/kids should be weaned at an early age. Six weeks is common. Weaning at 30 days is possible if lambs/kids are big enough and are consuming adequate dry feed. Lambs have been successfully weaned as early as 2 weeks of age. At weaning, lambs should weigh at least 25-30 lbs.; kids, 20 lbs. or 2.5 times their birth weight.

In order to wean lambs/kids at an early age, it is essential to get them consuming dry feed as soon as possible. By the time the lambs/kids are a week old, they should have access to a creep feed which is palatable and contains 18% – 20% crude protein. Young lambs/kids will consume more feed if is coarsely ground, though a pelleted ration may also be fed. Soybean meal makes a good starter feed. The biggest challenge is constructing a feeder that the lambs/kids cannot stand or play in.

Ample, fresh water should be available at all times. There are differing opinions as to whether orphan lambs/kids should be offered hay. A common recommendation is to wait until lambs/kids are three weeks old before feeding them any hay. Hay, especially alfalfa, can cause bloat [2]. Some producers do not feed hay until after weaning.

Lambs/kids should be vaccinated for overeating disease and tetanus by the
time they are six weeks of age, followed by a booster three to four weeks later. They should be vaccinated earlier (3-4 weeks of age), if they did not receive adequate protection through the colostrum.

Earlier vaccinations may not be effective due to the immature immune system of young lambs and kids. Weaning should be abrupt [7] and lambs/kids should be left in familiar surroundings at the time of weaning to minimize stress. If orphan lambs/kids are properly fed and managed, they should gain nearly as well as lambs/kids being raised on their dams.

**Editor's Note:** For a quick guide on how to feed specific milk replacers available commercially, be sure to check out this [article on the Maryland Small Ruminant Page](https://u.osu.edu/sheep/2019/01/15/raising-lambs-and-kids-artificially/).

Posted by [Braden Campbell](https://u.osu.edu/sheep/2019/01/15/raising-lambs-and-kids-artificially/) at 8:00am

Artificial rearing of lambs on milk replacer diets

J. Thompson, F. Rulofson, and D. Hansen

For many reasons, extra or orphaned lambs occur in nearly every flock at lambing time. These lambs result from ewes that die after giving birth to a live lamb or ewes that fail to have sufficient milk for the number of lambs produced. This occurs often in flocks with ewes that have a high incidence of triplets and quadruplets.

Extra lambs should be grafted to another ewe whenever possible. Our goal is for ewes to raise the extra lambs if the ewes have the available milk. If you have three lambs in any combination of adopted or natural, leave the two closest in size with the ewe and remove the odd one, whether it is the largest or smallest. Lambs not grafted to another ewe can be raised on milk replacer.

With multiple births, the weakest lamb usually is selected for artificial rearing on milk replacer because it is less capable of competing at the udder. Make the decision to remove the lamb from the ewe as soon as possible after birth. This eases the lamb's training period and enhances lamb survival.

Feeding the newborn lamb
All lambs need to receive colostrum soon after birth. Colostrum is the source of antibodies for newborn lambs and serves as a source of nutrients, especially energy, which is important in preventing hypothermia. Pay close attention to the amount of colostrum newborn lambs receive.

Research indicates a newborn lamb should receive 3 ounces of colostrum per pound of body weight. Give this during the first 18 hours of life to build up sufficient antibody levels and nutrients.

A 10-pound lamb would receive 30 ounces of colostrum divided into four equal doses (at birth, 6 hours, 12 hours, and 18 hours). If no colostrum is available from the mother or another ewe, use colostrum from goats or cows. We recommend that you keep a supply of frozen colostrum available.

If you cannot provide the indicated amount of colostrum, give as much as you have and make certain that the lambs receive it as early in life as possible.

Frozen colostrum
Periodically freezing high quality colostrum is a good management practice. This ensures that colostrum is available the next time a newborn lamb needs it. We recommend freezing colostrum in single feeding sizes (8 ounces). This amount can be rapidly frozen and thawed. Thaw frozen colostrum and feed it at body temperature.

The best method for thawing is at room temperature, but this probably will take too long. Be careful when thawing; do not use high heat. High heat destroys the antibodies, which is the reason for feeding colostrum to newborn lambs. Avoid thawing colostrum in microwave as it is difficult to prevent "hot" areas while thawing or warming.

Colostrum supplements
Special "home brew" recipes for colostrum are not effective and should not be used. They do not contain antibodies, so it is advisable to start the lamb on milk replacer rather than to use a "home brew" concoction that is less digestible to the lamb.

Synthetic colostrum substitutes are available, but more research is

James M. Thompson, Extension sheep specialist; Franz C. Rulofson, Extension livestock agent (Deschutes County); and Donald Hansen, Extension veterinarian, Oregon State University.
Feeding lambs

After lambs receive three feedings of colostrum over the first 12 to 18 hours of life, wait 4 to 5 hours before feeding them liquid milk replacer. Lambs may either be self fed or hand fed milk replacer. Self feeding requires less labor and allows the lamb to suckle as often as it desires and to set its own level of consumption. Self feeding also helps prevent digestive upsets.

To train lambs to suckle on self feeders, start them on cold formula and help the lambs feed every 6 hours until they learn to nurse from the nipple feeder. One or two nipple-trained lambs in the same pen will help lead untrained lambs to the nipples.

Feed the lambs colostrum that is the same temperature you plan to use throughout the feeding period. Lambs may reject the colostrum if you change temperature.

If you feed milk replacer by free choice, make sure it is cold to prevent over consumption at a single feeding. Lambs consume 1 to 2 quarts of milk replacer daily on self feeders. This equals ½ to 1 pound of dry milk replacer a day. Remember these amounts if you hand feed artificially reared lambs.

Offer hand-fed formula at body temperature four to six times daily for the first 3 days. Then feed at least twice daily and gradually increase the amount to coincide with the intake level of self-fed lambs.

Milk replacers

Use a milk replacer designed for lambs and follow the manufacturer’s directions. It should contain 30 to 32 percent fat, 22 to 24 percent protein, and 22 to 25 percent lactose (dry matter basis). Protein should come from milk protein, and fat should come from an animal source.

Do not use milk replacers made for calves and pigs on lambs as they do not contain enough protein and fat. Fresh cow’s milk also is not suitable for orphan lambs for the same reason. You can use fresh goat’s milk to raise orphan lambs successfully.
Feeding equipment
If you plan to feed lambs by free choice, you will need a feeder. Size depends on the number of lambs you are handling. A feeder for liquid milk replacer also should keep the milk clean. You also may need to cool the milk to prevent spoilage. Figures 1, 2, and 5 show examples of feeders. On self feeding systems, allow 3 to 5 lambs per nipple in groups of 15 lambs or less.

Three nipple types are available. The self-primed type has a valve and is attached to a plastic tube. Lambs can suckle these with minimum effort, and it may be best suited for weak lambs. This type of nipple tends to clog easily and is difficult to clean. Another type of nipple (Figure 4) is attached to a plastic tube, and the lamb has to be able to suck so it will pull the milk replacer through the tube and nipple. The third, newer type, is the bottom feeding nipple. The milk flows by gravity. Train lambs on the type of nipple you plan to use during the entire feeding period.

Keep feeding utensils as germ-free as possible. Infectious diarrhea easily spreads from dirty equipment and the environment.

Facilities
Place lambs to be raised on milk replacer in a draft-free, well-ventilated area. Use a heat lamp suspended away from walls (this prevents lambs from crowding on top of one another) to provide supplemental heat until the lambs are nursing well. Research indicates that lambs raised at 68°F gain weight faster than those raised at 46°F.

Lambs may be raised on gravel, dirt, or concrete floors bedded with straw or wood shavings.

Raising lambs on a slotted or expanded metal floor may be the easiest way to keep an area clean and dry. Provide about 2 square feet per lamb on expanded metal and 6 to 7 square feet per lamb on bedded solid floors.

Creep feeding
Offer creep feed to lambs once they start on the milk replacer. The feed should be palatable and contain at least 20 percent crude protein. Many shepherds use soybean meal or a creep feed that is at least 50 percent soybean meal to start artificially reared lambs on dry feed. Do not feed hay or oats to start lambs on dry feed as these feeds tend to cause bloat. Avoid leafy alfalfa hay for up to 2 weeks after weaning since it also can result in bloat problems. Provide fresh, clean water at all times.

Locate containers for feed and water outside the pen area with the lambs having access to these through a panel. This type of arrangement allows lambs to eat but not be able to contaminate feed and water with fecal matter. Keep feed fresh by offering just slightly more than they will consume in a 24-hour period.

Weaning
Wean lambs at about 4 weeks of age or when the lambs have consumed 20 to 25 pounds of dry milk powder. Feeding milk replacer longer than this is not cost effective. Before weaning, make sure lambs are eating some solid
food. Research at the U.S. Sheep Experiment Station at Dubois, ID, indicates that weaning lambs abruptly from milk at 4 to 5 weeks works better than offering a diluted milk replacer the last week.

Keep lambs healthy
All artificially reared lambs should be vaccinated for enterotoxemia (Clostridium perfringens, types C and D) shortly after starting them on milk replacer and again 3 weeks later. Lambs that do not receive colostrum should be vaccinated immediately with clostridium type C and D antitoxin.

If scours occur, check the environment for contamination, drafts, and proper temperature. Evaluate your sanitation procedures, and if scours persist, treat the lambs with antibiotics recommended by your veterinarian.

Figure 5.—An example of a milk replacer feeder attached to the outside of a pen. This feeder uses a Lam-Bar nipple and tube.
Livestock Guard Dogs, Llamas and Donkeys  

by W.F. Andelt

Livestock Guard Dogs

Guard dogs can be used effectively to protect sheep from predation by coyotes (Canis latrans), dogs, black bears (Ursus americanus), and mountain lions (Felis concolor). They can be used to protect small or large flocks in fenced pastures, on open range and in feedlots.

Characteristics

Most guard dogs are large and imposing, weigh 75 to over 100 pounds and stand 25 inches or more at the shoulder. Most have long white hair, although some are brown or gray.

Guard dogs do not herd or chase sheep. They work independently of a shepherd and can be left unattended with a flock. Their normal behavior is calm and placid; most spend much of their time dozing or walking with their flocks. However, all breeds are wary of intruders, and fierce and fearless when provoked.

Successful guard dogs are trustworthy (will not harm sheep), attentive to the sheep, and aggressive toward predators. These traits are instinctive and develop in most dogs with proper handling and minor training.

Purchasing a Guard Dog

Visit one or more reputable breeders that raise dogs for predator control instead of show. They can be found through farm magazine advertisements or by consulting the Colorado State University Cooperative Extension wildlife damage control specialist or USDA/APHIS/Wildlife Services. The Akbash and Great Pyrenees are the most popular breeds, although the Anatolian Shepherd, Komondor, Maremma and Shar Planinetz are also used in Colorado.

Buy a pup between 6 and 8 weeks old, or an older dog that was raised with sheep. Examine the pup, and parents if possible. Adults should have sound shoulders, legs and feet and be certified or guaranteed free of hip dysplasia. Be sure that neither parent exhibits excessive aggressiveness or shyness. These traits are likely to show up later in the pup. Look for sound muscle and bone structure in the pups, including well-shaped heads, jaws and teeth. The teeth should meet, or preferably overlap in a scissors bite. Check eyes and ears for discharges. The pup should be confident, outgoing and friendly. Avoid a pup that seems overly shy, or one that dominates its litter mates — it may later try to dominate you.

Rearing and Training

Treat your dog like a working partner in the operation from day one. Most troubles occur because the owners forget that the dogs are workers, not pets. Do not let the dogs play with children or herd dogs or hang around the house.
How Do Guard Dogs Work?

Rearing guard dogs with sheep creates an attachment or bond between the dog and the sheep. As the dog matures, it spends much of its time near the sheep and repels other animals that enter its personal space. This aggressiveness is limited by a decreased tendency to chase, a product of generations of selection for dogs that do not chase sheep. Even if the dog chases an intruding coyote away, it soon stops the chase and returns to the flock.

Signs of a Working Dog

When your dog matures and begins to work it will stay with the sheep willingly and its barking and scent-marking with urine will increase. These behaviors notify coyotes that a dog is present and help deter them from approaching the sheep. Coyotes usually remain in the area but are prevented from killing sheep.

Some Akbash and Great Pyrenees begin working at 6 months of age, whereas Komondors usually start later. Most dogs become more effective as they age. Once they learn their job is to guard the sheep, they usually work out the details without training. This may even mean coming back to the barn or farm yard during the day if the sheep are kept close to the house. The important thing is that they are with the sheep when the danger from predators is highest.

Put the dog with sheep and leave it there. The best companions for a small pup are a few head of bum lambs in a small pen, preferably in a barn or isolated away from the flock. Place the pups with lambs at 8 weeks old, when pups develop a strong bond with sheep.

If the pup is very young, put a chicken wire fence between it and the lambs. This gives it regular contact with the lambs but protects it from being trampled. Even when the pup is old enough to be with lambs, it is a good idea to provide a place where it can get away to rest, eat and be alone. A low fence or a creep with a few extra slats works fine. During this early exposure, check the pup regularly to ensure that it adjusts to being with lambs.

As the pup gets older, integrate it into the working operation. Introduce it to equipment, machinery, other livestock (horses, cattle, chickens), and herding dog(s) so later it will not guard the sheep from them. It is important to spend time with the pup so it is not afraid of you and will allow you to catch it later. However, always return it to the lambs after a short time and praise it when it goes into the pen and greets the lambs. Do not pet or reward the dog when it wanders away from the sheep.

Begin the dog in obedience training (“come,” “no”) during its early exposure to sheep. Supervise the dog when it is first introduced to newborn lambs and reprimand it if it chases sheep. Remember, the dog is a working partner and cannot perform this role if it does not understand its job.

As the dog gets older, give it more opportunities to make decisions and take responsibilities. Move it from a small pen to a larger pen to a pasture, and from a few head of lambs to the flock it eventually will guard. Observe the dog carefully, especially after each move or change in routine. Make sure it adjusts properly, and correct any undesirable behaviors early. It is especially important that the dog remains with the sheep. Return the dog to the flock any time it tries to leave. Always praise the dog when it stays with the flock.

Raise the pup with lambs that you intend to incorporate into the main flock. Once one group of sheep accepts the dog, other sheep unaccustomed to guard dogs tend to accept it more quickly. If your sheep are spooky of a new dog, it may be best to introduce them in a small corral.

Routine worming, vaccination and examination of your dog are essential for good health and performance. Regularly check ear canals, eyes, mouth and feet. Keep nails and hair on feet and under tail clipped, if needed. Look for cuts and scratches that can become infected or abscessed. You may need to shear or brush the dog’s coat during hot weather. Provide high-quality dog food in a self-feeder near the sheep at all times. Put a barrier around the feeder to exclude the sheep, or the dog may remain near the feeder, guarding it from the sheep.

How Many Guard Dogs Are Needed?

Most producers that have less than 200 sheep, or graze sheep in less than 200-acre fields, usually use one or two guard dogs. Producers that graze 1,000 ewes and their lambs on open range often use two to five (usually three) dogs. The number of dogs used usually depends on the extent of predation, dispersion of sheep, and amount of brushy cover on the range.

Effectiveness of Guard Dogs

Guard dogs significantly reduce coyote predation on domestic sheep in Colorado. Producers who did not have guard dogs lost 5.9 and 2.1 times greater proportions of lambs to predators than producers who had dogs in 1986 and 1993.

The number of Colorado sheep producers using guard dogs increased from about 25 in 1986 to over 159 in 1993. Twenty-three percent of producers used guard dogs in 1999. The percentage of sheep with dogs in fenced pastures and on open range increased from 7 percent in 1986 to 68 percent in 1993. A total
of 125 of these producers estimated that their 392 dogs reduced predation losses by $891,440 in 1993.

Of 160 producers using guard dogs between 1990 and 1993 and for at least one year in Colorado, 84 percent rated their dogs’ overall predator control performance as excellent or good, 13 percent as fair, and 3 percent as poor. The number of producers rating their dogs as excellent or good at reducing predation by specific predators was: 140 to 160 (88 percent) for coyotes, 46 of 64 (72 percent) for black bears, 32 of 43 (74 percent) for mountain lions and 85 of 109 (78 percent) for domestic dogs. A total of 154 of 161 producers (96 percent) would recommend use of guard dogs to other producers. Fourteen of 21 producers in Colorado and 15 of 17 producers in Kansas indicated that guard dogs reduced their reliance on other predator control techniques.

Dr. Jeff Green and Roger Woodruff reported that the success rate in protecting livestock did not vary between Great Pyrenees, Komondors, Akbash, Anatolian Shepherds, Maremmana and hybrids, nor did the rate of success differ between males and females or intact and neutered dogs. However, neutering may decrease wandering. In Colorado, ratings of the effectiveness of guard dogs by producers using one breed of dog did not differ among breeds, but producers that used multiple breeds rated Akbash more effective than Great Pyrenees and Komondors. Dogs reared with livestock from less than 2 months old had a significantly higher rate of success than dogs that were older than 2 months when placed with livestock.

Advantages and Disadvantages

The major advantages of using guard dogs include predation decreased or eliminated, reduced labor to confine sheep at night, more efficient use of pastures for grazing, reduced reliance on other predator control techniques, and greater peace of mind.

Major disadvantages of guard dogs include dogs that harass, injure or kill sheep; dogs that do not stay with sheep; dogs that are aggressive toward people; and dogs that are injured or die prematurely.

Few owners experience all the problems or all the benefits. Many of the disadvantages are relatively uncommon. Most producers surveyed feel strongly that the advantages of their dog(s) far outweigh the disadvantages.

Guard dogs are not compatible with toxicants to control predators. Some producers train dogs to avoid M-44s by allowing them to set off M-44s loaded with pepper. However, any mistakes by the dog are likely fatal. Dogs that have been tied probably will not die if captured in a snare. Most dogs probably will not be injured in traps if removed in reasonable time. The principal causes of premature death are accidents (dogs hit on the road) and shooting. Contact neighbors and tell them about the dog. Post a notice about the dog near public roads.

Komondors appear more aggressive toward people than Akbash, Great Pyrenees and Anatolians. In areas where encounters between guard dogs and humans are likely, such as on public lands, consider less aggressive breeds.

Guard dogs are not a cure-all for the predator problem. Their effectiveness is influenced by a variety of factors and their use requires a strong commitment by the owners. The use and effectiveness of guard dogs has increased with additional research and experience, but some livestock producers continue to require other animal damage-control measures in addition to their dogs.

Llamas

During 1990, Iowa State University researchers surveyed 145 producers, primarily in Montana, Wyoming, Colorado, California and Oregon, to determine the effectiveness of llamas for reducing coyote and dog predation on sheep.
Relative Effectiveness of Guard Dogs, Llamas and Donkeys

Guard dogs effectively deter coyote and dog predation in fenced pastures and on open range, whereas llamas and donkeys appear best suited to fenced pastures of less than 300 acres.

Producers using guard dogs reported a lower percent sheep loss than producers using llamas.

Several producers indicate guard dogs can effectively deter bear and mountain lion predation, whereas llamas and donkeys apparently are afraid of mountain lions, and their effectiveness in deterring bear predation is unknown.

Donkeys were rated less successful than guard dogs and llamas. However, these comparisons are inconclusive because all three species were not rated in the same surveys or under the same conditions.

Compared to guard dogs, llamas and donkeys appear less prone to accidental death, are long-lived, do not require special feeds, stay in the same pasture as sheep, do not need to be raised with sheep, and are less susceptible to traps, snares, M-44s, and toxic collars.

Producers reported that they lost an average of 21 percent of their ewes and lambs annually before acquiring a llama, and 7 percent afterwards. An average annual savings of $1,253 was reported by 87 of the producers. Eighty percent of the producers rated their guard llamas as effective or very effective. In a Utah study, producers with llamas lost significantly fewer sheep to predators than producers without llamas during the first year of use, but sheep mortalities did not differ between producers with and without llamas during the second year. In Utah, 90 percent of producers rated their guard llamas as effective or very effective. Nine percent of producers in Colorado used llamas to guard sheep during 1999.

Llamas are naturally aggressive toward coyotes and dogs. Typical responses of llamas to coyotes and dogs are being alert; alarm calling; walking to or running toward the predator; chasing, kicking, or pawing the predator; herding the sheep; or positioning themselves between the sheep and predator.

The average producer used one gelded male llama for 250 to 300 sheep in 250 to 300 acre pastures. One llama was more effective than multiple llamas. The effectiveness of gelded males, intact males and females was similar. However, more intact males (25 percent of 61) than gelded males (5 percent of 135) attempted to breed ewes. Some llamas were aggressive toward the sheep.

