Small ruminant neonatal nutrition

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Abstract
Loss of preweaned lambs and kids is a significant economic burden on small ruminant enterprises. Nutrition is an important factor impacting neonatal losses. Four critical nutritional phases can impact neonatal viability: maternal gestational diet adequacy, colostrum feeding, milk feeding and rumen development, and post-weaning feeding practices. As with any farm animal, consumption of adequate amounts of high-quality colostrum is the single most critical event in the life of a small ruminant. In contrast to dairy cattle, no guidelines defining volume and immunoglobulin (Ig) content for sheep and goat colostrum to ensure adequate passive transfer are available. Similarly, there are no well-defined criteria for determining success or failure of passive transfer in sheep and goats. The second most critical event of the neonatal small ruminant is adequate rumen development to facilitate a smooth transition during the weaning process. This presentation will address these 4 nutritional phases with emphasis on colostrum management practices and rumen development as methods to improve neonatal survivability and viability.

Key words: sheep, goats, colostrum quality, passive transfer, rumen development, neonatal nutrition

Introduction
The recent National Animal Health Monitoring System (NAHMS) sheep survey shows an increase in lamb crop losses from 10.2% to 12% between 1994 and 2019.[1] The 2015 NAHMS Goat survey showed average kid losses at 19.4% with losses of 18.3%, 13.3% and 20.7% reported for Angora, milk and meat breed goats, respectively.[2] Of these losses, more than 75% are due to nonpredator reasons suggesting room for improvement relative to small ruminant neonatal management. Survival of the neonatal sheep or goat is a significant metric in assessing farm economics and animal welfare. Low and high birth weights are associated with lower survival rates in lambs and kids.[3-6] Consumption of an adequate amount of colostrum with appropriate immunoglobulin (Ig) content is the single most important event in the life of the newborn lamb or kid.[3,6] Unfortunately, colostrum management practices evaluating Ig concentration and passive transfer adequacy are not practiced as is the situation with dairy cattle, nor are there reference criteria for assessment.

It is obvious nutrition plays an important role in these factors as well as the dam's milk production.[7] In considering the role of nutrition in neonatal survival and productivity, one must address 4 critical nutritional phases in raising the preweaned lamb or goat kid as follows:

- Phase 1: Pregnancy nutrition to supply adequate nutrients for normal fetal development, survivability and nutrient storage in support of postnatal life.
- Phase 2: Colostrum for passive Ig transfer followed by milk feeding to support early growth.
- Phase 3: Feeding for adequate rumen development in preparation for weaning to solid feed.
- Phase 4: Post-weaning feeding practices to achieve desired growth rate.

This presentation will address each of these 4 critical nutritional phases relative to its impact on lamb and kid survival and growth with emphasis on the 2 most critical issues of colostrum management and rumen development.

Period 1) Maternal pregnancy nutrition
The last third of pregnancy often attracts the most attention as a result of the recognized exponential fetal growth occurring over this period and greater nutritional burden of late pregnancy on the dam.[8,9] The late gestational diet will greatly impact herd or flock prevalence of pregnancy toxemia and hypocalcemia. Unlike dairy cattle, sheep and goats are more prone to hypocalcemia during late gestation as a function of blood calcium loss to fetal bones and inadequate dietary intake. Late gestation diet, especially energy intake, will affect colostrogenesis.[10] Gestational protein status and dietary content has been associated with improved maternal immunity to parasites resulting in reduced postpartum fecal egg shedding.[11,12] Recent research has shown gestational nutrition in the first and second trimesters also has significant implications on neonatal development and survivability. The study of epigenetics or what is termed "fetal programming" has shown maternal gestational under or over-nutrition can impart lifelong effects on the developing offspring.[13] Early maternal nutrition can influence organ development, glucose regulatory mechanisms, future offspring fertility, and number of hair follicles.[13-17]

More attention has been placed on the role of trace minerals in their biologic roles, especially as antioxidants, on fetal and neonatal development and survival.[18-20] Milk is known to be insufficient in providing most of the trace elements to the nursing offspring. Survival of the neonate under this nutritional challenge is dependent upon hepatic mineral reserves obtained during gestation.[21] Particularly problematic in sheep and goats are deficiencies of copper, iodine, selenium and potentially zinc relative to perinatal health and survival. Copper has been especially of concern due to the complex interaction between copper, molybdenum, sulfur and iron affecting its availability to the animal.[22] The author has identified many clinical cases of infertility, stillbirth and weak, ill-thrift sheep and goats that was attributed to measured high forage molybdenum resulting in secondary copper deficiency disease. These trace minerals are intimately associated with immune function, which may impact the neonate's ability to manage infectious enteritis conditions leading to repeated bouts of infectious or parasitic diarrhea.