Nearly all llamas in the Iowa survey were not raised with sheep and were not trained to guard sheep. The adjustment period for the llamas and sheep lasted only a few hours for half the llamas, and nearly 80 percent adjusted within a week. Llamas introduced to sheep in corrals were apparently more effective guardians initially than those introduced in pastures, but in time losses were similar. Otherwise, the llamas’ success was not related to age of llama when introduced, age of llama (after 1 or 2 years old) when guarding, if lambs were present or absent when the llama was introduced, or between open and covered (forests, shrub lands, gullies, ravines, etc.) habitat.

Gelded males cost $700 to $800 and intact males about $100 less.

Most producers reported that daily care for llamas was the same as for sheep and no special feeds were provided. Average annual expense was $90 for feed (not including pasture) and $15 for veterinary costs. A 250-pound gelded llama consumes 7 to 10 pounds of good grass hay per day. Depending on the area, llamas need to be dewormed two to four times per year. If food is provided for llamas, place it in a feeder high enough to be out of reach of sheep.

For information on llamas or names of breeders, contact the International Llama Association, P.O. Box 370505, Denver, Colorado 80237, (303) 756-9004; or Rocky Mountain Llama and Alpaca Association, 593 19-3/4 Road, Grand Junction, Colorado 81503, (970) 241-7921.

Donkeys

Donkeys have recently been used with sheep and goats in an attempt to deter predation by coyotes and dogs. During 1999, 3 percent of producers in Colorado used donkeys to protect sheep. About 1,000 to 1,800 of 11,000 Texas sheep and goat producers used guard donkeys in 1989. Donkeys apparently have an inherent dislike for dogs and other canids. They will bay, bare their teeth, run and chase, and attempt to bite and kick an intruder. In Texas, 59 percent of producers rated donkeys as good or fair for deterring predation (primarily by coyotes) in one survey. In another survey, 20 percent rated their donkeys as excellent or good.

Researchers recommend using only one jenny (female) or gelded jack (male) per pasture; intact jacks are too aggressive, and two or more donkeys might stay together instead of being with the sheep. They also recommend about a four to six week period for the donkey to bond with the sheep. Remove donkeys during lambing because they might trample lambs or disrupt the ewe-lamb bond. Challenge a new donkey with a dog to test its response to canids. Do not use
donkeys that are not aggressive. Donkeys are apparently most effective in small, open pastures or where sheep are cohesive and graze together. Feeds containing anabolic agents, such as monensin (Rumensin) and lasalacida (Bovatec), apparently are poisonous to donkeys.

Donkeys can be obtained from the Bureau of Land Management or U.S. Forest Service under the Wild Free-Roaming Horse and Burro Act for $75. They also can be obtained at stockyard auctions and from breeders for $20 to $250. Annual upkeep averaged $66 per donkey in one study.

1Colorado State University Cooperative Extension wildlife specialist (retired) and associate professor, fishery and wildlife biology.
**Introduction**

Transmissible diseases are preventable when producers implement biosecurity practices. To help prevent spread of disease, a two-week quarantine of newly purchased sheep, those returning from a show or from being bred elsewhere should be enforced. Quarantine includes keeping these sheep separate from the home flock. The stress of movement can trigger underlying diseases in sheep. Testing for Ovine Progressive Pneumonia virus (OPPy) and Johne’s disease will prevent introduction to the flock.

Lamb mortality is largely responsible for limiting profitability. For decades, lambs have died due to disease that can be prevented. Lamb deaths can be categorized in three ways:

- Lambs die prior to and at birth
- Lambs die at pre-weaning
- Lambs die post-weaning, but before marketing or retention

Common sheep diseases that affect the size of a producer’s lamb crop fall into categories of nutritional, infectious, management-induced and metabolic causes. Many of these diseases are preventable with best health management practices, including sound nutrition, timely vaccinations, parasite control and improved biosecurity practices. New or small flock producers should become familiar with the signs and symptoms of specific diseases.

Sheep production can be more profitable through consultation with professionals, such as a knowledgeable veterinarian. However, sheep health work often comprises only a minority of most veterinarians’ practices, so there may be instances in geographic areas where interest or expertise are lacking. Additional information can be accessed on the Maryland small ruminant website, [sheepandgoat.com](http://sheepandgoat.com), and the *SID Sheep Production Handbook*, vol. 8.

**Chronic diseases**

Major diseases that negatively affect lamb crop can be chronic in nature and result in ewes or rams with poor body condition scores (BCS), thus producing fewer embryos, fetuses and, ultimately, the birth of fewer live or less vigorous lambs. Examples of chronic diseases that can influence flock productivity include foot scald, foot rot and foot abscess. Diagnosis requires examination by an experienced individual. Treatment and prevention hinge on the correct diagnosis. For example, scald may be treated with a walk-through foot bath or individual application of 10% zinc sulfate and then moving the group to drier footing. Area around animals’ water sources and feeders should be kept dry.

Foot rot treatment requires a more intensive approach involving examination of all feet of every sheep in the affected group, individual antibiotic treatment and housing on dry ground during treatment. Unresponsive sheep must be culled.

While buying sheep from foot rot-free flocks is an option, guidance is appreciated by flock owners with foot rot present in their flock. Eradication of foot rot is possible during the non-spread periods, or dry times of the year. Producers should examine every foot with minimal trimming to assess infection status. Infected sheep can be culled or treated with long-acting tetracycline or gamithromycin and kept on dry ground. The group of uninfected sheep must be re-checked to ensure they remain uninfected. Another approach is to treat all of the sheep in the flock with the antibiotic and keep sheep off contaminated areas for a minimum of two weeks. Foot abscess is an individual animal problem that may or may not respond to antibiotic treatment and foot soaking in an antiseptic solution, depending on the chronicity and extent of the abscess. Amputation of the affected claw may be necessary.

OPPy has been shown to result in a lower lamb crop through multiple factors. OPPy infected ewes can be in a lower BCS, which itself contributes to lower reproductive rates. This virus targets both halves of the udder resulting in an accumulation of cells and scar tissue, which reduces milk production. Affected ewes that lamb with twins or triplets may be unable to successfully raise them (Keen J. 1997). Thorough explanations of testing for, controlling and eradicated OPPy are available at [oppsociety.org](http://oppsociety.org).

Bacterial mastitis is another production-limiting condition of the sheep udder. But unlike OPPy, bacterial mastitis only affects one side of the udder. The timing of infection varies in the ewe. This condition is rarely a flock problem but has a significant impact.
Chronic diseases (cont.)

on milk production. Chronic low-grade mastitis infections often go unnoticed by producers until an affected ewe’s lamb is found dying. There is also an acute form of mastitis where an affected ewe becomes very sick from absorption of systemic toxins from the infected mammary gland causing a high fever and generalized toxemia. The usual cause of this type of mastitis is either one of two possible bacteria, *Manheimia hemolytica* or *Staphylococcus aureus*. The affected gland is destroyed by this infection. Environment plays a role in the occurrence of bacterial mastitis. Mastitis risk increases from damp, dirty bedding in confinement housing or bedding in the same location especially under trees where limited shade concentrates animals or after wet weather. Immune function also contributes to the occurrence of mastitis. Immune function is affected by micronutrients (copper, selenium, zinc, manganese) intake. Producers should routinely feel ewes’ udders at lambing and weaning, for asymmetrical halves and hard lumps, record findings, and cult ewes with damaged udders. Attention should be paid to the dryness and cleanliness of the environment of lactating ewes by bedding pens or moving grazing ewes to minimize areas that are muddy or have a concentration of sheep feces.

During pregnancy, contagious infectious agents can cross the placental barrier and infect the gestating fetus, resulting in late-term abortion. If infected earlier in pregnancy, the fetus can be resorbed and the infected ewe appears open during ultrasound scanning or at lambing. The three most common agents that cause abortion in sheep are *Campylobacter* spp., bacteria; *Toxoplasma gondii*, a protozoan parasite; and *Chlamydia abortus*, a rickettsia bacterium. These agents are transmitted through sheep’s oral consumption. Toxoplasmosis is spread by young, immunologically naive cats eating infected rodents and those cats defecating on feed, including stored grain, hay or pasture. The other two agents are spread by infected sheep via feces or aborted material. In the face of an outbreak from *Chlamydia* abortions, long-acting injections of oxytetracycline may be helpful. In the face of an outbreak from *Campylobacter*, an antibiotic sensitivity should be performed as these bacteria have become less predictable regarding which antibiotic may be effective.

Reduce risk of abortion

- Keep ewes in good BCS throughout pregnancy
- Provide access to mineral specifically formulated for sheep, every day
- Avoid overcrowding
- Use feeders to limit feeding off the ground
- Keep stored feed safe from fecal contamination by young cats
- Remove known and suspect aborting ewes from the rest of the pregnant flock

These disease agents frequently enter a previously uninfected flock via purchased ewes. When possible, ewes of different sources should be kept separate during their first pregnancy and mixed after lambing. Vaccines are available in the United States for some *Campylobacter* spp. and *Chlamydia abortus*. Annual vaccination against *Campylobacter* or chlamydial abortion pre-breeding and at mid-gestation is advised in at-risk flocks where the disease has been diagnosed or is suspected, or in recently purchased ewes.

Preventative feed additives, such as Deccox® have been proven to be effective against toxoplasmosis. Veterinary assistance is critical in guiding a flock’s specific approach when faced with an abortion outbreak. Aborted fetuses and placentas must be submitted to a veterinary diagnostic laboratory to diagnose the cause of abortion.

Late gestation disease

Metabolic diseases of late gestation include pregnancy toxemia, which is also referred to as ketosis, and hypocalcemia. Pregnancy toxemia can affect multiple ewes in a flock that are usually pregnant with two or more lambs. These ewes are not eating enough energy for their needs. Regrouping the affected and at-risk ewes will reduce further cases. This can be done by sorting the late pregnant ewes with BCS of ≤ 2 into a “special needs” group. Ewes with very large bellies should also be sorted into this group as they are most likely carrying triplets. This group needs to be fed more energy, which can be accomplished a variety of ways depending on feedstuffs available.

Hypocalcemia can be seen in late pregnant ewes after a feed change or after stressful episodes. The calcium demands 3 to 4 weeks prior to lambing are high, and will continue to increase due to calcification of fetal bones. Since it takes 24 hours for calcium to be mobilized from bones of the ewe to the fetus, ewes are susceptible to developing low-serum calcium. While this condition is straightforward to treat, producers should consult a nutritionist to determine feed changes. Rapid response to calcium treatment is a means of identifying low calcium from ketosis. Most hypocalcemia cases occur in late gestation in sheep.
While there are many diseases that overlap between pre- and post-weaning, the primary cause of mortality in grazing lambs is parasitism, including stomach or intestinal worms and coccidiosis. While both infections can be managed, producers should consult their veterinarian if unfamiliar with symptoms and treatment.

**Pre-weaning disease**

The most common pre-weaning lamb health issues are hypothermia, starvation, naval infections, pneumonia and diarrhea. The prevalence of these diseases is affected by the health status and BCS of the ewes and adequacy and management of the lambing facilities. Producers should record lamb losses to guide future management changes. Inexperienced producers should work out a base cost for lamb necropsies to be performed by their veterinarian. Recommendation of prevention options for the top three conditions diagnosed should be included with this service.

Hypothermia can be a primary cause of death when the ambient conditions are too cold and/or wet for newborn lambs. It can also be a secondary cause of death when a lamb has been milk-deprived over a few days during cooler weather. Starvation occurs due to lack of milk because of mastitis, poor genetics, udder/teat conformation or inadequate ewe nutrition. Naval infections result from exposure to a wet environment prior to umbilical cords drying and falling off. Insufficient colostral intake may be a risk factor in these infections. Pneumonia in neonatal lambs is often the result of inadequate ventilation and deficient tissue mineral levels necessary for immune function. Diarrhea in baby lambs can result from different infectious agents where contamination levels become higher because of overcrowding, poor sanitation, and poor colostral intake and absorption. Causes include bacteria such as *E. coli*, *Salmonella* spp., or *Clostridium perfringens* type C, or viruses including strains of rotaviruses which may be acting in combination with *Cryptosporidium parvum*.

**Post-weaning disease**

Common post-weaning diseases include acidosis and enterotoxemia. Lambs on lush pasture or free choice concentrate, that have not received a complete series of vaccinations against *Clostridium perfringens* type D are susceptible to rapid overgrowth of this bacteria. The condition shows up as a very sick lamb that dies within a few hours of becoming ill. Often a few lambs are initially affected. The group should be re-vaccinated immediately. Half to one pound of dry hay should also be fed in addition to the lambs’ regular feed. The outbreak generally stops after vaccination.

Acidosis is caused by excess intake of concentrates when:

- Lambs eat too much at self-feeders
- Varied feed consumption changes due to groups of lambs being turned in together
- Feed intake fluctuates because of dramatic changes in weather or the ration is aggressively changed to include higher percentages of concentrates

While there are many diseases that overlap between pre- and post-weaning, the primary cause of mortality in grazing lambs is parasitism, including stomach or intestinal worms and coccidiosis. While both infections can be managed, producers should consult their veterinarian if unfamiliar with symptoms and treatment.

Flock owners should employ best health practices that are specific for their region and management style. Information to guide which local practices to adopt are readily available from fellow sheep producers, local veterinarians, extension staff, and peer-reviewed websites including sheepusa.org, wormx.info and sheepandgoat.com.
Author & reviewers

Author: Cynthia Wolf, D.V.M., University of Minnesota, St. Paul, Minnesota

Reviewers: Reid Redden, Ph.D., Texas A&M AgriLife Extension, San Angelo, Texas; Dan Morrical, Ph.D., Iowa State University, Ames, Iowa; Susan Schoenian, M.S., University of Maryland Extension, Kearneysville, Maryland; and Rodney Kott, Ph.D., Former Montana State University Extension Sheep Specialist, Fredericksburg, Texas

Literature cited


Sheep Medicine, 2nd ed. P. Scott, CRC Press, 2015.


American Consortium of Small Ruminant Parasite Control website: wormx.info

More information

U.S. Lamb Resource Center
http://lambresourcecenter.com/production-resources/productivity/

National Sheep Improvement Program
http://www.nsip.org

U.S. Sheep Industry Roadmap
http://lambresourcecenter.com/reports-studies/roadmap/
# Zoonotic Diseases of Sheep and Goats

<table>
<thead>
<tr>
<th>Zoonotic Disease</th>
<th>Etiologic Agent</th>
<th>R</th>
<th>Transmission</th>
<th>Clinical Signs in Sheep and Goats</th>
<th>Clinical Signs in People</th>
<th>Prevention for Sheep and Goats</th>
<th>Prevention for People</th>
</tr>
</thead>
</table>
| Anthrax          | Bacillus anthracis | AH | Ingestion: (animals); spores when grazing; contaminated feed, bone meal; (people) undercooked meat | Incubation period: 1-10 days  
Sudden death, lack of rigor mortis; highly infectious blood from mouth, nose, anus fails to clot; respiratory difficulty, edema in neck, throat, shoulders (cattle, sheep, goats, equines); swine usually asymptomatic | Incubation period: 1-10 days, can be variable  
Cutaneous: pustules; dark black scab (eschar)  
Gastrointestinal: severe vomiting; bloody stools  
Respiratory: flu-like signs; respiratory distress  
All forms: sepsis, shock, death | Clean and disinfect; dispose of carcasses – burn if possible; don’t contaminate soil with infectious blood; vaccinate | Wash hands; wear personal protective equipment (PPE) (gloves, mask, eye protection, coveralls); cover wounds; ventilate animal areas; disinfect hides; avoid suspect animals and don’t eat their meat |
| Brucellosis      | Brucella melitensis | AH | Direct contact: reproductive tissues/fluids  
Ingestion: reproductive tissues/ fluids; contaminated feed, water  
Fomites | Incubation period: varies  
Reproductive: abortion, stillbirths; retained placentas; placentitis; orchitis; epididymitis  
Musculoskeletal: arthritis; lameness; spondylitis | Incubation period: 2-4 weeks, up to 6 months  
Flu-like: headache; fever; fatigue; chills; aches  
Chronic: waxing, waning fever; bone, joint infections  
Reproductive: epididymo-orchitis; seminal vesiculitis and prostatitis; abortion or premature birth | Clean and disinfect; vaccination; prevent exposure to wild or feral swine; obtain animals from Brucella-free sources; screening; isolate infected animals; establish separate area for birthing; remove, destroy aborted fetuses, placentas | Wash hands; wear PPE (gloves, mask, eye protection, coveralls); cover wounds; do not touch your face; be cautious when vaccinating; wear gloves when handling animal tissues |
| Campylobacteriosis | Campylobacter jejuni, C. coli, C. fetus | H | Ingestion: feces; reproductive tissues; contaminated soil, water  
Direct contact: infected animals  
Fomites | Incubation period: 3-25 days  
Asymptomatic in most species  
Gastrointestinal: mucoid, blood-flecked diarrhea  
Reproductive: abortion | Incubation period: 1-10 days  
Gastrointestinal: mild to severe GI distress; fulminating or relapsing colitis; fever; headache; muscle pain; children and immunosuppressed at most risk for diarrhea  
Reproductive: (C. fetus) miscarriage; premature birth; infant meningitis followed by death | Clean and disinfect (including AI equipment); remove manure; prevent overcrowding; vaccinate (animals may still be carriers); isolate aborting animals; remove, destroy aborted fetuses, placentas; control rodents | Wash hands; wear gloves; keep children/vulnerable people away from animals, feces; don’t consume undercooked meat, raw dairy, untreated water; wash fruits, vegetables; disinfect kitchen surfaces; don’t cross-contaminate |
| Caseous lymphadenitis | Corynebacterium spp. | | Direct contact: abscesses  
Inhalation: aerosols  
Fomites | Incubation period: 1-3 months  
Abscesses: peripheral lymph nodes and lungs | Incubation period: 1-2 weeks suspected  
Abscesses: suppurrative granulomatous lymphadenitis; rectal and chest abscesses | Clean and disinfect; fly control; remove manure; quarantine new animals; isolate infected animals; treat promptly; disinfect equipment after use; prevent skin injuries | Wash hands; wear gloves and mask; cover wounds; don’t touch fluid draining from lesions; don’t consume raw dairy |

R=Reportable Disease; A=for animals, H=for humans
<table>
<thead>
<tr>
<th>Zoonotic Disease</th>
<th>Etiologic Agent</th>
<th>Transmission</th>
<th>Clinical Signs in Sheep and Goats</th>
<th>Clinical Signs in People</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlamydioidosis</td>
<td><em>Chlamydia abortus</em></td>
<td>Inhalation: aerosols</td>
<td>Incubation period: varies</td>
<td>Incubation period: 2-4 weeks, up to 6 months</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Direct contact:</td>
<td>Reproductive: (sheep, goats) late term abortion, stillbirth, low birth weight or premature offspring; (cattle) abortion, retained placentas, mastitis</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>tissues/fluids</td>
<td></td>
<td>Reproductive: stillbirth; abortion; pre-term labor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ingestion:</td>
<td></td>
<td>Flu-like: fever; headache; dry cough; vomiting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>contaminated feed, water</td>
<td></td>
<td>Systemic: septicemia; renal dysfunction; pneumonia</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Clean and disinfect; remove manure; maintain closed herd; isolate aborting animals; establish separate area for birthing; remove, destroy aborted fetuses, placentas</td>
<td>Wash hands; wear PPE (gloves, mask, coveralls); don't touch your face; clean, disinfect boots</td>
</tr>
<tr>
<td>Colibacillosis</td>
<td><em>Escherichia coli</em></td>
<td>Ingestion:</td>
<td>Incubation period: varies</td>
<td>Incubation period: 1-16 days with most signs in 3-4 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td>contaminated soil, food, water</td>
<td></td>
<td>Gastrointestinal: watery diarrhea; hemorrhagic colitis; nausea; vomiting; abdominal pain; cramping</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Direct contact: feces</td>
<td></td>
<td>Systemic: hemolytic uremic syndrome (HUS); fever</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fomites</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contagious etchyma</td>
<td><em>Parapoxivirus</em> (Sore mouth)</td>
<td>Direct contact:</td>
<td>Incubation period: 2-3 days</td>
<td>Incubation period: 3-7 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td>scabs; lesions</td>
<td>Asymptomatic in adults</td>
<td>Cutaneous: small, firm red-blue papule (usually on hands/fingers), progresses to hemorrhagic bulla or pustule, +/- central crust; becomes weeping nodule covered by thin crust, usually self-limiting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fomites</td>
<td>Cutaneous: (young sheep/lambs) pustules, vesicles, scabs on mouth, muzzle, eyelids, nostrils, teats, udder</td>
<td>Wash hands; wear gloves; cover wounds</td>
</tr>
<tr>
<td>Cryptosporidiosis</td>
<td><em>Cryptosporidium spp</em></td>
<td>Ingestion:</td>
<td>Incubation period: 3-5 days</td>
<td>Incubation period: 2-3 days to 2 weeks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>oocyst-contaminated food, water, soil</td>
<td>Asymptomatic</td>
<td>Gastrointestinal: mild to severe profuse, watery diarrhea; abdominal cramps; anorexia; nausea; gas; malaise</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fomites</td>
<td>Gastrointestinal: (neonatal calves, lambs, kids, piglets) watery diarrhea; tenesmus; anorexia; weight loss</td>
<td>Wash hands; wear PPE (gloves, coveralls); don't drink untreated water; wash fruits, vegetables; don't cross-contaminate; avoid young, sick animals if vulnerable</td>
</tr>
</tbody>
</table>

Additional disease information available at [http://www.cfsph.lsu.edu/DiseaseInfo/](http://www.cfsph.lsu.edu/DiseaseInfo/). Table last reviewed January 2021
<table>
<thead>
<tr>
<th>Zoonotic Disease</th>
<th>Etiologic Agent</th>
<th>Transmission</th>
<th>Clinical Signs in Sheep and Goats</th>
<th>Clinical Signs in People</th>
<th>Prevention for Sheep and Goats</th>
<th>Prevention for People</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cysticercosis/Taeniasis</td>
<td>Taenia spp.</td>
<td>Ingestion: gravid proglottids in pastures; contaminated food, water or soil</td>
<td>Incubation period: months to years</td>
<td>Incubation period: variable; 8 weeks to years</td>
<td>Asymptomatic</td>
<td>Gastrointestinal: proglottids in stools; nausea; gas; diarrhea; constipation; abdominal pain; poor appetite</td>
</tr>
<tr>
<td>Dermatophilosis</td>
<td>Dermatophilus congolensis (Lumpy wool - sheep, Streptothricosis - goats)</td>
<td>Direct contact: skin lesions, Fomites: soil, thorns, Mechanical vectors: biting insects</td>
<td>Incubation period: 1-30 days</td>
<td>Incubation period: 1-10 days</td>
<td>Cutaneous: (cattle, sheep, goats, horses) serous exudates at base of hair shaft (&quot;paintbrush lesions&quot;), crusts, alopecia; found in young animals/wet environments</td>
<td>Cutaneous: multiple pustules on hands, forearms; rupture, leaving reddish crater-like cavity</td>
</tr>
<tr>
<td>Echinococcosis</td>
<td>Echinococcus granulosus sensu lato complex (cystic echinococcosis), E. multilocularis (alveolar echinococcosis)</td>
<td>Ingestion: gravid proglottids on fur; from plants, contaminated water, soil</td>
<td>Incubation period: not known</td>
<td>Incubation period: variable, months to years</td>
<td>Respiratory: bronchopneumonia; respiratory difficulty</td>
<td>Various organs: cysts in liver and lungs (most common), may grow faster in immunocompromised individuals</td>
</tr>
<tr>
<td>Hydatid disease</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Systemic: abdominal distension; ascites; icterus; heart failure; lameness; sudden death</td>
<td></td>
</tr>
<tr>
<td>Erysipelosis</td>
<td>Erysipelothrix Rhusiopathiae</td>
<td>Direct contact: animals, fluids</td>
<td>Incubation period: 1-7 days</td>
<td>Incubation period: 1-7 days</td>
<td>Musculoskeletal: (lams) polyarthritis</td>
<td>Cutaneous: acute localized cellulitis; painful red/purple firm swelling, usually on hands and fingers; generalized disease possible</td>
</tr>
<tr>
<td>Erysipeloid in people</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Giardiasis</td>
<td>Giardia duodenalis or G. intestinalis</td>
<td>Ingestion: cysts in contaminated food, water, soil</td>
<td>Incubation period: 3-10 days</td>
<td>Incubation period: 1-45 days; signs usually within 1-2 weeks</td>
<td>Asymptomatic, young more affected</td>
<td>Gastrointestinal: mild-severe, acute-chronic diarrhea</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Direct contact: infected animals; grooming (self or others)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Additional disease information available at [http://www.cfsph.iastate.edu/DiseaseInfo/](http://www.cfsph.iastate.edu/DiseaseInfo/). Table last reviewed January 2021
<table>
<thead>
<tr>
<th>Zoonotic Disease</th>
<th>Etiologic Agent</th>
<th>Transmission</th>
<th>Clinical Signs in Sheep and Goats</th>
<th>Prevention for Sheep and Goats</th>
<th>Clinical Signs in People</th>
<th>Prevention for People</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leptospirosis</td>
<td>Leptospira spp.</td>
<td>Direct contact: infected urine; contaminated water; aborted tissues</td>
<td>Incubation period: 7-12 days</td>
<td>Reproductive: abortion; decreased fertility; stillbirth; weak offspring</td>
<td>Incubation period: 7-12 days</td>
<td>Acute/septicemic phase: fever, chills, conjunctival suffusion, headache; myalgia; nausea; vomiting</td>
</tr>
<tr>
<td>Weil's disease in humans</td>
<td>- Sheep can serve as maintenance hosts of Hardjo serovar</td>
<td></td>
<td></td>
<td>Systemic: (lamb, kids) fever; ceterus; anemia; death</td>
<td></td>
<td>Immune phase: anicteric (common) or icteric forms; aseptic meningitis; stiff neck; headache; kidney failure; pulmonary hemorrhage; edema; dyspnea; death</td>
</tr>
<tr>
<td>Listeriosis</td>
<td>Listeria monocytogenes</td>
<td>Ingestion: improperly fermented silage; spoiled/decaying feed, plant matter; soil</td>
<td>Incubation period: 1 day to 7 weeks</td>
<td>Reproductive: (sheep) abortion; stillbirth</td>
<td>Incubation period: 2 weeks for nonpregnant individuals; 2 weeks to 2 months for pregnant women</td>
<td>Reproductive: abortion; stillbirth; premature birth</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Direct contact: reproductive tissues/fluids</td>
<td>Neurologic: ataxia; circling; nystagmus; torticollis; cranial nerve deficits</td>
<td>Ocular: &quot;silage eye,&quot; keratoconjunctivitis</td>
<td>Neurologic: meningitis; meningoencephalitis</td>
<td>Systemic: septicemia; fever, chills; headache; dizziness</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mange/Acariasis</td>
<td>Sarcopes scabiei var ovis (sheep)</td>
<td>Direct contact: infected animals</td>
<td>Incubation period: 10-60 days</td>
<td>Cutaneous: pruritus; dermatitis; alopecia; crustated skin (sheep) non-woolly areas of head; (goats) head, neck,</td>
<td>Incubation period: &lt;24 hours to 4 days</td>
<td>Cutaneous: severe pruritus on arms, chest, abdomen, thighs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fomites: contaminated bedding</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sarcopes scabiei var caprae (goats)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Scabies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q Fever</td>
<td>Coxiella burnetii</td>
<td>Inhalation: aerosols</td>
<td>Incubation period: 1-3 weeks; varies</td>
<td>Reproductive: abortion; stillbirth; weak offspring; (goats)</td>
<td>Incubation period: 2 days to 6 weeks, average of 2-3 weeks</td>
<td>Flu-like: fever; chills; malaise; joint pain; sweating</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Direct contact: reproductive tissues</td>
<td></td>
<td>puerulent cotyledons</td>
<td></td>
<td>Respiratory: mild productive cough</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ingestion: contaminated feed, water</td>
<td></td>
<td></td>
<td></td>
<td>Gastrointestinal: (children) nausea; vomiting; diarrhea</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fomites: ticks</td>
<td></td>
<td></td>
<td></td>
<td>Cutaneous: (children) rash</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vectors: ticks</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Additional disease information available at [http://www.cfsph.iastate.edu/DiseaseInfo/](http://www.cfsph.iastate.edu/DiseaseInfo/). Table last reviewed January 2021
<table>
<thead>
<tr>
<th>Zoonotic Disease</th>
<th>Etiologic Agent</th>
<th>Transmission</th>
<th>Clinical Signs in Sheep and Goats</th>
<th>Prevention for Sheep and Goats</th>
<th>Clinical Signs in People</th>
<th>Prevention for People</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rabies</td>
<td>Lyssavirus</td>
<td>Direct contact: infected animal saliva (bite, droplet on mucous membrane, aerosol, broken skin)</td>
<td>Incubation period: 10 days to 6 months</td>
<td>Clean and disinfect; vaccinate (including dogs and cats); quarantine exposed animals (can re-vaccinate exposed animals and confine under strict observation for 45 days); isolate, euthanize, test symptomatic animals; prevent access to wildlife</td>
<td>Incubation period: a few days to several years, most commonly 1-3 mos.</td>
<td>Wash hands; wear PPE around exposed animals (gloves, eye protection, coveralls); avoid saliva; get rabies vaccine if high-risk; cover wounds; stay away from places where bats live (wear PPE if you can’t)</td>
</tr>
<tr>
<td>Ringworm/Club Lamb Fungus Dermatophytosis</td>
<td>Microsporum spp., Trichophyton spp.</td>
<td>Direct contact: infected animals; skin lesions Fomites</td>
<td>Incubation period: 2-4 weeks</td>
<td>Clean and disinfect, specially shared equipment; quarantine and test new animals; isolate and treat affected animals; prevent exposure to rodents; do not overcrowd</td>
<td>Incubation period: 1-2 weeks</td>
<td>Wash hands; wear PPE (gloves, coveralls); clean, disinfect equipment; treat infected animals; treat infected people</td>
</tr>
<tr>
<td>Salmonellosis</td>
<td>Salmonella spp.</td>
<td>Ingestion: contaminated feed, water Direct contact: infected animal, feces Fomites Reproductive: vertical (poultry) Mechanical vectors: flies</td>
<td>Incubation period: varies; less than 1-2 days if severe Gastrointestinal: severe enteritis +/- blood; young most affected Reproductive: abortion; decreased milk (cattle) Systemic: (lambs, kids) septicemia; CNS signs; pneumonia</td>
<td>Clean and disinfect, especially equipment, buildings; remove manure; practice good biosecurity; control vectors; reduce stress; prevent overcrowding; provide colostrum; purchase from Salmonella-free sources; quarantine new animals; isolate and treat, or cull, carriers</td>
<td>Incubation period: 6-72 hours Gastrointestinal: acute diarrhea (+/- blood); abdominal pain; nausea; vomiting; dehydration Flu-like: fever; muscle pain; headache; malaise; chills Systemic: immunocompromised most at risk; bacteremia</td>
<td>Wash hands; wear gloves; wash and/or peel fruits, vegetables; don’t consume raw dairy; cook meat, poultry, eggs to proper internal temperature; reheat foods thoroughly; refrigerate leftovers; don’t cross-contaminate; don’t drink untreated water</td>
</tr>
<tr>
<td>Staphylococcosis including methicillin-resistant Staphylococcus aureus (MRSA)</td>
<td></td>
<td>Direct contact: skin wounds; feces Fomites Inhalation: aerosols (dust)</td>
<td>Incubation period: variable</td>
<td>Clean and disinfect; remove manure; don’t overcrowd; isolate infected animals; good hand hygiene when milking; separate grooming equipment/tack for each horse; wear face mask, gloves when handling animals</td>
<td>Incubation period: variable; 4-10 days Cutaneous: skin, soft tissue infection; necrotizing fasciitis; staphylococcal scalded skin syndrome Gastrointestinal: acute gastroenteritis; nausea; vomiting; diarrhea; abdominal pain; +/- fever; headache; blood or mucus in vomit or stool</td>
<td>Wash hands; wear PPE (gloves, mask); cover wounds; avoid touching animal wounds, secretions; do not share personal items (e.g., towels); refrigerate leftovers; don’t cross-contaminate foods; refrigerate raw milk immediately to prevent enterotoxin formation</td>
</tr>
</tbody>
</table>

Additional disease information available at [http://www.cfsph.iastate.edu/DiseaseInfo/](http://www.cfsph.iastate.edu/DiseaseInfo/). Table last reviewed January 2021
<table>
<thead>
<tr>
<th>Zoonotic Disease</th>
<th>Etiologic Agent</th>
<th>Transmission</th>
<th>Clinical Signs in Sheep and Goats</th>
<th>Clinical Signs in People</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Toxoplasmosis</strong></td>
<td>Toxoplasma gondii</td>
<td>H</td>
<td>Incubation period: not known</td>
<td>Incubation period: 5-23 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Reproductive: congenital infection; abortion; stillbirth</td>
<td>Flu-like: fever; malaise; myalgia; lymphadenopathy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>mummification</td>
<td>Ocular: chorioretinitis; vitreous inflammation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Neurologic: (lambs, kids) weakness; ataxia; anorexia; inability to nurse; death</td>
<td>Reproductive: abortion; stillbirth (1st trimester)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Clean and disinfect; keep cats out of animal areas, barns, pastures; do not let cats prey on rodents or birds; do not feed cats raw/undercooked meat; keep cats out of animal areas; control insects; remove and destroy aborted fetuses, placenta</td>
<td>Congenital: chorioretinitis; hydrocephaly; encephalitis; visual and learning disabilities later in life</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Wash hands; wear gloves if gardening, touching sand; cook meat properly; freeze meat for &gt;3 days at 5°F to kill parasites; wash, peel fruits, vegetables; avoid cross-contamination in the kitchen; do not drink untreated water</td>
</tr>
<tr>
<td><strong>Tuberculosis, bovine</strong></td>
<td><em>Mycobacterium bovis</em></td>
<td>AH</td>
<td>Incubation period: varies; months to years</td>
<td>Incubation period: variable; several months to years</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Asymptomatic</td>
<td>Respiratory: fever; cough; chronic weight loss</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Systemic: weight loss; weakness; emaciation; fever</td>
<td>Systemic: fever; weight loss; malaise; other signs vary</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Respiratory: chronic cough, bronchopneumonia; tachypnea; dyspnea</td>
<td>Neurologic: meningitis; meningoencephalitis (rapidly fatal for all ages); chronic meningitis</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gastrointestinal: intermittent diarrhea; constipation</td>
<td>Wash hands, wear PPE (gloves, mask or respirator); clean, cover wounds; do not consume raw dairy; cook meat to proper internal temperature; wear a mask if you are infected</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Reproductive: abortion; infertility; mastitis; metritis</td>
<td></td>
</tr>
<tr>
<td><strong>Tularemia</strong></td>
<td><em>Francisella tularensis</em></td>
<td>AH</td>
<td>Clean and disinfect (organism may be resistant); remove manure; avoid high pressure hoses when cleaning; provide good ventilation; do not overcrowd barns; control rodents; minimize exposure to reservoirs (deer fencing, barriers, protect feed from rodents); tuberculin testing; quarantine reactors until negative then cull</td>
<td>Incubation period: 3-5 days, can range from 2-20 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ulceroglandular: flu-like, papule at inoculation site, ulceration, regional lymph node swelling</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Glandular: same as ulceroglandular, but no papule</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Oculoglandular: painful, purulent conjunctivitis with regional lymphadenopathy, often unilateral</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Oropharyngeal: local lymphadenopathy; exudative stomatitis, pharyngitis; nausea; vomiting; GI bleeding</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pneumonic: cough; dyspnea; pneumonia; death</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Typhoidal: (rare) severe systemic disease</td>
</tr>
</tbody>
</table>

Additional disease information available at [http://www.cfsph.iastate.edu/DiseaseInfo/](http://www.cfsph.iastate.edu/DiseaseInfo/). Table last reviewed January 2021.
CONSensus STATEMENTS

Consensus Statements of the American College of Veterinary Internal Medicine (ACVIM) provide the veterinary community with up-to-date information on the pathophysiology, diagnosis, and treatment of clinically important animal diseases. The ACVIM Board of Regents oversees selection of relevant topics, identification of panel members with the expertise to draft the statements, and other aspects of assuring the integrity of the process. The statements are derived from evidence-based medicine whenever possible and the panel offers interpretive comments when such evidence is inadequate or contradictory. A draft is prepared by the panel, checked by KH followed by solicitation of input by the ACVIM membership which may be incorporated into the statement. It is then submitted to the Journal of Veterinary Internal Medicine, where it is edited before publication. The authors are solely responsible for the content of the statements.

Management of Coxiella burnetii infection in livestock populations and the associated zoonotic risk: A consensus statement

Paul J. Plummer1 | J.Trenton McClure2 | Paula Menzies3 | Paul S. Morley4,5 | René Van den Brom6 | David C. Van Metre4

1Department of Veterinary Diagnostic and Production Animal Medicine and the Department of Veterinary Microbiology and Preventive Medicine, College of Veterinary Medicine, Iowa State University, Ames, Iowa
2Department of Health Management, Atlantic Veterinary College, University of Prince Edward Island, Charlottetown, Prince Edward, Canada
3Department Population Medicine, Ontario Veterinary College, University of Guelph, Guelph, Ontario, Canada
4Department of Clinical Sciences, College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, Colorado
5Colorado School of Public Health, Fort Collins, Colorado
6GD Animal Health, Deventer, The Netherlands

Correspondence
Paul J. Plummer, Iowa State University, Veterinary Diagnostic and Production Animal Medicine, Veterinary Microbiology and Preventive Medicine, Iowa State University College of Veterinary Medicine, Ames, Iowa. Email: pplummer@iastate.edu

Infections caused by Coxiella burnetii, commonly referred to as coxiellosis when occurring in animals and Query fever when occurring in humans, are an important cause of abortions, decreased reproductive efficiency, and subclinical infections in ruminants. The organism also represents an important zoonotic concern associated with its ability to aerosolize easily and its low infectious dose. Available diagnostic tests have limited sensitivity, which combined with the absence of treatment options in animals and limited approaches to prevention, result in difficulty managing this agent for optimal animal health and zoonotic disease outcomes. The purpose of this consensus statement is to provide veterinarians and public health officials with a summary of the available information regarding management of C. burnetii infection in livestock populations. A discussion of currently available testing options and their interpretation is provided, along with recommendations on management practices that can be implemented on-farm in the face of an outbreak to mitigate losses. Emphasis is placed on biosecurity measures that can be considered for minimizing the zoonotic transmission risk in both field and veterinary facilities.

KEYWORDS
abortion, Coxiella burnetii, coxiellosis, Q fever, shedding, zoonotic

1 | INTRODUCTION

Query fever, (Q fever) was first described as a febrile illness of abattoir workers in Australia in 1937. Subsequently, the causative agent was identified as Coxiella burnetii, a ubiquitous, small, pleomorphic,
Intracellular Gram-negative bacteria. Infections principally occur through inhalation or ingestion, although infection by blood transfusion occurs. Infections in animals are termed coxiellosis. Coxiellosis occurs in a variety of species, with domestic ruminants serving as the most important reservoir for human infection. Coxiellosis is frequently subclinical, with clinical disease manifesting most commonly in small ruminants as late-term abortion, stillbirth, and birth of weak offspring and rarely as abortion or reproductive failure in cattle. Placental membranes, fetuses, and uterine fluids from clinically affected animals can contain massive numbers of C. burnetii; however, the agent can be shed in large numbers during parturition in clinically unaffected animals. The organism replicates within the trophoblasts of the placenta and after the logarithmic growth phase, produces a spore-like bacterial form termed a small cell variant (SCV); these SCVs are responsible for persistence of the organism in dust, manure, and the air of farms. Aerosols originating from infected farms can act as a source of infection for humans.

In this document, we define coxiellosis-positive herds as those with evidence of infection (identification of C. burnetii or its DNA in biological samples obtained from livestock), which might or might not result in clinical disease and shedding in individual animals. While serologic testing cannot rule-out infection, in most cases it alone is not sufficient to document coxiellosis at the herd level, and additional testing focused on documenting the presence of the organism is warranted. At the individual animal level, evidence of infection with the organism, with or without clinical disease would be considered coxiellosis; however, the extent and duration of shedding is unpredictable in affected animals.

Query fever and coxiellosis are considered to be re-emerging diseases in many countries. Recently, outbreaks of abortion in sheep and goats with concurrent human illness have occurred worldwide. Although human infections are often asymptomatic or mild, debilitating complications can occur.

There are several relevant publications available for human and veterinary health professionals, which provide guidance for livestock and public health concerns related to C. burnetii. These are summarized in Table 1. The objective of this consensus statement is to complement these documents and to provide more focused recommendations—based on the literature and expert opinion—regarding the clinical management of animals on premises with confirmed or suspected coxiellosis. These recommendations focus primarily on ruminants; however, pertinent discussions are also included related to companion animals, horses, and wildlife. Specific questions addressed in this statement include:

1. How can coxiellosis be most accurately diagnosed at the herd/flock level with consideration of the individual animal level?
2. How can infected herds and flocks be managed to control clinical and subclinical disease, including shedding of the agent and transmission to other herds and flocks?
3. How can the zoonotic risks be mitigated?