Period 2) Colostrum management and milk feeding
Like other ruminant species, sheep and goats have minimal transfer of maternal immunoglobulin (Ig) across the placenta resulting in the newborn being agammaglobulinemic. Feeding adequate amounts of high-quality colostrum to ensure successful passive Ig transfer is considered one of the most critical events in the ruminant animal's life. Beyond Ig, colostrum provides energy, protein, a bolus of fat-soluble vitamins (i.e., A, D,

and E) and minerals, both macrominerals and trace minerals.[23] Additionally, colostrum contains many growth factors and maternal leukocytes that are believed to initiate the fetal active immune response.[23]

Colostrum quality in small ruminants

Like other ruminants, IgG isotypes 1 and 2 are the predominant Ig in colostrum. Minimal concentrations of IgA and IgM may be found. Limited studies have documented Ig concentrations in goat colostrum across various breeds.[24-28] Among these studies there is tremendous variation in the determined mean IgG concentration with large standard deviations. Some studies had mean IgG concentrations below 20 mg/mL,[25,26] while other study findings were in the 50 to 70 mg/mL range.[24,27,28] Comparisons across these studies with the recognition of geographic population of goats would suggest a strong nutritional influence on colostrum quality. There is a paucity of published information characterizing colostrum quality in sheep.[27] The survey study of Kessler et al. shows significant difference in colostrum Ig concentration between meat and dairy breeds of sheep and goats where dairy breeds had lower Ig concentration.[27]

At Penn State we have completed 2 studies evaluating goat and sheep colostrum quality and relating IgG concentration to Brix measurement as a practical method of assessing sheep and goat colostrum quality. Our study found higher IgG concentrations in goat and sheep colostrum compared to these published studies, though there was a large standard deviation and range. Mean (± SD) IgG concentrations of 71.0 ± 36.8 mg/mL and 94.7 ± 74.5 mg/mL were determined for goat and sheep colostrum, respectively. Of interest all sheep samples were obtained from our Penn State sheep flock comprised of Hampshire and Dorset breeds. There was a significant difference between colostrum for these 2 breeds. We confirmed previous published work showing Brix refractometer can be used to evaluate goat colostrum quality. Use of Brix for sheep colostrum was more challenging due to the thickness of the colostrum. Diluting the colostrum with saline (1 part colostrum:3 parts saline) allowed for more consistent Brix measures.

Passive transfer adequacy

Unlike the information available for dairy cattle, there are few studies characterizing serum IgG concentrations in lambs and kids and relating back to colostrum quality or total IgG consumption. As part of our Penn State studies, we measured serum total protein (TP) and IgG concentrations in kids and lambs between 2 and 7 days of life. Mean serum TP for kids and lambs were similar at 6.0 g/dL with a range between 4.5 and 7.8 g/dL. Mean serum IgG concentrations in kids and lambs were also similar at approximately 15 mg/mL. Again, there was a wide range in measured IgG concentration. The average total IgG mass consumed by the kids to achieve this serum IgG concentration was 35 g. Colostrum was fed twice within the first 24 hours at a rate of 6-8 oz/feeding. Using the new consensus recommendations for calf serum IgG and TP, our sheep and goat samples would be in the Fair to Good categories, though our TP would be in the Good and Excellent categories.[29] Further work is needed to determine if the calf recommendations are appropriate for lambs and kids. All commercial lamb and kid colostrum supplements or replacers are of bovine origin and the recommended feeding rate is much below our measure of total IgG intake resulting is lower serum IgG concentrations.[30]