## 2 | Diagnosis of C. burnetii in Individual Animals

To determine the presence or freedom of infection because of C. burnetii in livestock operations, the strengths and limitations of diagnostic tests in various clinical scenarios must be understood. Diagnostic tests detect either the agent (Table 2) or immunological evidence of previous exposure (Table 3) to C. burnetii.

A number of commercial PCR kits are available for C. burnetii DNA detection. A commonly used target gene is IS1111, which is present in multiple copies on the genome, but varies in the exact copy number by genotype. A commercial European kit uses the GAPDH gene target. When warranted, molecular based bacterial genotyping can be performed to gain insights into the epidemiology and pathogenicity of the isolate.

A positive antibody titer is evidence of current or previous infection with C. burnetii, but is not necessarily indicative of current or prior shedding or disease. Importantly, seronegative animals (regardless of test used) can be actively shedding the organism. Serologic tests evaluate antibodies to two distinct antigenic forms of C. burnetii called phase I and phase II. Most commercially available antibody tests for livestock detect the summative titer to phase I and phase II antibodies. Data in humans suggest that when independently analyzed, phase II antibodies indicate an acute infection when found in higher titers than phase I antibodies. However, phase-specific antibody testing in livestock remains poorly characterized at present.

Enzyme linked immunosorbent assay (ELISA) is preferred for large-scale screening of the infection status livestock. The CHEKIT Q Fever Antibody ELISA, (IDEXX Laboratories, Inc.) is based on C. burnetii purified antigens of the 9-Mile tick-sourced strain. It can be used on serum, plasma and milk of ruminants. The manufacturer claims 100% sensitivity and 100% specificity based on tests performed on 81 samples of animals with known infection status. In Europe, the LSIVET Ruminant Milk/Q Fever (Laboratoire Service International, Lissieu, France) is an ELISA test using an ovine-derived antigen. Sensitivity is estimated to be 85% and specificity at

### Table 1 Publications that augment and synergize with this consensus statement

<table>
<thead>
<tr>
<th>Focus</th>
<th>Title</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Diagnosis and Management of Q Fever — United States, 2013 Recommendations from CDC and the Q Fever Working Group</td>
<td>US Centers for Disease Control and its affiliate Q Fever Working Group</td>
</tr>
<tr>
<td></td>
<td>Evaluation of Factors that Would Initiate or Propagate Epidemic Coxiellosis in the United States. Domesticated Goat Population</td>
<td>USDA Centers for Epidemiology and Animal Health</td>
</tr>
</tbody>
</table>
TABLE 2  Summary of diagnostic test used for detection of evidence of infection with C. burnetii

<table>
<thead>
<tr>
<th>Test</th>
<th>Diagnostic specimen</th>
<th>Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Observation</td>
<td>Placental membranes with at least 1–2 cotyledons, fetal tissues, and vaginal mucous</td>
<td></td>
</tr>
<tr>
<td>of Bacteria</td>
<td></td>
<td>Pinkish red coccobacillary; usually intracellular bacteria on modified Ziehl-Neesen, Giminez, and Glensa stains.</td>
</tr>
<tr>
<td>Polymerase Chain</td>
<td>Abortive tissues, individual and BTM and milk products, feces, vaginal mucus, and</td>
<td>PCR generally indicates presence of DNA from live or bacteria, from infection or contamination.</td>
</tr>
<tr>
<td>Reaction</td>
<td>environmental samples</td>
<td>qPCR allows for better interpretation of the significance of results:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sensitivity and specificity of the test depend on the gene target of the assay.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PCR on blood may augment, but should not replace other methods of testing as sensitivity is not known.</td>
</tr>
<tr>
<td>Bacterial culture</td>
<td>Abortive tissues, individual and BTM and milk products, fecal material, vaginal mucus, and</td>
<td>Rarely performed because of human health risk and fastidious growth requirements of the organism.</td>
</tr>
<tr>
<td></td>
<td>environmental samples</td>
<td>Must be done in Biosafety Level 3 laboratory.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Requires relatively high levels of shedding to be reliably cultured.</td>
</tr>
</tbody>
</table>

* Positive results may need to be reported to local public and/or animal health officials.

95%.24 Phase-specific ELISAs have been developed but are not widely available for clinical application.91

Although infection with C. burnetii does stimulate cell mediated immunity (CMI), diagnostic testing of CMI is not commercially available. In one study, the interferon-gamma assay did not differentiate between exposed and non-exposed goats.28 Additional research regarding CMI testing for diagnosis of coxiella infections is needed.

3  DIAGNOSIS OF C. BURNETII INFECTED HERDS AND FLOCKS

Subclinical infection with C. burnetii in ruminants is far more common than clinical infection. This creates a challenge in arriving at the correct diagnosis when investigating abortion outbreaks, trying to assess zoonotic risk, or determining freedom from infection in individuals or groups of animals. Most animals that abort because of C. burnetii infections are not systemically ill.6 Coxiella-associated abortion outbreaks with >10% attack rates during the lambing/kidding season of a flock or herd are not uncommonly reported in small ruminants. Neonates can also be born alive but weak during abortion outbreaks.6 In cattle, abortion is uncommon, although it has been hypothesized that there is an association between reproductive failure and infection.35

3.1 Investigating C. burnetii as the cause of abortion

When investigating the cause of abortion, both the placenta and the aborted fetuses should be examined. Severe placentitis is frequently present in small ruminants affected by C. burnetii infections. Extracellular and intracellular organisms are usually visible in large numbers when direct smears of cotyledon tissues and histopathological sections are examined microscopically.24,56,67 Lesions in the placenta of cows that abort because of C. burnetii infections are typically much milder.25 Quantitative PCR (qPCR) results can be helpful when determining if C. burnetii is the most likely cause of the abortion in small ruminants, rather than simply being concurrently shed or representing environmental contamination. Animals with abortion caused by C. burnetii tend to have qPCR Ct values that correspond to several orders of magnitude greater quantities of organisms (eg, 10^9–10^10 copies/µL) than those associated with asymptomatic long-term shedding or environmental contamination.38,39 In cases of abortion with C. burnetii, fetal tissues (liver, abomasal fluid, and lung) can also be PCR-positive. High numbers of organisms as evidenced by qPCR values combined with histopathologic placental lesions provide strong evidence that the abortion is caused by C. burnetii. However, identification of PCR-positive samples regardless of the quantity of organisms detected should trigger a discussion of the zoonotic implications of the findings and evaluation of the biological risk it entails.

TABLE 3  Summary of diagnostic test used for detection of evidence of exposure to C. burnetii

<table>
<thead>
<tr>
<th>Test</th>
<th>Diagnostic specimen</th>
<th>Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELISA</td>
<td>Serum</td>
<td>Preferred for large scale screening of livestock.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Good agreement withIFA results.</td>
</tr>
<tr>
<td>Immunofluorescence</td>
<td>Serum</td>
<td>Definitive serological test in human medicine.</td>
</tr>
<tr>
<td>Assay (IFA)</td>
<td></td>
<td>Less widely utilized in veterinary medicine due technical requirements.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very good agreement with ELISA.</td>
</tr>
<tr>
<td>Complement Fixation</td>
<td>Serum</td>
<td>Less sensitive than most ELISA (as low as 10% in aborting animals); good specificity (&gt;98%).17-19</td>
</tr>
<tr>
<td>Test (CFT)</td>
<td></td>
<td>Negative ELISA samples may show low CFT titres, possibly detecting IgM.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limited utility In livestock.</td>
</tr>
</tbody>
</table>

*With all serological tests listed, seronegative animals may shed the organism.
3.2 | Patterns of shedding in aborting herds/flocks

Before aborting, shedding of bacteria in vaginal fluids is absent or minimal, even when bacterial counts in utero are substantial. This limits the utility of using PCR as a prepartum assessment of an animal’s risk of abortion or post-partum shedding. However, bacterial shedding patterns change dramatically at abortion or parturition. After aborting, bacterial shedding can be detected by PCR in vaginal mucus, feces, and milk, but patterns of shedding are different among species. In cattle, vaginal shedding of C. burnetii is typically very short (<14 days) while shedding in milk occurs for much longer periods. Among infected goats during the first postpartum, the proportion of does shedding in milk, feces or vaginal mucus is similar for individuals that abort and those that kid normally (30%–50%). Milk shedding patterns in goats are similar to vaginal shedding but with lower numbers of pathogens and for longer periods (8 weeks or more). The level of vaginal shedding typically decreases by 2–3 weeks post kidding.

3.3 | Abortion, serological response, and shedding

Sheep and goats that abort are usually seropositive at the time of abortion, although titers can decrease with time. However, infected, seropositive herd-mates can undergo normal parturition and deliver healthy offspring. Additionally, seronegative small ruminants can have PCR-positive vaginal swabs after parturition. During outbreaks of coxiellosis, aerosol contamination of sampling supplies because of high environmental load can occur and lead to false positive test in pathogen detection.

3.4 | Herds or flocks infected with C. burnetii in the absence of abortions—shedding patterns

It is common to encounter flocks or herds where bacteria are being shed without any history of abortion or other abnormal reproductive events. In such cases, the numbers of organisms being shed is typically much lower than seen in aborting ones, but the proportion of animals shedding can still be as high as 90%–100%. Shedding is common in birth fluids, vaginal mucus, milk, and feces but the relative quantity of bacteria shed in these bodily fluids differs by species in a pattern similar to that of aborting herds/flocks.

3.5 | Serological status and shedding

In dairy cattle, seroconversion tends to occur within the first ninety days of lactation, with young multiparous cattle being the most likely to seroconvert. Serologic status of individual cows is moderately predictive of shedding status. Approximately 65% of cows with PCR-positive milk samples remain seronegative.

Similarly, in small ruminants, there is poor correlation between risk of bacterial shedding and serological status. Among sheep and goats that shed C. burnetii by any route, the proportion of seropositive sheep is low (<10%) and moderate in goats (~50%). A high proportion of goats shedding at parturition will be seronegative one month later and in contrast, a high proportion of non-shedding goats are frequently seropositive.

3.6 | Bulk tank milk (BTM) testing and herd/flock status

Immunological testing of BTM has been evaluated as a means to evaluate the likelihood of previous infection and the risk shedding bacteria in healthy dairy herds. In dairy cattle, PCR based BTM testing results for a given herd generally provide consistent results over time. BTM antibody concentrations in that species is strongly predictive of within-herd seroprevalence; detection of a within-herd prevalence of >20% is possible with a BTM ELISA. There appears to be good agreement between seroprevalence and BTM antibody concentration in dairy sheep flocks. As such, BTM ELISA is a useful test for large-scale screening programs to detect flocks that have been previously infected, although BTM PCR may be more sensitive for detection of actively infected/shedding flocks. In dairy goat herds, BTM ELISA also is similarly predictive of shedding status when measured with BTM PCR (cut-off 100 bacteria/mL milk) and also for detecting previously infected herds with a seroprevalence of >15% (SP ratio of 43%). Bulk tank milk containing >10⁵ C. burnetii/mL as estimated by qPCR is associated with herd seroprevalence of ≥50% in dairy cattle.

4 | LOW-RISK HERD/FLOCK STATUS FOR C. BURNETII INFECTION

It is often important to evaluate whether individuals or groups of animals have a low risk for shedding C. burnetii, such as when animals are used for teaching, research or when planning obstetrical procedures in clinical veterinary practice. As previously stated, serological testing of individual animals does not reliably predicting the likelihood of shedding in any species. Detection of shedding by PCR can be used to determine current status; however, that shedding status can change rapidly. For example, a pregnant goat can be PCR-negative and seronegative immediately before parturition, but still shed bacteria during a normal parturition. The following recommendations are based on first principles of disease surveillance, the epidemiology of coxiellosis, and the accuracy of available diagnostic tests.

The infection status of the population is often used to make inferences regarding the status of individuals. Unfortunately, the best method for determining whether flocks or herds have a low likelihood of current or previous infection has not been well established. It is much easier to detect evidence of infection than it is to determine freedom from infection. Given the zoonotic nature of coxiellosis, the practitioner needs to determine the level of risk that they are willing to assume with regard to their efforts to determine infection status. This decision process might differ because of the highly infectious and zoonotic nature of this organism. Flock-level status with C. burnetii is often subject to more rigorous proof of low to no risk of infection than other disease agents. Online calculators can be used to determine the percentage of the herd that needs to be sampled to achieve a reasonable degree of confidence of detecting infection. (See the sample size and FreeCalc calculators at AusVet: http://epitools.ausvet.com.au). This resource also provides a calculator for estimating true prevalence when using imperfect tests. Also, see the sample size calculators for risk-based sampling and representative sampling.
5 | SURVEILLANCE OF COXIELLOSIIS IN CATTLE, SHEEP, AND GOAT FARMS

The main aim of surveillance for shedding of C. burnetii is to detect shedding in an early stage, so that environmental contamination and human exposure can be prevented or minimized. Based on the characteristics of the different tests, several PCR techniques seem most applicable for routine surveillance of shedding of C. burnetii in samples of different origin from domestic ruminants. Surveillance of shedding in dairy ruminants can be performed using BTM samples. Further research on testing of environmental and air samples is necessary before they are implemented into surveillance programs.29,59–62

After a large human Q fever outbreak in the Netherlands, several compulsory disease control measures were implemented nationwide. A compulsory vaccination program in dairy goat herds was initiated, and its efficacy monitored using BTM PCR and surveillance for abortion. This control program allowed officials to certify individual herds as having a low-risk of coxiellosis, and to provide early detection of any change in herd status.53

6 | CONTROL OF COXIELLOSIIS

Several studies have investigated risk factors of coxiellosis in ruminants in the past decade.20,64–67 Factors that were associated with lower risk of seropositivity in ruminants in these studies included quarantine of new animals entering the farm, use of stringent hygiene measures for visitors, limited introduction of new animals, prompt removal of birth materials immediately postpartum, and frequent cleaning or changing of bedding. When attempting to control coxiellosis, the primary goal should be the reduction of zoonotic risk associated with shedding during an abortion event, during normal parturition, or through shedding in the milk and manure. The following control measures can be considered for achieving these goals.

6.1 | Vaccination

In portions of the European Union, vaccination using a phase I killed C. burnetii vaccine (Coxitevac, Ceva Sante Animale) is recommended for use in goats for reduction of abortion risk and shedding of C. burnetii. In vaginal fluids, feces, and milk and in cattle for reduction of shedding. It has proven to be effective at reducing bacterial shedding levels (<200 organisms per vaginal sample in 24% of vaccinated animals) under experimental conditions, as well under field circumstances.5,68–71 The vaccine instructions are to administer to nonpregnant animals at least 3 weeks before breeding; ideally animals are initially vaccinated when young (goats at 3 months of age), 3 weeks later, and then followed by an annual booster vaccination. The effect on bacterial shedding is most pronounced in goats when vaccinated before their first pregnancy.58 In contrast, vaccines developed from killed phase II (SCV) organisms did not affect the course of the disease or excretion.5 Reduced shedding in sheep after vaccination with a phase 1 vaccine during pregnancy has been reported.72 However, no reduced shedding was observed after vaccination during pregnancy in goats.68 At the time of writing of this
consensus statement, there is not a commercially available phase I vaccine licensed and available in the US. The Canadian Food Inspection Agency has stated it will issue a biologic import permit allowing provisional use of a commercial phase I vaccine in Canadian herds and flocks when the need is demonstrated (personal communication P. Menzies).

6.2 Antibiotic treatment to control abortion and shedding of *C. burnetii*

Overall, there is a lack of scientific evidence of efficacy of antimicrobial drugs when used in attempts to control abortion or shedding of *C. burnetii*. Because of this lack of evidence and the need to promote antimicrobial stewardship, it is the opinion of this consensus panel that antimicrobial drugs should not be used for control or treatment of coxiellosis. In vitro, *C. burnetii* is sensitive to several antimicrobial drugs, including tetracycline. In-feed administration of antimicrobial drugs do not reach target concentrations in reproductive tissues or the fetus.

In the face of an outbreak, treatment with two successive injections of oxytetracycline during the last month of pregnancy has been proposed for use in goats. But to date, there are no well-controlled field trials demonstrating an evidence-based benefit of this intervention in goats. The same treatment regimen has been evaluated in sheep, but our study also implemented concurrent vaccination and suffered from low statistical power, making interpretation of results difficult. In cattle, antimicrobial treatment with injectable oxytetracycline was not associated with decreased shedding in milk.

Another study suggested that a single treatment with oxytetracycline, administered at drying off, had no effect on the bacterial load.

6.3 Expected clinical course at the herd-level

The most beneficial tool that has been described for management of clinical disease is the implementation of vaccination using phase I form of the killed bacteria. Once coxiellosis is confirmed on a premises, infections should be considered endemic in the population. Animal infection and shedding should generally be expected for multiple years to come, even in the face of intervention measures, including vaccination. In cases of coxiellosis abortion storms, the rate of coxiellosis related abortions is likely to decrease after initial introduction, but shedding during normal parturition will continue. Despite the difficulty in eliminating the presence of the organism it is critical that measures are to decrease the environmental load and the related zoonotic infection risk.

6.4 Controlling environmental contamination and transmission

The SCV of *C. burnetii* is profoundly resistant to environmental stress, desiccation, and most commonly used disinfectants. It can survive in the environment for prolonged periods of times (years to decades), and is readily aerosolized in dust. Based on epidemiologic data collected during the outbreak in the Netherlands, wind dispersion aerosols can result in dissemination of the disease for up to 5 km downwind of infected facilities. The greatest risk of aerosol formation and subsequent human transmission appears to be linked with parturition of animals, especially sheep and goats. When small ruminant farms are ecologically infected, measures should be taken to minimize the potential aerosol formation from highly infected materials. The presence of an abortion storm may increase this risk because of a higher proportion of animals shedding and should be addressed appropriately as described below.

Measures that can be implemented to control transmission, environmental contamination and consequently minimize zoonotic risk include:

- Segregate periparturient animals from other high-risk animals (gestating and young). This may decrease exposure to the high level or organisms in aborted fluids.
- Manage parturient animals in an enclosed environment with controlled airflow to lower risk for downwind transmission. This may increase risk of seroconversion for animals housed within the same environment.
- Eliminate land application of fresh manure.
- Compost manure for 90 days before land application and transport manure and apply only on damp low wind days.
- Promptly remove and dispose of aborted fetus and uterine fluids either by closed composting or burning.
- Move naïve or gestating animals to areas of the farm that are upwind of aborting animals.
- Minimize development of excessively dry and dusty environments in animal housing areas (e.g. by gently wetting down dusty environments) and around barns.

Mammals, both wild and domestic birds, and ticks can act as reservoirs of infection and also potential mechanisms of transmission. *C. burnetii* shedding occurs from all domesticated species. Farm dogs and farm cats commonly scavenge on and might disseminate the organism in the local environment. These non-livestock species also experience clinical abortion associated with this organism and, zoonotic disease has ensued. Infected horses, mules and donkeys in rare cases can abort. *C. burnetii* shedding has been described in many species of wild animals commonly encountered on farms, including wild migratory and nonmigratory birds. Methods to reduce risk from these species, particularly those that are reproductively active, have not been shown yet to be effective; however, it might be prudent to restrict their access to livestock whenever feasible.

6.5 Quarantine

In many US states and other animal health jurisdictions, coxiellosis is a reportable disease. If infection and disease is documented in these jurisdictions, state animal health officials ultimately have control of regulatory actions that may be required. According to the National Association of State Public Health Veterinarians and National Assembly of State Animal Health Officials guidance document, quarantine of infected herds is "generally not recommended."
6.6 | Using individual testing to eradicate infection from a herd/flock

Strategies focused on managing coxiella using an individual test and remove approach are unlikely to succeed and are not recommended because reliable, consistent identification of infected animals using the currently available diagnostic tests remains problematic. As discussed above, some serologically negative animals shed the organism, and shedding is often intermittent and inconsistent except during the parturient and immediately postparturient period making identifying all positive animals difficult by PCR. Further, the high level of environmental contamination combined with the extreme persistence of this organism in the environment allow for continued exposure and make eradication difficult.