Period 3) Milk feeding and rumen development

The second most critical nutritional event in a ruminant neonate is negotiating a successful transition from milk to solid feed consumption. Feeding of whole milk from the dam is the most common method feeding lambs and kids. In small ruminant dairy operations, milk is harvested for product sales and milk replacer is provided to the neonates. Small operations that process their own milk may allow the lamb or kid to nurse until early weaning then collect milk for processing. There are many commercial milk replacers marketed for lambs and kids. Again, bovine milk proteins comprise the protein sources. Similar to calf milk replacers, protein sources should be milk proteins with no plant processed proteins. Review the guaranteed analysis to see that the crude fiber content is less than 0.15%, then read the ingredients label for the protein sources. The better lamb and kid milk replacers will contain between 25 and 30% protein and fat. Kids do not tolerate as high total solids compared to lambs, but one should not mix milk replacers to have more than 20% total solids.

Milk allows for rapid, quality growth; however, it does nothing to prepare the rumen for the required microbial fermentation of plant materials as the sole source of essential nutrients. Contrary to popular beliefs among many producers, forage feeding and microbial fermentation does not significantly contribute to the required metabolic and physiologic activities of the rumen papillae. Research with lambs and kids shows rumen papillae development is responsive to microbial production of butyrate predominately, and propionate to a lesser extent, equivalent to what has been documented in calves.[31,32] Both butyrate and propionate are volatile fatty acids generated primarily during sugar and starch fermentation. Fiber fermentation predominately generates acetate, which does not initiate rumen papillae development or metabolic activity. Rumen development can be initiated by feeding a grain-based creep feed. Some commercial creep feeds are adding sodium butyrate to further stimulate rumen development. Rumen development can occur during grazing of lush spring grass pasture as these cool season grasses contain a fair amount of sucrose polysaccharides (i.e., fructosans) that will ferment to butyrate predominately.

Period 4) Postweaning feeding

Weaning from a liquid diet to a solid feed diet is one of the most stressful periods in the life cycle. Many of the weaning practices used in dairy calves on high milk diets can be used for lambs and kids. Reduce milk feeding to encourage more grain consumption. Most problems arise during this period immediately following weaning due to either excessive stress conditions or inadequate rumen development. The weaned lamb or kid will continue to have high protein requirements to support their lean tissue growth. Once they are no longer consuming milk to meet their amino acid needs, they will need to rely on microbial protein generated in the rumen. Rumen development continues for a few months following weaning. This means the weaned ruminant is not as an efficient ruminant as an adult and thus will need to consume better quality forages where the neutral detergent fiber is more digestible.

The feed being consumed prior to weaning should be the same feed offered in the immediate post-weaning period. One can allow the weaned lamb or kid to consume more creep feed and offered a minimal amount of high-quality forage. Many post-weaned diets are complete pelleted or textured mixes. The post-weaning diet should be tailored to the intended purpose of the animal, growth, finishing or replacement. Finishing diets will contain a minimal amount of fibrous ingredients such as ground alfalfa hay or cottonseed hulls. In finishing diets, it is important to monitor dietary calcium and phosphorus content as well as consider adding ammonium chloride or similar acidifying ingredient to minimize the potential for urolithiasis. Growing diets will contain more forage sources to reduce dietary energy density and progressively have lower dietary protein content with advancing growth and age.

Summary

Neonatal survival followed by efficient growth is a key factor in a sustainable small ruminant enterprise. There are opportunities for improvement in reducing preweaned lamb and kid losses with nutrition playing a critical underpinning role. Four nutritional phases are recognized relative to impacting survival and health of the neonatal small ruminant starting with maternal gestational nutrition through post-weaning feeding. Two most critical periods of neonatal ruminants are timely and adequate colostrum feeding and ensuring proper rumen development prior to weaning. Criteria for evaluating colostrum quality and assessing passive transfer are in the early stages of development for lambs and kids. Breed differences exist, but nutrition may have a more important role than what is considered in dairy cattle. Direct application of dairy cattle colostrum criteria may not be appropriate for sheep or goats. Creep feeding or lush pasture grazing is necessary to generate rumen butyrate that will facilitate adequate rumen papillae growth and metabolic activity allowing for an easier transition to solid feed. Many opportunities exist for veterinarians to help support small ruminant clients improve their neonatal management practices.

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