6.7 | Depopulation and breeding ban

Facing an epidemic of human Q fever concurrent to small ruminant coxiellosis, the Netherlands utilized a multi-pronged approach to limit transmission to humans. In addition to vaccination, the government initiated a program to depopulate all pregnant goats on infected farms and concurrently placed a permanent breeding ban on all non-pregnant animals on infected farms that were not vaccinated before their first pregnancy. These measures were intended to reduce the likelihood of postparturient shedding of the bacterium either from abortion or normal kidding. Together with vaccination, this approach did ultimately aid in stopping the epidemic; however, questions remain regarding the necessity of the depopulation efforts. Based on the epidemiologic data and our current knowledge of vaccine efficacy, use of a depopulation approach is not appropriate in most farm management plans. In agreement with this assessment, the NASPHV and NASHO guidance document states "mass euthanasia of infected herds is never warranted." 21

7 | Zoonotic Risks and Mitigation Strategies

Diagnostic testing strategies used to identify infections in humans have been defined and discussed in detail elsewhere. 22 Table 4 provides characteristics of people that have higher risks for exposure and infection. Most exposure to C. burnetii is via infection with the SCV form, usually through inhalation of aerosolized bacterium, although ingestion of contaminated milk products is also possible. 7 As few as 1–10 organisms are cable of causing an infection. 104 Approximately half of human infections with C. burnetii are asymptomatic. 105 Acute-onset clinical disease occurs 2–6 weeks postexposure in the other half. 105 Most acute clinical infections results in flu-like symptoms (fever, headache, chills, sweating, and fatigue). Some people develop severe headaches that originate from the retro-orbital area. Without treatment, the febrile episodes resolve in 10–14 days and most people fully recover, although there are some that develop a post Q fever fatigue syndrome. 22 However, some individuals require antibiotic treatment to recover and a small proportion of those can require hospitalization. 22 Because of the nonspecific clinical signs of acute Q fever and its self-limiting course in most people, it is probably vastly underreported. 22 This is supported by the high seroprevalence among people that have a high risk of infection, including veterinarians. 69–71 Approximately 30%–50% of patients with acute, symptomatic Q-fever develop pneumonia, while a small proportion of other develop acute hepatitis, myocarditis and meningoencephalitis. 22

Clinical disease associated with the chronic form of Q-fever occurs in <5% of people that develop acute symptomatic infections, although chronic disease has been reported in people with no history of acute symptoms. 22 Chronic Q fever can develop months to years after the acute infection. 7,22 Endocarditis and other vascular infections are the most common manifestation of chronic Q fever but can also present as chronic hepatitis, osteomyelitis, septic arthritis, and chronic pneumonia. 22
7.1 | How can people protect themselves from Q fever?

There are two approaches for protecting people from infection (in the absence of human vaccination, which is only available in Australia): avoiding situations that lead to exposure, and use of hygiene and personal protective equipment (PPE) to reduce the likelihood of infection. When possible, people with a higher risk of developing severe consequences from infection (e.g., people with cardiac valvular disease, immunosuppression, and pregnancy) should consider avoiding situations associated with a higher likelihood of exposure. If this is not possible, then infection risks should be minimized by optimizing environmental hygiene, through optimal adherence to hand hygiene, and by using of PPE including gloves, protective outerwear, and respiratory protection. It is difficult to provide clear-cut recommendations regarding which people should use PPE and when and how rigorously the precautions should be applied. This is because it is clear that infection and shedding prevalences are often high in ruminants, and the seroprevalence for C. burnetii is high among high-risk professions (as high as 60%), but the number of documented cases of Q fever in people is relatively small. Further, most of these clinical Q fever cases are mild and self-limiting. However, the severe health consequences in a small minority of clinically affected individuals means that the risks for zoonotic infections cannot be ignored. It is clear that when a documented case of Q fever in a person has epidemiological links to farm exposures, other personnel associated with that farm might have an increased risk of developing clinical Q fever in the same period, and higher levels of precautions are warranted. Thus, the risk of serious health consequences for an individual that becomes infected needs to be considered in context with the exposure risk of the situation. Concern for these circumstances is not uniform because people have varying levels of risk-aversion regarding this disease problem. As a result, infection control practices that are employed for C. burnetii frequently vary depending among individuals and institutions. However, there is an ethical responsibility for employers and institutions to promote awareness and education regarding risks for zoonotic infection, and to facilitate the ability for individuals to protect themselves. Thus, employers have a responsibility to make it easy and acceptable for individuals to use infections control methods that fit their individual situation and their personal level of risk-aversion.

In situations described above where exposure is likely, such as during parturition of infected small ruminants, infection can occur through inhalation of small particle aerosols. Use of eye protection such as splash shields and high-efficiency respiratory protection is needed to protect workers in these situations. Surgical masks or dust masks might be helpful in preventing inhalation of larger droplets, but they are not sufficient to prevent inhalation of small particle aerosols or fine dusts. Tight-fitting respirators (e.g., full- or half-face canister respirators) and N95 masks should only be used by trained personnel that are medically cleared to use this type of PPE. Alternatively, powered air-purifying respirators can be worn by trained individuals without the need for fit-testing, which can increase flexibility of management protocols. Use of gloves and rigorous adherence to hand hygiene practices will help to prevent inadvertent oral exposures. Because of risks for infection with a variety of important zoonotic agents, including C. burnetii, personnel involved in obstetrical procedures should also prevent skin exposures by using appropriate barrier clothing. It has also been recommended that administrative personnel providing oversight for occupational safety might want to collect and store pre-exposure serum samples to aid in diagnosis of C. burnetii infections, should the need arise.

It situations where previous testing and the health history of a flock or herd suggests that there is a low risk of C. burnetii Infection, it might be considered reasonable to employ less rigorous infection prevention methods, especially when working on nonobstetrical health/disease problems. However, in situations where the infection status of individuals, or source flocks or herds, is unknown, it is advisable that more stringent precautions be applied because of the ubiquity of C. burnetii.

7.2 | Recommendations for management of animals in a veterinary hospital

Veterinary personnel caring for livestock cannot be protected from all risk of exposure to C. burnetii, regardless of the precautions that are employed. However, there are opportunities to mitigate risk, especially in veterinary hospital settings. As animals are admitted to a facility, the clinician should assess the risk of zoonotic exposure to Coxiella and should preemptively develop an individualized infection control plan for that patient. As discussed, periparturient sheep and goats have the highest risk for vaginal shedding of C. burnetii, especially from parturition until 2 weeks postpartum or longer. Small ruminants presenting with a history of dystocia, abortion, stillbirth or offsprings that fail to thrive, have a particularly high likelihood of shedding, but these signs can also be caused by other infectious and noninfectious causes of abortion. Ruminants with no history of individual or farm level reproductive disorders can shed the organism asymptotically. It should also be noted that all domestic species have been documented to be capable of shedding the organism, so routine biosecurity measures including hand washing, eliminating storage or consumption of food and drink in animal care areas, and use of appropriate hospital-dedicated clothing should be advocated in all areas of the hospital (both large and small animal). Table 5 summarizes some characteristics that will assist veterinarians in assessing the zoonotic disease hazard posed by individual patients.

There are no published evaluations regarding the efficacy of coxiellosis management strategies in veterinary hospitals, but general principles of biosecurity and infection control should be employed in developing plans for management of this disease in hospital settings (Table 6).

7.3 | Recommendations for control of human exposures in the field

Some of the precautions that are recommended for control of exposure to C. burnetii in veterinary hospitals may be difficult or impossible to apply in field circumstances. Consideration of the likelihood of infection in herds/flocks, and in individual animals can provide a basis for appropriately adjusting the rigor of precautions commensurate...
TABLE 5 Characteristics used to aid in the assessment of the risk of zoonotic exposure to C. burnetii

<table>
<thead>
<tr>
<th>Risk category</th>
<th>Patient characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Risk</td>
<td>• Male ruminants.</td>
</tr>
<tr>
<td></td>
<td>• Nonpregnant female ruminants.</td>
</tr>
<tr>
<td></td>
<td>• Pregnant small ruminants that will be leaving the facility before parturition.</td>
</tr>
<tr>
<td></td>
<td>• Other parturient mammals.</td>
</tr>
<tr>
<td>Intermediate Risk</td>
<td>• Periparturient small ruminants without an individual or farm level history of recent dystocia, abortion, stillbirth, or offspring that are born weak and undersized.</td>
</tr>
<tr>
<td></td>
<td>• Periparturient cattle.</td>
</tr>
<tr>
<td></td>
<td>• Periparturient felines that have been confined to the indoors.</td>
</tr>
<tr>
<td>Highest Risk</td>
<td>• Periparturient small ruminants from a herd/flock with a known history of coccidiosis, or from a herd/flock with a history of recent dystocia, abortion, stillbirth, or offspring that are born weak and undersized.</td>
</tr>
<tr>
<td></td>
<td>• Periparturient felines if they have outdoor access.</td>
</tr>
</tbody>
</table>

with the risk of exposure. This will also facilitate easier management of animals in situations where the infection risk is low. Contact with flocks/herds that have a higher infection risk (known endemic infection status or during abortion outbreaks), and interaction with animals in key shedding circumstances (eg, contact during periparturient events) should trigger use of more rigorous prevention methods.

Frequent contact with animals or their environments increases the risk for a variety of zoonotic infections. As such, it is always advisable to use separate clothing for activities involving contact with livestock and to change out of this clothing before returning to a person’s home, areas where food is prepared or consumed, and before contacting individuals that have increased risks for zoonotic infections (eg, young children, elderly, etc). Strict attention to hand hygiene will also decrease risks for zoonotic infections, particularly before any hand-to-face contact (eg, eating, smoking, etc), before and after animal contact, and before returning to vehicles or home.

Infection principally occurs through inhalation or ingestion. Prevention strategies should counter these types of exposures to prevent anthropogenic transmission to people and animals. Use of water impervious protective outer attire (ie, barrier gowns) that is disposable or facilitates cleaning and disinfection between contact with different animals will help to prevent transmission when working with periparturient animals. These items should be changed or cleaned and disinfected changed after working with periparturient animals or their environments (eg, cleaning) and when exiting the livestock-rearing facilities. As discussed previously, rigorous attention to hand hygiene and appropriate use of eye and respiratory protection are essential to prevent human infections in high infection risk circumstances. Veterinary personnel and producers should consult with an occupational health physician before employing any type of respirator.

Where possible, it is also important to dispose of the afterbirth and contaminated bedding shortly after parturition to minimize

TABLE 6 Biosecurity measures that should be considered based on the risk posed by different types of patients

<table>
<thead>
<tr>
<th>Risk category</th>
<th>Possible infection control and biosecurity measures that should be considered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Risk</td>
<td>• Assurance of personnel training on clinical signs of Q fever and how to mitigate their risk. The NASPHV document provides some good materials for this process, especially Appendix 2: Q Fever Factsheet and Appendix 3: Personal Protective Actions &amp; Equipment for Animal Owners, Caretakers. In addition, these individuals should be instructed to immediately seek medical attention if they develop symptoms consistent with Q fever and that they should specifically notify their physician of a potential exposure.</td>
</tr>
<tr>
<td></td>
<td>• General best practice hospital biosecurity measures including: Use of dedicated clothing and footwear on the clinic floor that does not leave the hospital, use of standard barrier precautions at all times and frequent thorough hand washing after handling animals and excluding food and drink from animal housing areas.</td>
</tr>
<tr>
<td>Intermediate Risk</td>
<td>Above precautions plus:</td>
</tr>
<tr>
<td></td>
<td>• When performing procedures involving reproductive fluid and tissues, veterinary personnel should use disposable plastic sleeves and/or gloves and either a face shield or protective eyewear and respiratory protection (see discussion regarding use of respirators).</td>
</tr>
<tr>
<td></td>
<td>• All reproductive tissues (placenta) and bedding contaminated with amniotic and allantoic fluids should be removed as soon as possible, handling and disposing in a manner that prevents further exposure to humans or animals, as well as preventing environmental contamination.</td>
</tr>
<tr>
<td></td>
<td>• Personnel with known risk factors for Q fever should be excluded from exposure to these animal care situations.</td>
</tr>
<tr>
<td></td>
<td>• Personnel exposed to animals considered to have a greater risk of shedding C. burnetii should seek medical attention if they develop signs related to Q-fever (including fever or flu-like illness).</td>
</tr>
<tr>
<td>Highest Risk</td>
<td>Above precautions plus:</td>
</tr>
<tr>
<td></td>
<td>• Patients that have a high likelihood of shedding C. burnetii should be managed separately from other susceptible animals in areas of facilities that have separate ventilation and are easy to clean and disinfect. This might be easiest to achieve in a separate facility such as an isolation facility.</td>
</tr>
<tr>
<td></td>
<td>• Because human infection can result from exposure to contaminated droplets, small particle aerosols, and dusts, use of eye protection (eg, face shields) and respiratory protection should be facilitated and encouraged, if not required. Respirators must only be used after appropriate training, medical clearance, and fit testing.</td>
</tr>
<tr>
<td></td>
<td>• Personnel exposed to animals that should monitor themselves for signs of infection (eg, fever, flu-like illness, etc). Maintaining a daily log of body temperature may be recommended for people with highest likelihood of exposure and infection, especially if they have risk factors for severe Q-fever. People that develop any signs of illness should seek advice from a healthcare professional.</td>
</tr>
</tbody>
</table>
TABLE 7  Disinfectants that have demonstrated at least some level of efficacy in deactivating C. burnetii and could be used in veterinary facilities or farms

<table>
<thead>
<tr>
<th>Product</th>
<th>Level of efficacy and reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary ammonium/detergent (MicroChem-Plus)</td>
<td>Complete inactivation after a 30 minutes contact time.</td>
</tr>
<tr>
<td>70% Ethanol</td>
<td></td>
</tr>
<tr>
<td>1% Peroxygent (Virkon S)</td>
<td>Complete inactivation after a 30 minutes contact time, but requires frequent reapplication because of rapid evaporation.</td>
</tr>
<tr>
<td>1:100 dilution of hypochlorite</td>
<td>&gt;90% reduction in infectivity after a 30 minutes contact time.</td>
</tr>
<tr>
<td></td>
<td>&gt;90% reduction in infectivity after a 30 minutes contact time.</td>
</tr>
</tbody>
</table>

NOTE: All organic matter should be removed before cleaning, and proper PPE should be worn during clearing.

Environmental contamination and prevention of human and animal exposures. Even in situations where circumstances prevent complete cleaning, best efforts should be made to remove contaminated materials. When possible, cleaning with detergents and water, followed by use of disinfectants should be employed. Guidelines for cleaning and disinfection best practices have been previously published. Recommendations regarding disinfection are described below. Routine cleaning and disinfection of lambing/kidding pens has been demonstrated to be associated with a lower risk of human salmonellosis in producers. During this cleaning on farms with documented coxiellosis, it is recommended that a fit tested N95 mask be used, and essential if another individual developed Q fever. In addition, farm personnel that are pregnant or are otherwise at higher risk of developing Q fever based on the description should consider taking a higher level of precautions, including using a fit tested N95 mask.

7.4  Recommendations for management of animals used in veterinary teaching

For teaching laboratories involving small ruminants, use male and nonpregnant females that have not given birth in the previous 2 months. Use of animals with impending parturition or early postpartum small ruminants for elective teaching exercises should be limited where possible.

7.5  Disinfection

The SCV is highly resistant to many commercially available disinfectants as well as heat, pressure, and drying. Therefore, removal of contaminated materials (eg, bedding) through standard cleaning protocols likely provides the most immediate benefit and may lower the level of bacteria in the environment. Scrubbing with detergents and rinsing with copious amounts of water (where possible) should be emphasized whenever possible as a means to reduce the environmental load of infectious organisms. However, care should be taken to prevent aerosolization through use of high pressure washers or moving of bedding using leaf blowers and pressure washers, and personnel should use appropriate PPE during cleaning and disinfection. There is little published research regarding the efficacy of cleaning and disinfection processes, but Table 7 provides a list of some possible disinfectant options that may provide better efficacy.

8  FUTURE DIRECTIONS

While scientists have made important strides during the last decade in improving our understanding of the animal and human health implications related to C. burnetii infections, a number of issues still need to be addressed. The authors of this report believe that the following actions should be prioritized by scientists, regulators and other government officials:

- Considered the highest priority by this consensus panel is the need to develop, validate, and license an effective C. burnetii vaccine(s) for use in livestock as an aid for controlling coxiellosis in North America. To be useful, the vaccine should prevent reproductive losses, and very importantly minimize shedding of infectious organisms to the greatest extent possible. As described above, vaccines that use phase 1 antigens are the best tool (and in many cases the only reasonable tool) for managing coxiellosis in animals. The low efficacy of antibiotic treatment, coupled with the difficulty associated with providing effective biosecurity for a highly infectious airborne pathogen, severely limits the ability of veterinary and public health officials to effectively manage coxiellosis.

- Providing access to an effective and safe vaccine for humans is also important to prevent disease among people with a high risk of exposure or high risks for severe disease consequences. There are no vaccines approved for use in humans in North America, but there is a phase 1 strain whole cell C. burnetii vaccine that is commercially available in Australia (Q-Vax, CSL). It is routinely used for people working in high-risk occupations, including veterinarians and veterinary students. This vaccine has been shown to be effective in preventing Q fever disease when administered to people documented to be seronegative. Importantly, people that have been exposed to C. burnetii before vaccination can suffer from local and occasionally severe systemic adverse effects.

- There is a need for additional research related to the role of antibiotics in the management and control of abortions and pathogen shedding in livestock. The human literature suggest that antibiotic treatment can be effective in control and eliminating pathogen shedding in humans; however, similar responses have not been observed in ruminants (see section above).

- To allow for improved disinfection of hospital facilities there is a need for additional work focused on the development of effective bactericidal products and applications.

- There is a critical need for the development of novel testing approaches that can identify animals that are subclinically infected with coxiellosis before parturition. At present, none of the available diagnostic assays allow the reliable pre-parturient detection of animals that will shed organism at parturition. This greatly hampers biosecurity control measures and increases human risk of exposure.
While currently technically challenging and not widely available, genotyping of clinical coxiella isolates holds great potential to improve our understanding of coxiella epidemiology and transmission. Additional efforts in this area may improve our understanding of the role of genotypic similarity or differences in animal reservoirs of infection and continue to build our understanding of the difference in zoonotic risk associated with different genotypes.

CONFLICT OF INTEREST DECLARATION

P. Plummer: National Association of State Public Health Veterinarians paid expenses and a per diem to serve on their consensus guideline panel related to Coxiellosis and the public health response.

P. Menzies: Member of the Q fever committee (unpaid) for the National Association State Public Health Veterinarians (2012-13). Invited to participate in a Q fever Roundtable group for Interactive Forums Inc. Conducted research from 2010 through 2013 on prevalence of Coxiella burnetii infection in sheep flocks and goat herds in Ontario and their farm workers, associated risk factors and potential adverse effects on flock productivity and human health. The funding agencies were Animal Health Surveillance Initiative—OMAFRA U of Guelph Agreement, Ontario Ministry of Health and Long-Term Care. The project was part of activities as an academic research. Conducted research from 2013 through 2015 on prevalence and strain identification of Coxiella burnetii on dairy goat farms and in associated wildlife. The funding agencies were Emergency Management—OMAFRA U of Guelph Research Program, Centre for Goat Research & Innovation (funds from the Ontario government), Canada Research Chair (NSERC) Funds Laurentian University Canada.

P. Morley: Paid consultant for Mississippi State University, University of Georgia, North Carolina State University, Washington State University, and University of Pretoria on infection control in veterinary hospitals.


OFF-LABEL ANTIMICROBIAL DECLARATION

Authors declare no off-label use of antimicrobials.

INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE (IACUC) OR OTHER APPROVAL DECLARATION

Authors declare no IACUC or other approval was needed.

ORCID

Paul J. Plummer http://orcid.org/0000-0002-5784-8382

REFERENCES

47. Hogerwerf L, Koop G, Klinkenberg D, et al. Test and cure of high risk
Cowdria burnetii infected pregnant dairy goats is not feasible due to
of endemic Cowdria burnetii infection in cattle by application of
151:291–300.
for Q fever diagnosis: correlation among serological (CFT, ELISA) and
molecular analyses. Comp Immunol Microbiol Infect Dis. 2012;35:
375–379.
son of diagnostic potential of serological, molecular and cell culture
171:147–152.
evaluating the prevalence of Cowdria burnetii, potential risk factors
for infection, and agreement between diagnostic methods in goats in
52. Taurel AF, Guatteo R, Joly A, et al. Relationship between the level of
antibodies in bulk tank milk and the within-herd seroprevalence of
levels in bulk-tank milk as an epidemiological tool to search for the
status of Cowdria burnetii in dairy sheep. Epidemiol Infect. 2011;139:
1631–1636.
54. van den Bröm R, van Engelen E, Luttikholt K, et al. Cowdria burnetii
in bulk tank milk samples from dairy goat and dairy sheep farms in
55. Martin SW, Shoukri M, Thoburn MA. Evaluating the health status of
herds based on tests applied to individuals. Prev Med. 1992;14:
33–43.
56. van den Bröm R, van Engelen E, Yus J, et al. Detection of Cowdria
burnetii in the bulk tank milk from a farm with vaccinated goats, by
a sheep and a goat flock associated with human infections. Epidemiol
information system to identify a dairy goat farm as the most likely
source of an urban Q-fever outbreak. BMC Infect Dis. 2010;10.
60. García-Perez AL, Astobiaga I, Barandika JF, et al. Investigation of
Cowdria burnetii occurrence in dairy sheep flocks by bulk tank milk analy-
61. de Bruin A, van Alphen PT, van der Plaats RQ, et al. Molecular typing
of Cowdria burnetii from animal and environmental matrices during Q
62. Eisenberg SW, Nielen M, Santema W, Houwers DJ, Heederik D, 
Koets AP. Detection of spatial and temporal spread of Mycobacte-
rium avium subsp. paratuberculosis in the environment of a cattle
63. van Engelen E, Luttikholt S, Peiperkamp K, Vellamera P, van den Bröm
R. Small ruminant abortions in The Netherlands during lambing sea-
64. Meadows S, Jones-Biton A, McEwen S, et al. Cowdria burnetii sero-
positivity and associated risk factors in sheep in Ontario, Canada.
65. Meadows S, Jones-Biton A, McEwen S, et al. Cowdria burnetii sero-
positivity and associated risk factors in goats in Ontario, Canada. Prev
66. Schimmer B, Luttikholt S, Hautvast JL, Graat EA, Vellamera P, 
Duynhoven YT. Seroprevalence and risk factors of Q fever in goats
67. van den Bröm R, Moll L, van Schalk G, Vellamera P. Demography of Q


119. Banazis M. Development of tools for surveillance of Coxiella burnetii in domestic ruminants and Australian marsupials and their waste. School of Veterinary and Biomedical Sciences Division of Health Sciences. Murdoch, Australia: Murdoch University; 2009.


Vaccinations can reduce the prevalence or severity of infectious diseases and are an integral part of any flock management program. In addition, vaccinations can improve overall flock health, resulting in decreased death loss and improved productivity. Vaccinations can improve reproductive efficiency by reducing infertility, embryonic deaths, and abortions.

Vaccination protocols vary widely by production type, region, producer preference, disease exposure, previous disease problems, and other flock-specific aspects. Other factors, such as proper nutrition management and good health practices, can also influence vaccination efficacy. A veterinarian can help tailor vaccination protocols to fit the needs and goals of an operation.

For the Sheep 2011 study, the U.S. Department of Agriculture's National Animal Health Monitoring System (NAHMS) collected data on sheep health and management practices from a representative sample of operations in 22 of the Nation's major sheep-producing States, which were divided into three regions. These operations collectively represented 85.5 percent of the ewe inventory and 70.1 percent of U.S. farms with ewes. Information on vaccination practices was collected on operations with 20 or more ewes.

General vaccination practices

The majority of operations (81.6 percent) vaccinated at least one of their sheep or lambs in 2010. The percentage of operations that vaccinated at least one sheep or lamb was similar by flock size (table 1) and by region (table 2).

Table 1. Percentage of operations that vaccinated any sheep or lambs during 2010, by flock size

<table>
<thead>
<tr>
<th>Flock Size (number of ewes)</th>
<th>Percent Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small (20–99)</td>
<td>80.3</td>
</tr>
<tr>
<td>Medium (100–499)</td>
<td>83.1</td>
</tr>
<tr>
<td>Large (500 or more)</td>
<td>89.5</td>
</tr>
<tr>
<td>All operations</td>
<td>81.6</td>
</tr>
</tbody>
</table>

Table 2. Percentage of operation that vaccinated any sheep or lambs during 2010, by region

<table>
<thead>
<tr>
<th>Region</th>
<th>Percent Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>West</td>
<td>87.6</td>
</tr>
<tr>
<td>Central</td>
<td>76.9</td>
</tr>
<tr>
<td>East</td>
<td>82.7</td>
</tr>
</tbody>
</table>

For all sheep age groups, the most commonly used vaccines were clostridial C and D, and tetanus. Over half of operations vaccinated their nursing lambs for clostridium C and D (enterotoxemia) and tetanus (60.5 and 55.0 percent, respectively) [table 3]. Overall, 71.4 percent of operations vaccinated at least one of their sheep or lambs for clostridium C and D, and 64.5 percent vaccinated for tetanus.

1 Regions:
West: California, Oregon, Washington
Central: Colorado, Idaho, Kansas, Montana, New Mexico, South Dakota, Texas, Utah, Wyoming
East: Iowa, Kentucky, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, Virginia, Wisconsin

United States Department of Agriculture • Animal and Plant Health Inspection Service • Safeguarding American Agriculture
Table 3. For operations with the specific sheep type, percentage of operations that vaccinated nursing lambs, weaned feeder (market) lambs, weaned replacement lambs, ewes, or rams against the following diseases during 2010

<table>
<thead>
<tr>
<th>Vaccine type</th>
<th>Nursing lambs</th>
<th>Weaned feeder (market) lambs</th>
<th>Weaned replacement lambs</th>
<th>Ewes</th>
<th>Rams</th>
<th>Any</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clostridial</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7- 8-way, blackleg, malignant edema</td>
<td>19.2</td>
<td>12.7</td>
<td>15.3</td>
<td>20.5</td>
<td>14.8</td>
<td>29.5</td>
</tr>
<tr>
<td>Clostridial C &amp; D (enterotoxemia)</td>
<td>60.5</td>
<td>39.8</td>
<td>37.9</td>
<td>38.8</td>
<td>28.8</td>
<td>71.4</td>
</tr>
<tr>
<td>Tetanus</td>
<td>55.0</td>
<td>32.9</td>
<td>33.0</td>
<td>34.0</td>
<td>25.3</td>
<td>64.5</td>
</tr>
<tr>
<td>Respiratory</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBR-PI-3</td>
<td>1.9</td>
<td>0.6</td>
<td>0.6</td>
<td>0.0</td>
<td>NA</td>
<td>2.7</td>
</tr>
<tr>
<td>Pneumonia (Pasteurella/Mannheimia)</td>
<td>0.8</td>
<td>0.6</td>
<td>0.8</td>
<td>1.5</td>
<td>0.5</td>
<td>2.1</td>
</tr>
<tr>
<td>Digestive</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scours (E. coli)</td>
<td>0.3</td>
<td>0.8</td>
<td>0.3</td>
<td>0.3</td>
<td>NA</td>
<td>0.9</td>
</tr>
<tr>
<td>Rotavirus</td>
<td>NA</td>
<td>NA</td>
<td>0.0</td>
<td>0.0</td>
<td>NA</td>
<td>0.0</td>
</tr>
<tr>
<td>Reproductive</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ram epididymitis bacterin (Brucella)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>0.0</td>
<td>NA</td>
</tr>
<tr>
<td>EAE (Chlamydiophila abortus)</td>
<td>NA</td>
<td>NA</td>
<td>5.7</td>
<td>7.6</td>
<td>NA</td>
<td>8.1</td>
</tr>
<tr>
<td>Leptospirosis</td>
<td>NA</td>
<td>NA</td>
<td>2.9</td>
<td>4.1</td>
<td>NA</td>
<td>4.2</td>
</tr>
<tr>
<td>Campylobacter fetus/jejuni (vibrio)</td>
<td>NA</td>
<td>NA</td>
<td>10.7</td>
<td>14.6</td>
<td>NA</td>
<td>15.2</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lumpy jaw (caseous lymphadenitis)</td>
<td>1.5</td>
<td>0.8</td>
<td>2.0</td>
<td>2.4</td>
<td>2.5</td>
<td>3.4</td>
</tr>
<tr>
<td>Footrot</td>
<td>0.3</td>
<td>0.1</td>
<td>1.1</td>
<td>3.4</td>
<td>2.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Rabies</td>
<td>0.0</td>
<td>0.1</td>
<td>0.6</td>
<td>1.1</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>Sore mouth (contagious ecthyma)</td>
<td>8.1</td>
<td>2.7</td>
<td>4.3</td>
<td>1.5</td>
<td>0.9</td>
<td>11.0</td>
</tr>
</tbody>
</table>

Collectively, 11.0 percent of operations vaccinated for sore mouth. Because the sore mouth vaccine contains live virus, vaccinating for sore mouth is only recommended when a flock is already infected with the virus. Vaccinating an uninfected flock will introduce the infection to the flock. The highest percentage of operations that vaccinated for sore mouth (70.6 percent) used a commercially available sore mouth vaccine (table 4). An autogenous sore mouth vaccine from a veterinarian was used by 5.9 percent of operations, and only operations in the Central region used an autogenous sore mouth vaccine from a veterinarian.

When the autogenous sore mouth vaccine was used, it was typically administered by the owner/operator (86.2 percent of operations); farm workers administered the vaccine on less than one-third of operations (29.0 percent). Because sore mouth is a zoonotic pathogen and giving the live vaccine can induce infection in humans, glove use during vaccination is recommended. Nearly half of the owner/operators that administered the vaccine wore gloves (45.4 percent), compared with just 13.1 percent of farm workers that administered the vaccine.
Table 4. For operations that vaccinated any sheep* for sore mouth during 2010, percentage of operations by type of vaccine most recently used, and by region

<table>
<thead>
<tr>
<th>Vaccine</th>
<th>West</th>
<th>Central</th>
<th>East</th>
<th>All operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado Serum Company</td>
<td>88.6</td>
<td>57.6</td>
<td>78.4</td>
<td>70.6</td>
</tr>
<tr>
<td>Autogenous vaccine from veterinarian</td>
<td>0.0</td>
<td>11.1</td>
<td>0.0</td>
<td>5.9</td>
</tr>
<tr>
<td>Other</td>
<td>10.4</td>
<td>24.3</td>
<td>0.0</td>
<td>16.0</td>
</tr>
<tr>
<td>Do not know</td>
<td>1.0</td>
<td>7.0</td>
<td>21.6</td>
<td>7.5</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

* Nursing lambs, weaned feeder (market) lambs, weaned replacement lambs, ewes, or rams.

Summary

For all age groups, the vaccines used most commonly were clostridial C and D and tetanus: nearly three-fourths of operations vaccinated for clostridium C and D, and about two-thirds of operations vaccinated for tetanus. Compared with the clostridial and tetanus vaccines, the other vaccines available garner less industry-wide agreement as to their need or effectiveness.

Vaccination is an important tool for disease control, but it is not the only tool available for preventing disease and losses due to animal morbidity and mortality. Other tools include biosecurity, nutrition, and handling practices.

For more information, contact:
USDA-APHIS-VS-CEAH-Nahms
NRRC Building B, M.S. 2E7
2150 Centre Avenue
Fort Collins, CO 80526-8117
970.494.7000
http://aphis.usda.gov/nahms

#683.0114

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual’s income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA’s TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410, or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

Mention of companies or commercial products does not imply recommendation or endorsement by the USDA over others not mentioned. USDA neither guarantees nor warrants the standard of any product mentioned. Product names are mentioned solely to report factually on available data and to provide specific information.
Health Management and Biosecurity Practices on U.S. Sheep Operations

Biosecurity is a system of practices designed to reduce the risk of introducing disease to an operation. Biocontainment is closely related to biosecurity but includes measures that reduce the spread of disease on an operation and from one operation to another. Together, biocontainment and biosecurity programs decrease infections and promote healthier more productive livestock.

As part of the Sheep 2011 study, the U.S. Department of Agriculture's National Animal Health Monitoring System (NAHMS) collected data on sheep health and management practices from a representative sample of operations in 22 of the Nation's major sheep-producing States, which were divided into 3 regions. These operations collectively represented 85.5 percent of the ewe inventory and 70.1 percent of U.S. farms with ewes.

General practices

General biosecurity practices may include isolation of new arrivals, disease management practices administered to new arrivals (e.g., vaccination), isolation of sick sheep, rodent and pest control, equipment cleaning, minimizing visitor access to sheep, and manure management.

Flock additions and reintroductions

Adding new sheep to the flock is a great way to improve stock and introduce new bloodlines. However, new additions can also introduce disease agents to the flock, including scrapie, ovine progressive pneumonia (OPP), Johne's disease, and caseous lymphadenitis (CL). In 2010, 33.0 percent of operations minimized their risk of introducing new disease to their flock by not adding new sheep, other than by natural birth, while 28.6 percent of operations did add new lambs or sheep other than those born on the operation. Management practices that reduce the risk of disease introduction by new additions include isolation, vaccination, shearing, foot trimming, deworming, and evaluating animal health status before flock introduction (figure 1).

Figure 1. For operations that added sheep in 2010, percentage of operations that performed the following health management practices on new sheep before they arrived at the operation

---

1 Regions:
West: California, Oregon, Washington
Central: Colorado, Idaho, Kansas, Montana, New Mexico, South Dakota, Texas, Utah, Wyoming
East: Iowa, Kentucky, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, Virginia, Wisconsin
Isolating new additions before placing them with the resident flock can reduce the risk of disease introduction. Less than half of all sheep operations that added new sheep (40.2 percent) quarantined new arrivals. As shown in figure 2, replacement ewe lambs less than 1 year old were quarantined for 28.5 days, on average. The recommended quarantine period is often 30 days, which, depending on the disease, might not be long enough.

**Figure 2. For operations that quarantined new sheep or lambs in 2010, operation average* number of days new arrivals were quarantined, by sheep type**

<table>
<thead>
<tr>
<th>Sheep type</th>
<th>Number of Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replacement ewe lambs less than 1 year old</td>
<td>28.5</td>
</tr>
<tr>
<td>Replacement ewe lambs 1 year or older</td>
<td>25.6</td>
</tr>
<tr>
<td>Replacement ram lambs less than 1 year old</td>
<td>38.0</td>
</tr>
<tr>
<td>Replacement ram lambs 1 year or older</td>
<td>23.9</td>
</tr>
<tr>
<td>All other sheep and lambs</td>
<td>57.0</td>
</tr>
</tbody>
</table>

*A single value for each operation is summed over all operations reporting and divided by number of operations reporting.

Similar to new sheep added to the flock, sheep that leave the operation to attend an event can introduce disease agents to the flock when they return. Overall, 33.7 percent of operations had sheep or lambs leave and return after attending a fair, show, sale, rodeo, or after visiting another operation. Other ways sheep have contact with sheep from other operations include fence-line contact, grazing with sheep from other operations, and sheep from other flocks visiting the operation. Just over one-third of operations in which sheep had opportunities for contact with other sheep (34.6 percent) made efforts to decrease nose-to-nose contact.

**Physical contact with other animals**

A number of diseases can be spread from other animals to sheep. For example, toxoplasmosis is an economically important disease commonly carried by cats and causes abortion and still births in many mammals, including sheep and humans. Sheep are infected by ingesting feed, bedding, pasture, or water contaminated by cat feces. During 2010, nearly all operations (94.1 percent) had some type of cat present. As shown in figure 3, feral or stray cats are also common; 74.5 percent of operations reported their presence.

**Figure 3. Percentage of operations by type of cats present during 2010**

<table>
<thead>
<tr>
<th>Cat type</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any cats</td>
<td>94.1</td>
</tr>
<tr>
<td>Any litters of kittens</td>
<td>46.4</td>
</tr>
<tr>
<td>Wild or exotic (e.g., bobcats)</td>
<td>28.9</td>
</tr>
<tr>
<td>Feral or stray</td>
<td>74.5</td>
</tr>
<tr>
<td>Outdoor domestic or indoor with outside access</td>
<td>79.2</td>
</tr>
</tbody>
</table>

Rodents also contribute to the spread of disease. For example, rodents are attracted to sheep feed, and feed contaminated by rodent fecal matter can serve as a source of pathogens. Rodent control is, therefore, an important part of biosecurity. Cats were used for rodent control on 79.2 percent of operations; 63.4 percent of operations used traps, bait, and/or poison to control rodents (figure 4).

---

*2 Cats that are either outdoor domestic or indoor with outside access; commonly referred to as "barn cats."
Figure 4. Percentage of operations by method used control rats and mice during 2010

<table>
<thead>
<tr>
<th>Method</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cats</td>
<td>79.2</td>
</tr>
<tr>
<td>Dogs</td>
<td>27.1</td>
</tr>
<tr>
<td>Traps, bait, and/or poison</td>
<td>63.4</td>
</tr>
<tr>
<td>Professional exterminator</td>
<td>1.9</td>
</tr>
<tr>
<td>Other</td>
<td>2.5</td>
</tr>
<tr>
<td>Any of the above</td>
<td>95.1</td>
</tr>
</tbody>
</table>

Shearing

The shearing process presents another potential source of disease introduction to a flock and between members of the same flock. For example, the blades of shears can carry diseases between operations and between individual sheep. If the skin of an infected animal is broken (either before or during the shearing process) and the shears used on the animal are not disinfected before another animal is shorn, there is the possibility for disease introduction/spread. As shown in figure 5, a majority of operations with 20 or more ewes that sheared sheep never disinfected shears between individual sheep.

Figure 5. For operations that sheared sheep during 2010, percentage of operations* by frequency shears were disinfected between individual sheep

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Always</td>
<td>54.0%</td>
</tr>
<tr>
<td>Sometimes</td>
<td>15.3%</td>
</tr>
<tr>
<td>Never</td>
<td>8.4%</td>
</tr>
<tr>
<td>Did not know</td>
<td>22.2%</td>
</tr>
</tbody>
</table>

*For operations with 20 or more ewes.

Additionally, the order in which sheep are sheared can impact disease transmission. Shearing from the youngest to oldest animals can decrease the likelihood of disease spread from older carrier sheep to younger naive sheep; this strategy, however, is not a common practice among U.S. sheep operations; 91.6 percent of operations with 20 or more ewes reported that sheep were not shorn in a particular order. Just 3.8 percent of operations that sheared sheep in 2010 sheared them from youngest to oldest, while 4.5 percent sheared sheep from oldest to youngest.

Biosecurity measures for visitors

Visitors can include people such as veterinarians, other sheep producers, shearsers, extension agents, nutritionists, feed company consultants, customers, and renderers. Visitors, especially those who have contact with animals from other operations, can introduce disease agents via their boots, clothing, vehicles, or other equipment. Overall, 97.1 percent of sheep operations had visitors enter the sheep production area during the previous 12 months. Nearly all these operations (96.6 percent) allowed visitors access to sheep-raising areas.

Hand-washing is an easy and effective method of preventing disease transmission and was always or sometimes required for visitors on 14.4 percent of operations (figure 6). In addition, 28.3 percent of operations always required visitors to park vehicles away from sheep areas, while another 12.0 percent sometimes required visitors to park away from sheep areas.
Lambing management and biosecurity

Periparturient ewes and newborn lambs are especially susceptible to infectious diseases because their immune system might be suppressed from either the stresses of pregnancy and birthing (ewes) or from an immature immune system (lambs). Cleaning the lambing area is, therefore, crucial in preventing disease transmission from ewe to lamb and from ewe to ewe. Prions (the cause of scrapie) and bacterial organisms (including the causative agents of Q fever and Johne’s disease as well as Salmonella species and Toxoplasma gondii) can be shed into the environment by tissue and fluid left by infected ewes following birth. Cleaning the manure and waste bedding from the lambing area during lambing season is crucial in preventing disease transmission. Figure 7 shows that 10.9 percent of operations cleaned the manure and waste bedding from the lambing area between each lambing, and 14.8 percent did so between two or more lambings. One-fourth of operations (25.4 percent) never cleaned the lambing area.

Abortions are frequently caused by infectious organisms that may be transmitted among ewes, making aborted fetuses and placentas a potential source of infectious organisms. In 2010, 43.8 percent of operations experienced abortions in their flock. Of these operations, 79.6 percent removed the placentas and/or fetuses as soon as possible (figure 9).
Manure management

Manure and bedding management is crucial in lambing areas, but it is also a key tool in reducing the spread of disease from infectious organisms shed in fecal material as well as reducing the parasite load of the sheep. Manure removed from the sheep pastures, sheds, barns, and feeding areas must then be disposed of. The majority of operations (79.4 percent) disposed of manure by applying it to land either owned or rented by the operation (figure 10).

Veterinarians and disease prevention

Part of a veterinarian’s job is to assist producers in preventing disease by consulting with owners on biosecurity and best management practices. In 2010, less than one-fourth of operations (23.9 percent) had a private veterinarian visit the operation for any sheep-related reason. On these operations, the two most common reasons for consulting a veterinarian were disease diagnosis and disease prevention (42.8 and 41.9 percent of operations, respectively) [figure 11].
Figure 11. For operations that consulted a veterinarian in 2010, percentage of operations by reason for consultation

<table>
<thead>
<tr>
<th>Reason</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disease diagnosis</td>
<td>42.8</td>
</tr>
<tr>
<td>Disease prevention</td>
<td>41.9</td>
</tr>
<tr>
<td>Interstate health certificate</td>
<td>22.2</td>
</tr>
<tr>
<td>Nutrition information</td>
<td>11.3</td>
</tr>
<tr>
<td>Production management</td>
<td>11.2</td>
</tr>
<tr>
<td>Lambing problems</td>
<td>31.8</td>
</tr>
<tr>
<td>Breeding soundness exam</td>
<td>10.9</td>
</tr>
<tr>
<td>Pregnancy check</td>
<td>6.1</td>
</tr>
<tr>
<td>Lameness</td>
<td>9.0</td>
</tr>
<tr>
<td>Other</td>
<td>8.0</td>
</tr>
</tbody>
</table>


The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual’s income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA’s TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250–9410, or call (800) 795–3272 (voice) or (202) 720–6382 (TDD). USDA is an equal opportunity provider and employer.

Mention of companies or commercial products does not imply recommendation or endorsement by the U.S. Department of Agriculture over others not mentioned. USDA neither guarantees nor warrants the standard of any product mentioned. Product names are mentioned solely to report factually on available data and to provide specific information.

Summary

Biosecurity and biocontainment practices can reduce the risk of disease introduction to an operation and the spread of disease on an operation. Each operation should develop its own plan, using customized protocols based on specific risks faced by the operation. When developing biosecurity and biocontainment plans, producers are encouraged to use the resources available to them, such as veterinarians, extension agents, and published resources.

For the Sheep 2011 study, the U.S. Department of Agriculture’s National Animal Health Monitoring System collected data on sheep health and management practices from a representative sample of operations in 22 of the Nation’s major sheep-producing States, which were divided into three regions. These operations collectively represented 85.5 percent of the U.S. ewe inventory and 70.1 percent of U.S. farms with ewes.

One objective of the Sheep 2011 study was to examine lambing management practices. Understanding commonly used lambing management practices can help producers identify problems on their operations and provide ideas for improved production.

Overall, 96.0 percent of lambs were born alive during 2010. The average number of live lambs born per exposed ewe was 1.3 for all operations. Operations in the East region had the highest average rate of live lambs per exposed ewe (1.5); lambing rate decreased as operation size increased. Very small operations and small operations averaged 1.4 live lambs per exposed ewe, while large operations (500 or more ewes) averaged 1.2 live lambs per exposed ewe. A higher percentage of lambs were born dead in the East region (5.2 percent) than in the West or Central regions (3.4 and 3.5 percent, respectively). Feedlot and dry lot operations were not included in lambing data calculations.

Lambing season

The highest percentage of all lambs born (alive or dead) were born in February through May for all operations (figure 1). Very small operations had the highest percentage of lambs born in February (28.6 percent), while large operations saw the highest percentage of lambs born in May (26.1 percent). A much smaller increase in the percentage of lambs born per month occurred during October through December on all operations sizes, except very small operations. Lambs born during this period can be marketed during the Easter season, when lamb prices are generally highest. Overall, 24.5 percent of operations bred at least some of their ewes for out-of-season lambing (September through December). A low percentage of herded/open range operations (5.6 percent) bred ewes out of season compared with the other operation types.

Figure 1. Percentage of all lambs born (alive or dead), by month and by flock size

<table>
<thead>
<tr>
<th>Flock size</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>All operations (1 or more)</td>
<td>10.0%</td>
</tr>
<tr>
<td>Large (500 or more)</td>
<td>2.5%</td>
</tr>
<tr>
<td>Very small (fewer than 20)</td>
<td>75.5%</td>
</tr>
</tbody>
</table>

Over three-fourths of all operations had one defined breeding season per year, while 10.0 percent had no defined breeding season (figure 2). Designating a specific breeding season allows producers to monitor the reproductive efficiency of their flocks and allows them to concentrate their labor during their busiest lambing times.

Figure 2. Percentage of operations by number of defined breeding seasons

- One: 75.5%
- Two: 11.9%
- Three: 10.0%
- None: 2.5%
Lambing location

A higher percentage of lambs in the East region (46.8 percent) were born in a barn or shed, compared with lambs in the West and Central regions (15.2 and 19.9 percent, respectively) [see table below]. The Central region accounted for the highest percentage of lambs born on the open range (28.4 percent). The use of an individual lambing pen was more prevalent in the East region (26.8 percent of lambs born) than in the West and Central regions (7.9 and 14.6 percent, respectively). Increased monitoring afforded by more confined lambing areas may influence the average number of live lambs born to exposed ewes, since administering assistance to ewes and lambs is more easily achieved when the animals are confined. However, there are a number of other factors, in addition to lambing observation, that influence the average number of live lambs born per ewe exposed.

Percentage of lambs born in 2010, by lambing location and by region

<table>
<thead>
<tr>
<th>Lambing location</th>
<th>Percent Lambs Born</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>West</td>
</tr>
<tr>
<td>Individual lambing pen</td>
<td>7.9</td>
</tr>
<tr>
<td>Barn or shed</td>
<td>15.2</td>
</tr>
<tr>
<td>Special lambing pasture</td>
<td>31.8</td>
</tr>
<tr>
<td>Other fenced pasture</td>
<td>29.2</td>
</tr>
<tr>
<td>Open range</td>
<td>8.4</td>
</tr>
<tr>
<td>Dry lot</td>
<td>7.5</td>
</tr>
<tr>
<td>Other</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Lamb supplementation

Feeding lambs high-quality colostrum following birth helps ensure the transfer of antibodies needed to protect lambs against disease. Usually, lambs receive adequate colostrum from their mothers but, for a variety of reasons, not always. At these times, it is necessary to supplement newborns using other colostrum sources. Just over half of operations (54.5 percent) gave lambs colostrum at birth from a source other than their mother. The majority of these operations (73.2 percent) used sheep colostrum from other ewes on their own operation. In addition, 73.2 percent of all operations supplemented lambs with milk or milk replacer. The most commonly used source of supplementation, however, was dried milk or milk replacer (74.6 percent of operations) followed by sheep milk from own operation (27.9 percent).

Castration and docking management

Of operations with ram lambs born on the operation, 68.5 percent castrated ram lambs; a higher percentage of large operations castrated ram lambs than small operations. The operation average age of ram lambs when castrated was 23.6 days. On herded/open range operations, ram lambs were castrated at an average age of 34.7 days, while rams on fenced range and pasture operations were castrated at an average age of 28.9 and 22.1 days, respectively. The majority of operations castrated ram lambs using a band (87.5 percent). The percentage of operations that used a band to castrate ram lambs decreased as flock size increased, while the percentage of operations that used a knife for castration increased as flock size increased. On very small operations, 93.1 percent used a band for castration and only 4.5 percent used a knife. On large operations, 56.9 percent used a band for castration and 34.5 percent used a knife.

Overall, 81.5 percent of lambs born alive were docked. Operations in the Central region docked a higher percentage of their lambs born (84.4 percent) than operations in the East region (74.9 percent). The choice of docking or not docking a lamb depends on many factors, including the projected use for the lambs, breed, and other reasons.

For more information, contact:
USDA-APHIS-VS-CEAH-NAHMS
NRRC Building 2, M.S. 2E7
2150 Centre Avenue
Fort Collins, CO 80526-8117
970-494-7000
http://aphis.usda.gov/nahms
#675.0114

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual’s income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA’s TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410, or call (800) 795-3272 (voice) or (252) 720-6382 (TDD). USDA is an equal opportunity provider and employer.
Producer Disease Awareness on U.S. Sheep Operations, 2011

For the Sheep 2011 study, the U.S. Department of Agriculture’s National Animal Health Monitoring System (NAHMS) collected data on sheep health and management practices from a representative sample of operations in 22 of the Nation’s major sheep-producing States, which were grouped into 3 regions. These operations collectively represented 70.1 percent of U.S. farms with ewes and 85.5 percent of the ewe inventory.

One objective of the Sheep 2011 study was to examine producers’ awareness of a select number of diseases: scrapie, Johne’s disease, ovine progressive pneumonia (OPP), Q fever, and toxoplasmosis. Q fever and toxoplasmosis can infect humans and are zoonotic diseases. Awareness of these particular diseases can increase operation productivity and decrease the impact of zoonotic disease spread from sheep. Data for this report on disease awareness were collected from 1,241 operations with 20 or more ewes. Full study results are available online at http://www.aphis.usda.gov/nahms.

Scrapie

Scrapie is a fatal degenerative disease affecting the central nervous system of sheep and goats. Infected flocks with a high percentage of susceptible animals can experience significant production losses. Animals sold from infected flocks can spread scrapie to naïve flocks, and the presence of scrapie in the United States prevents the export of breeding stock, semen, and embryos to many other countries. The USDA has established two programs—the National Scrapie Eradication Program (NSEP) and the Scrapie Flock Certification Program (SFCP)—that work in concert to eliminate scrapie from the Nation’s sheep flocks and goat herds. Both programs are cooperative efforts between producers, allied industry, accredited veterinarians, State animal health officials, and USDA’s Animal and Plant Health Inspection Service (APHIS).

The majority of operations (84.8 percent) reported that they were very familiar or somewhat familiar with scrapie (fig. 1). Operations in the West region were the most familiar with scrapie, with 94.9 percent reporting that they were very familiar (51.0 percent) or somewhat familiar (43.9 percent) with the disease (fig. 2).

Of the 84.8 percent of operations very or somewhat familiar with scrapie, nearly half (47.3 percent) implemented genetic selection to control scrapie in their flocks.

1 Regions:
West: California, Oregon, Washington
Central: Colorado, Idaho, Kansas, Montana, New Mexico, South Dakota, Texas, Utah, Wyoming
East: Iowa, Kentucky, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, Virginia, Wisconsin

2 There are many additional diseases of importance to sheep producers not covered in the Sheep 2011 study. These other diseases may also impact production and public health (e.g., zoonoses).
More information on scrapie can be found at: http://www.aphis.usda.gov/animal_health/animal_diseases/scrapie/

Johne's disease

Johne’s disease is a contagious, chronic, usually fatal infection that primarily affects the small intestines of ruminants. Found worldwide, Johne’s disease is caused by the bacterium *Mycobacterium avium* subspecies *paratuberculosis*, which belongs to the same family as tuberculosis and leprosy. Some strains preferentially infect species of ruminants (e.g., only cattle or only sheep); however, some cross infections do occur.

Most sheep are infected when young and do not show clinical signs until 2 to 6 years of age. In sheep, the most common indication an animal is infected with Johne’s disease is weight loss despite a normal appetite. Interestingly, despite the severity of the disease, over half the operations surveyed (55.9 percent) had either never heard of Johne’s disease or had heard of the name only (fig. 3).

![Figure 3. Percentage of all operations by reported level of familiarity with Johne’s disease](image)

Of operations very or somewhat familiar with Johne’s disease, 8.8 percent had a flock health management program specifically to control the disease.

Ovine progressive pneumonia

OPP is a slowly progressive, chronic viral disease of adult sheep caused by an ovine lentivirus. Most sheep never show clinical signs, and sheep that do typically do not display signs until 2 years of age or older. Common signs of OPP include increased breathing effort at rest, lagging behind the rest of the flock, progressive weight loss despite a normal appetite, and possibly hardbag syndrome, a noninflammatory mastitis. OPP is commonly passed from infected ewes to their lambs via colostrum and milk, or by inhalation of infected air droplets.

Once infected, animals remain infected for life. Flocks infected with OPP may have lowered production efficiency due to early culling, decreased milk production, and lower weaning weights. Half of all operations (53.5 percent) were either very familiar or somewhat familiar with OPP (fig. 5).
coxiellosis, the bacteria can infect a wide range of hosts, but the primary reservoirs are sheep, goats, and cattle. The disease is not generally considered problematic in animals, but it can cause abortion storms in sheep and goats and also poses a public health risk as it is zoonotic. When asked, the majority of sheep producers had never heard of Q fever or had heard of the name only (82.8 percent).

Figure 5. Percentage of all operations by reported level of familiarity with ovine progressive pneumonia

Figure 7. Percentage of all operations by reported level of familiarity with Q fever

More information about Q fever in humans can be found on the CDC Web site: http://www.cdc.gov/qfever/index.html

Toxoplasmosis

Toxoplasmosis in sheep is characterized by abortion storms in a flock. Toxoplasmosis, caused by infection with the protozoan parasite *Toxoplasma gondii*, is one of the most common parasitic infections of warm-blooded animals. Although more widely known for its infection of cats, *T. gondii* is found worldwide and its hosts include sheep and humans. Over half of the operations (54.0 percent) had either never heard of this zoonotic disease or had heard of the name only (fig. 8).

Figure 8. Percentage of all operations by reported level of familiarity with toxoplasmosis

Q fever

Q fever is an infection caused by the intracellular gram-negative bacterium *Coxiella burnetii*, found worldwide (except in New Zealand). Also called

For the 53.5 percent of operations that were very or somewhat familiar with OPP, 16.2 percent had a flock health management program specifically to control or prevent OPP. Nearly three-fourths of operations (72.7 percent) did not know their current OPP status while 18.7 percent reported never being infected with OPP, 5.4 percent indicated their flock was currently infected with OPP, and 3.3 percent indicated their flock was previously infected but was now OPP negative.
More information on toxoplasmosis in humans is available at:
http://www.cdc.gov/parasites/toxoplasmosis/index.html

For more information, contact:
USDA–APHIS–VS–CEAH–NAHMS
NRRC Building B, M.S. 2E7
2150 Centre Avenue
Fort Collins, CO 80526-8117
970.494.7000
http://www.aphis.usda.gov/nahms
#709.0615

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720–2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250–9410, or call (800) 795–3272 (voice) or (202) 720–6382 (TDD). USDA is an equal opportunity provider and employer.

Mention of companies or commercial products does not imply recommendation or endorsement by the U.S. Department of Agriculture over others not mentioned. USDA neither guarantees nor warrants the standard of any product mentioned. Product names are mentioned solely to report factually on available data and to provide specific information.
Disease and Mortality on U.S. Goat Operations

Poor goat health can cause economic losses for goat producers. Disease awareness and preventive management practices can reduce economic losses associated with poor goat health. Certain physiological symptoms are suggestive of disease in goats. Measuring the level of symptoms provides an estimate of the level of disease present in the U.S. goat herd.

The NAHMS Goat 2009 study was the first national study of the U.S. goat industry and was conducted in 21 of the Nation's major goat-producing States. These States represented 75.5 percent of U.S. goat operations and 62.2 percent of U.S. goats (NASS 2007 Census of Agriculture). Data for the study were collected from a stratified random sample of goat operations that kept at least one goat for meat, dairy, fiber, or other purposes. A total of 2,484 operations completed the study's first survey questionnaire and 634 completed a second mail-in questionnaire. The second questionnaire was limited to operations with 10 or more goats.

Deaths

Note: Data in this section represent only operations that had 10 or more goats.

Overall, 59.7 percent of operations had adult goats that died or were euthanized from July 1, 2008, to June 30, 2009, and 65.9 percent of operations had kids that died or were euthanized in the same period (excludes slaughtered goats and kids). A higher percentage of meat goat operations (74.1 percent) than dairy goat operations (55.0 percent) had kids that died or were euthanized. Overall, 13.8 percent of kids and 7.2 percent of adult goats died or were euthanized from July 1, 2008, to June 30, 2009. These mortality percentages were calculated by dividing the number of deaths in the 12-month period by the goat/kid inventory on July 1, 2009.

Disease awareness and management

Producers were asked to report the occurrence of symptoms commonly associated with several economically important goat diseases. These symptoms include joint swelling or crippled goats; weight loss; central nervous system signs; sores on foot area; udder inflammation; abscesses/bolus/lumps on the head or upper rear legs; and scabs around the mouth, udder, or hoof area. The above symptoms are suggestive of caprine arthritis encephalitis, Johne's disease, scrapie, footrot, bacterial mastitis, caseous lymphadenitis, or sore mouth, respectively.

The occurrence of producer-observed disease symptoms generally increased with herd size. More than one-third of large operations² reported that they had animals with mastitis or abscesses from July 1, 2008, to June 30, 2009 (35.8 and 34.9 percent of large operations, respectively). The increase in observed symptoms on large operations could be the result of more experienced producers on large operations who are more adept at identifying possible illnesses. Large operations also have more animals and typically add more new additions from outside the herd, which increases the risk of introducing new pathogens.

Producers were asked about their level of familiarity with several goat diseases. About half to three-fourths of operations were not familiar with Q fever, Johne's disease, and caprine arthritis encephalitis (78.0, 62.7, and 56.8 percent of operations, respectively) [figure 1]. Similarly, about half of operations were not familiar with caseous lymphadenitis (51.1 percent), brucellosis (49.3 percent), scrapie (46.6 percent), and sore mouth (44.1 percent).

Less than one-third of operations knew that brucellosis and sore mouth were infectious to humans (28.2 and 30.7 percent of operations, respectively). In general, the percentage of operations that knew that brucellosis, pinkeye (Chlamydia), Q fever, sore mouth, and toxoplasmosis were infectious to humans increased as herd size increased.

¹ States and Regions:
Northeast: Indiana, Iowa, Michigan, Missouri, New York, Ohio, Pennsylvania, Wisconsin
Southeast: Alabama, Florida, Georgia, Kentucky, North Carolina, Oklahoma (east), Tennessee, Texas (east), Virginia
West: California, Colorado, Oklahoma (west), Oregon, Texas (west), Washington.

² Operation size groups:
Very small: 1 to 9 goats
Small: 10 to 19 goats
Medium: 20 to 99 goats
Large: (100 or more goats).
### Figure 1. Percentage of operations by level of familiarity with the following diseases in goats

<table>
<thead>
<tr>
<th>Disease</th>
<th>Very</th>
<th>Somewhat</th>
<th>Not</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brucellosis</td>
<td>14.6</td>
<td>36.1</td>
<td>49.3</td>
</tr>
<tr>
<td>Caprine arthritis</td>
<td>15.4</td>
<td>27.8</td>
<td>56.8</td>
</tr>
<tr>
<td>Encephalitis</td>
<td>19.2</td>
<td>29.7</td>
<td>51.1</td>
</tr>
<tr>
<td>Caseous lymphadenitis</td>
<td>11.3</td>
<td>26.0</td>
<td>62.7</td>
</tr>
<tr>
<td>Johne's disease</td>
<td>6.0</td>
<td>18.0</td>
<td>76.0</td>
</tr>
<tr>
<td>Q fever</td>
<td>20.1</td>
<td>34.3</td>
<td>45.6</td>
</tr>
<tr>
<td>Scrapie</td>
<td>23.1</td>
<td>32.8</td>
<td>44.1</td>
</tr>
</tbody>
</table>

### Diseases

**Caseous lymphadenitis** is caused by the bacterium *Corynebacterium pseudotuberculosis*. Also known as boils or cheese glands, this disease is an important source of economic loss to sheep and goat producers. The percentage of operations in which producers observed goats with abscesses from July 1, 2008, to June 30, 2009, was relatively high (12.2 percent). Since drainage from abscesses can contaminate the environment and cause disease spread within a herd, it is important to avoid letting pus or other material from abscesses contact areas frequented by other goats. Recommendations include isolating affected animals until lesions heal or culling affected animals.

Since caseous lymphadenitis can also cause disease in humans (zoonotic), gloves should be worn when working with goats that have abscesses, especially when the abscesses are draining.

**Sore mouth**, also known as scabby mouth, orf, or contagious ectyma, is caused by a pox-virus and often appears as vesicles and thick scabs around the mouth, lips, nose, teats, udders, and hoof area of infected animals. Kids are most likely to be affected by sore mouth. Infection may reduce the amount kids eat or they might refuse to eat at all. Does, when affected on their udders, may refuse to allow kids to nurse and even abandon their kids. Sore mouth is a zoonotic infection; therefore producers should not touch scabs and should always wear gloves when working with these animals.

Overall, 4.4 percent of operations had observed goats with scabs around the mouth, udder, or feet from July 1, 2008, to June 30, 2009. Of operations with 10 or more goats, 14.9 percent indicated sore mouth was either suspected or confirmed on their operation during the previous 3 years.

The most common precaution taken by producers on these operations was to wash hands with soap and water after handling the goats (88.7 percent of operations). A little more than half of producers (54.4 percent) wore gloves when handling these goats.

**Johne's disease** in goats is difficult to diagnose and is one of several causes of weight loss despite a good appetite. Clinical signs common in cattle with Johne's disease are often not present in goats, and laboratory tests for Johne's disease are not as sensitive in goats as they are for cattle.

**Brucellosis** can be diagnosed by blood or tissue testing. Blood tests identify antibodies in the blood of animals that have been exposed to brucellosis, while testing tissues isolates the organism. About 6 percent of operations had tested any of their goats for brucellosis at least once during the previous 3 years.

Producers on operations with 10 or more goats were asked what type of brucellosis test had been used most recently. Of producers who knew what type of test had been used, 83.0 percent had used a blood test. Of operations that tested goats for brucellosis, 21.1 percent tested their goats for brucellosis because they drank the goat milk themselves.

**Q fever** is a zoonotic disease most often associated with infection in sheep, goats, and cattle, but it can also infect other domestic animals and wildlife. In sheep and goats, it often causes abortions and stillbirths. Humans often become infected by inhaling contaminated dust or consuming unpasteurized dairy products. In humans, Q fever symptoms are often mild and go undiagnosed. Of operations with 10 or more goats, only 0.3 percent reported that the producer, family members, or employees had ever been infected with Q fever. Acute infection may cause flu-like illness and pneumonia.

**Abortion**s can be caused by various diseases, including Q fever and toxoplasmosis, but are often the result of a combination of health issues. Of operations with 10 or more goats, 41.5 percent had ewes that had abortions or stillbirths from July 1, 2008, to June 30, 2009.

**Scrapie** is a fatal, degenerative disease affecting the central nervous system of sheep and goats. There are currently no tests available to determine genetic resistance/susceptibility to scrapie in goats. Keeping sheep on the same premises with goats can increase the risk of goats becoming infected with scrapie; however, not all scrapie cases in goats have been linked to exposure to sheep, so there is a possibility of transmission of the disease between goats. One way to protect a herd from disease introduction, including scrapie, is to keep a closed herd.
Mastitis

Note: Data in this section represent only operations with 10 or more goats that had does in milk from July 1, 2008, to June 30, 2009.

Overall, 2.8 percent of does in milk had clinical mastitis, and 30.7 percent of operations with one or more does in milk had at least one doe with clinical mastitis. Visual observations of the udder and/or milk was the most common method used for diagnosing mastitis (92.6 percent of operations), as opposed to using somatic cell counts or milk cultures.

Vaccinations

Note: Data in this section represent only operations that had 10 or more goats.

Vaccination can play an important role in reducing disease within a herd and should be part of any herd management program. Overall, 49.0 percent of operations vaccinated at least one goat or kid from July 1, 2008, to June 30, 2009. Of operations that vaccinated goats or kids, a higher percentage of operations in the Northeast region (12.8 percent) gave a sole mouth vaccine than operations in the Northeast region (2.2 percent). For the 8.2 percent of operations in which sole mouth was present, 16.0 percent used a sole mouth vaccine on at least one of their goats.

Because the sole mouth vaccine actually introduces infection, producers should not vaccinate unless sole mouth is already present in the herd. The vaccine is a live virus that causes disease in the vaccinated animal so it is best to vaccinate when disease will not cause production losses. For example, it is recommended that does be vaccinated 1 to 2 months prior to kidding so that there will be antibodies to sole mouth in theircolostrum, which will protect the newborn kids from disease. Use of gloves is recommended when vaccinating, as the vaccine can also cause disease in humans.

Kidding management and kid care

Note: Data in this section are for operations with 10 or more goats that had any kids born alive.

Colostrum provides valuable antibodies from the doe which help protect newborn kids against disease. Colostrum can be provided to newborns as soon as possible following birth. There are, however, a number of reasons for not letting newborns get colostrum from their mothers. For example, producers attempting to eliminate caprine arthritis encephalitis in the herd should remove newborns before they suckle mothers thought to be infected with the disease.

Overall, 43.2 percent of operations fed unweaned kids colostrum from the mother, either through nursing or by hand, while 21.5 percent fed colostrum from other goats (figure 2). A higher percentage of operations in the Northeast region (70.8 percent) fed unweaned kids colostrum from their mother than operations in the West or Southeast regions (39.2 and 31.9 percent, respectively). Three of four dairy goat operations (74.6 percent) fed unweaned kids colostrum from their mother (either by nursing or by hand) compared with 39.4 percent of meat goat operations.

Coccidia are tiny parasites that infect cells in the small intestine and can cause scour, unthriftiness, weight loss, and, in extreme cases, death. Coccidia are the most common cause of diarrhea or scour in goats from 3 weeks to 5 months of age. Overall, 43.4 percent of operations fed medicated feed to kids to prevent coccidia.

Culling

Operations cull animals because of disease, to reduce herd size, to improve genetics or desirable phenotypic traits, or to economize during episodes of high feed costs. Operations attempting to enlarge their herds are less likely to cull animals. The percentage of operations that culled either breeding bucks or does during from July 1, 2008, to June 30, 2009, increased with herd size, ranging from 8.1 percent of very small operations to 52.6 percent of large operations. About twice the percentage of operations culled breeding does (29.9 percent) as culled breeding bucks (14.5 percent), possibly because most operations have more breeding does than bucks. As a percentage of the July 1, 2009, breeding goat inventory, 15.3 percent of does and 20.6 percent of bucks were culled. The top three reasons does were culled were economic issues (27.3 percent of does culled), old age (24.4 percent of does culled), and low productivity (14.3 percent of does culled).

Producers were asked if specific symptoms had been observed in any goats or kids on the operation.
from July 1, 2008, to June 30, 2009. The symptoms listed were: joint swelling or crippled goats; weight loss in spite of good appetite; central nervous system signs; sores on hoof area with foul odor; mastitis; and abscesses, boils, or lumps on the head, shoulder, or upper rear legs.

When comparing operations by whether they culled or did not cull animals, there was a 2.4-fold greater chance (OR 2.4, 95% CI 1.1, 5.4) that operations that culled animals had observed three to five symptoms in goats or kids compared with operations that had observed no symptoms. It was about twice as likely that operations that culled animals had observed abscesses in goats or kids compared with operations that had not observed abscesses.

Summary

The occurrence of mastitis or abscesses was relatively common on large goat operations, possibly because producers on large operations are more experienced and adept at identifying symptoms of disease. Mastitis was common in operations with does in milk and was primarily diagnosed by visual observation. Many producers were not familiar with common goat diseases such as caseous lymphadenitis, sore mouth, Johne's disease, brucellosis, and Q fever. Only about one third of producers were aware that some of those diseases also are infectious to humans (zoonotic). Vaccinating at least one goat or kid was common, and operations in the West were more likely to vaccinate for sore mouth than operations in the other regions. Other health management practices such as isolating first kidding does were also relatively common. Culling was much more common on large operations than on smaller operations, and was also twice as likely to have taken place on operations that had observed several disease symptoms.

For more information, contact:
USDA–APHIS–VS–CEAH
NRRC Building B, M.S. 2E7
2150 Centre Avenue
Fort Collins, CO 80526-8117
970.494.7000
Email: NAHMS@usda.gov
http://www.aphis.usda.gov/nahms
#642.0112

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual’s income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250–9410, or call (800) 795–3272 (voice) or (202) 720–6382 (TDD). USDA is an equal opportunity provider and employer.

Mention of companies or commercial products does not imply recommendation or endorsement by the U.S. Department of Agriculture over others not mentioned. USDA neither guarantees nor warrants the standard of any product mentioned. Product names are mentioned solely to report factually on available data and to provide specific information.
Biosecurity on U.S. Goat Operations

Biosecurity is a system of practices designed to reduce the risk of disease introduction into a herd and prevent the spread of disease within a herd. Because disease transmission to even one animal can affect the health of the entire herd, biosecurity practices are an important part of the health management plan of all operations. Good biosecurity practices include proper handling of new animals and visitors; regular veterinary consultations; limiting contact with other animals; use of animal identification; and management of kidding areas and kidding products to minimize environmental contamination. Ideally, goat producers should work with a veterinarian experienced in goat production to develop practical and cost-effective biosecurity practices that reduce disease risk.

The NAHIMS Goat 2009 study was the first national study of the U.S. goat industry and was conducted in 21 of the Nation's major goat-producing States. These States represented 75.6 percent of U.S. goat operations and 82.2 percent of U.S. goats (NASS 2007 Census of Agriculture). Data for the study were collected from a stratified random sample of goat operations that kept at least one goat for meat, dairy, fiber, or other purposes. A total of 2,484 operations completed the study's first survey questionnaire and 634 completed a second mail-in questionnaire. The second questionnaire was limited to operations with 10 or more goats.

Herd additions

Adding new animals to a herd can introduce disease. One way an operation can prevent disease introduction is to keep a closed herd (adding animals only through kidding on the operation), although adding new animals from outside the herd is a great way to improve stock and bring in new bloodlines. When added, new animals should be quarantined and monitored for signs of disease. The duration of isolation must be sufficient for diseased animals to show clinical signs; however, it is important to be aware that infected animals may shed viruses without showing clinical signs.

Overall, 21.5 percent of operations had added goats or kids to the operation in the 12 months prior to the study (July 1, 2008 to June 30, 2009). Most operations that added adult goats obtained goats directly from another goat operation (72.8 percent of operations) or purchased goats at an auction market (23.5 percent of operations). Goats or kids obtained at an auction market or from another goat operation are considered a high risk for disease transmission compared with goats born on operation. Overall, 48.6 percent of operations that added goats or kids always isolated new additions, while 39.5 percent never isolated new additions. On average, new additions were isolated for a minimum of 21 days before introduction into the herd. A minimum of 30 days is recommended, and a longer quarantine is more likely to reduce transmission of previously unrecognized infections.

Another good practice is to require health management measures prior to introducing new animals. These measures can include veterinary examination, disease testing, deworming, and vaccinations. For operations with 10 or more goats that added goats in the previous 12 months, the most common health management practices used were inspecting new goats for abscesses or scabs (66.2 percent of operations) and internal parasite treatment (65.5 percent of operations) [figure 1]. Only 9.0 percent of operations required a veterinary examination, and only 11.6 percent required any individual animal testing for specific diseases.

---

1 States and Regions:
Northeast: Indiana, Iowa, Michigan, Missouri, New York, Ohio, Pennsylvania, Wisconsin
Southeast: Alabama, Florida, Georgia, Kentucky, North Carolina, Oklahoma (east), Tennessee, Texas (east), Virginia
West: California, Colorado, Oklahoma (west), Oregon, Texas (west), Washington

---

United States Department of Agriculture  •  Animal and Plant Health Inspection Service  •  Safeguarding American Agriculture
Figure 1. For operations\(^*\) that added goats during the previous 12 months, percentage of operations by health management practices required for new additions

<table>
<thead>
<tr>
<th>Practice</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Veterinarian examination</td>
<td>9.0</td>
</tr>
<tr>
<td>Any vaccinations</td>
<td>45.0</td>
</tr>
<tr>
<td>Foot trim</td>
<td>44.7</td>
</tr>
<tr>
<td>Medicated footbath</td>
<td>8.7</td>
</tr>
<tr>
<td>Internal parasite treatment</td>
<td>65.5</td>
</tr>
<tr>
<td>External parasite treatment</td>
<td>31.2</td>
</tr>
<tr>
<td>Inspect goats for abscesses and/or scars</td>
<td>66.2</td>
</tr>
<tr>
<td>Other</td>
<td>8.4</td>
</tr>
<tr>
<td>Any of the above</td>
<td>82.3</td>
</tr>
</tbody>
</table>

\(^*\)Operations with 10 or more goats.

Of operations that did not add any goats or kids during the previous 12 months, 49.6 percent had added goats or kids in the past 1 to 2 years and 54.8 percent had added goats or kids in the past 3 to 9 years.

Needle usage

Note: Data in this section represent only operations that had 10 or more goats.

Using the same needle when giving injections to several animals increases the risk of disease transmission between animals. The best practice is not to reuse needles. If this is not possible, disinfecting needles between animals can reduce the risk of disease transmission. Overall, 61.8 percent of operations had given at least one injection in the previous 12 months. Of operations that gave injections, nearly 49.6 percent used the same needle on more than one goat. Of these operations, 59.8 percent never chemically disinfected needles between animals. About one-fourth of operations (22.8 percent) always disinfected needles between animals, and the same needle was used on an average of 5.1 goats.

Use of veterinarian

A veterinarian experienced in livestock production can help develop practical and cost-effective biosecurity measures, and can be a good source of information about goat health and current issues in the goat industry. During the previous 12 months, about one-third of operations (34.8 percent) had consulted a veterinarian for reasons related to goat health, productivity, or management. One reason so few operations had consulted a veterinarian could be difficulty in finding a veterinarian experienced in goat production. The percentage of operations that consulted a veterinarian increased with operation size\(^2\), ranging from 28.7 percent of very small operations to 42.4 percent of large operations. A higher percentage of operations in the Northeast region\(^1\) (41.6 percent) consulted a veterinarian compared with operations in the Southeast region (30.8 percent).

Visitors

Visitors to goat operations include veterinarians, extension agents, nutritionists or feed company consultants, customers, renderers, and others. Visitors can contribute to disease spread from one location or herd to another by carrying disease agents on their vehicles, clothing, hands, or instruments. Overall, 68.7 percent of operations had visitors during the previous 12 months. Of these operations, 59.5 percent had visitors that entered the goat production area. The biosecurity measures always used for visitors by the highest percentages of operations were to have visitors park away from the goat area (35.0 percent) and to have visitors wash their hands before handling goats (14.4 percent) [figure 2].

Figure 2. For operations on which any visitors entered the goat production area during the previous 12 months, percentage of operations that always required the following biosecurity measures

<table>
<thead>
<tr>
<th>Biosecurity measure</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change into clean clothes or coveralls</td>
<td>1.9</td>
</tr>
<tr>
<td>Use a footbath before entry</td>
<td>1.9</td>
</tr>
<tr>
<td>Change into clean boots or shoe covers</td>
<td>5.5</td>
</tr>
<tr>
<td>Scrub shoes before entry or immediately after entry</td>
<td>3.0</td>
</tr>
<tr>
<td>Wash hands before handling goats</td>
<td>14.4</td>
</tr>
<tr>
<td>No contact with other livestock for at least 24 hr before visiting</td>
<td>2.8</td>
</tr>
<tr>
<td>Park away from goat area</td>
<td>35.0</td>
</tr>
<tr>
<td>Any</td>
<td>40.8</td>
</tr>
</tbody>
</table>

\(^2\)Operation size:

- Very small: 1 to 9 goats
- Small: 10 to 19 goats
- Medium: 20 to 99 goats
- Large: 100 or more goats

United States Department of Agriculture • Animal and Plant Health Inspection Service • Safeguarding American Agriculture
A higher percentage of very small operations (45.3 percent) required any of the biosecurity measures listed in figure 2 compared with large operations (29.7 percent). This finding is especially concerning because a higher percentage of large operations (74.0 percent) than very small operations (58.7 percent) had visitors, and a higher percentage of large operations with visitors than very small operations allowed visitors to enter the goat production area (64.7 and 53.4 percent, respectively). A higher percentage of dairy goat operations always required at least one biosecurity measure to prevent disease introduction by visitors who entered the goat production area (59.7 percent) compared with meat operations (35.1 percent).

Physical contact with other animals

Domestic and wild animals often serve as reservoirs (sources) of disease and minimizing contact with these animals is another important biosecurity measure. During the previous 12 months, almost 9 of 10 goat operations (88.8 percent) had dogs or cats on the operation and more than 5 of 10 (52.9 percent) had horses or donkeys. More than half of large operations (59.9 percent) had beef or dairy cattle. One-third of large operations (31.2 percent) had poultry, compared with about half of very small operations. A lower percentage of operations in the Southeast region (8.9 percent) had domestic sheep than operations in the West and Northeast regions (22.2 and 23.6 percent, respectively).

Overall, goats on 71.2 percent of operations had fence-line contact with or commingled with dogs, cats, raccoons, skunks, or opossums during the previous 12 months. Also, goats on more than 4 of 10 operations (43.9 percent) had commingled with or had fence-line contact with predators. Goats on one-third of operations (32.9 percent) had been in contact with deer, elk, antelope, or exotic hoof stock. In the West region, goats on one of five operations (21.2 percent) had fence-line contact or commingled with domestic sheep or goats from another operation, and goats on more than one-third of operations (37.2 percent) had contact with beef or dairy cattle from another operation.

Animal identification

The use of individual animal identification (ID) [a unique number assigned to each goat] and/or herd ID (farm name, farm logo, or a number unique to the farm) can be important tools in disease management and control. ID helps producers monitor important production parameters and makes it possible to trace an animal to its herd of origin if disease is diagnosed after an animal has been moved. Certain forms of ID are required by the USDA and/or individual States when animals are sold or when they are moved from their herd of origin. The percentage of operations that used either herd or animal ID increased with herd size, ranging from about one of three very small operations (30.7 percent) to three of four large operations (74.3 percent). Scrapie tags were the most common form of herd ID (15.6 percent of operations, representing 25.7 percent of goats and kids).

Kidding management

Note: Data in this section represent only operations with 10 or more goats that had kids born alive.

Does that become infected with certain pathogens for the first time while pregnant may abort, kid early, or have small or abnormal kids. Therefore, keeping first-kidding does away from others until after they have kidded may reduce the risk of infection. Overall, 38.1 percent of goat operations separated first-time kids from older does during kidding. Using the kidding area as a place to house sick goats is convenient when facilities are limited; however, this can also increase the risk of spreading infections within the herd.

Overall, 90.3 percent of operations did not house sick goats in the kidding area during the previous 12 months. This practice was less common on large operations (83.0 percent) than on small operations (95.1 percent). Ideally, manure and waste bedding should be cleaned from the kidding area after every birth, although doing so is not always practical, especially on large operations. One of four operations (25.7 percent) cleaned manure and waste bedding from the kidding area after each doe during the last kidding season, and 28.9 percent of operations never cleaned manure and waste bedding from the kidding area. A lower percentage of operations in the Northeast region (9.4 percent) than in the Southeast or West regions (34.1 and 35.3 percent, respectively) never cleaned manure and waste bedding from the kidding area.

Good biosecurity includes prompt removal of placentas and aborted fetuses. Placentas and aborted fetuses can harbor thousands of infectious organisms that can spread infections to other goats within the herd or to other animals on the farm. Dogs or cats can move placentas to areas that might contaminate feed, promoting transmission of infectious organisms.

A lower percentage of small and medium operations left placentas and aborted fetuses in the field or birthing areas (36.2 and 37.4 percent, respectively) than large operations (64.2 percent). A higher percentage of operations in the West and Southeast regions (52.6 and 41.6 percent, respectively) left placentas and aborted fetuses in the field and birthing areas than operations in the Northeast region (21.6 percent).
Summary

Introduction of disease to a naive herd can have serious economic consequences. Biosecurity measures can help reduce the risk of disease introduction. Goat producers can benefit from working with a veterinarian experienced in goat production to develop a cost-effective biosecurity plan for the operation. Recommended biosecurity practices include isolating new animals for 30 days, disinfecting needles between animals, limiting contact with outside animals, limiting visitor access to goat production areas, using animal identification, and managing kidding areas and kidding products to minimize environmental.

For more information, contact:

USDA–APHIS–VS–CEAH
NRRC Building B, M.S. 2E7
2150 Centre Avenue
Fort Collins, CO 80526-8117
970.494.7000
Email NAHMS@aphis.usda.gov
http://www.aphis.usda.gov/nahms

#640.0112

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual’s income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA’s TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250–9410, or call (800) 795–3272 (voice) or (202) 720–6382 (TDD). USDA is an equal opportunity provider and employer.

Mention of companies or commercial products does not imply recommendation or endorsement by the U.S. Department of Agriculture over others not mentioned. USDA neither guarantees nor warrants the standard of any product mentioned. Product names are mentioned solely to report factually on available data and to provide specific information.
| Ewe I.D. | Sire I.D. | Lamb I.D. | Birth Date | Sex | | | Comments |
|---------|----------|-----------|------------|-----| | | |
|         |          |           |            |     | | | |
|         |          |           |            |     | | | |
|         |          |           |            |     | | | |
|         |          |           |            |     | | | |
|         |          |           |            |     | | | |
|         |          |           |            |     | | | |
|         |          |           |            |     | | | |
|         |          |           |            |     | | | |
|         |          |           |            |     | | | |
|         |          |           |            |     | | | |
|         |          |           |            |     | | | |
|         |          |           |            |     | | | |
|         |          |           |            |     | | | |
|         |          |           |            |     | | | |
|         |          |           |            |     | | | |
|         |          |           |            |     | | | |