Small Ruminant Nutritional Case Studies

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Nutritional problems in small ruminants are challenging as often sheep and goats are considered "equivalent" from a nutrient requirement perspective; however, there are a number of important differences as well as similarities in disease issues. This presentation will demonstrate fundamental principles of nutritional diagnostics in field cases where Cu nutrition was either inadequate or excessive leading to clinical signs.

Case 1. Meat goat herd experiencing reproductive losses
This was a meat goat herd of 75 does located in western Pennsylvania. The herd maintains approximately a 165% kidding crop. The herd is primarily managed as a grazing herd and hay cuttings are harvested off some pastures to provide forage during the non-grazing winter period. Pastures and hay are predominately a cool season grass with only a small amount of clover. A free choice mineral product is available for use and late pregnant does are provided an on-farm grain mix comprised of soybean meal, corn grain, molasses and a vitamin/mineral premix.

Presenting Problem: Herd was experiencing poor fertility during breeding season. During the winter 8 does were lost for various reasons including pregnancy toxemia. A total of 29 kids were lost due to late term abortion or stillbirths. Owner admitted the does looked "rough" this year and samples had been submitted to evaluate herd parasite status.

Diagnostic Process: Three stillborn kids were submitted for necropsy. Necropsy results showed no infectious agents responsible for kid deaths, all liver mineral samples indicated low copper (Cu) status (10.5-16.6 µg/g wet weight; Reference: 25 – 100 µg/g wet weight). No other abnormalities were found to indicate cause of death. Forage samples were collected and submitted for nutrient analysis (Table 1).

Table 1. Hay sample nutrient content results (all values other than moisture on dry matter basis).

Parameter	**Units**	**Grass Hay #1** 1st cutting 2013	**Grass Hay #2** 2nd cutting 2012	**Kalmbach Goat Mineral (label values)**
Moisture	%	12.4	10.7	
Dry Matter	%	87.6	89.3	99
Crude Protein	%DM	10.4	14.9	
Adjusted Protein	%DM	9.9	14.6	
Soluble Protein	%CP	27.6	17.3	
Rumen Degradable Protein	%CP	63.8	58.6	
TDN	%DM	58.6	59.1	
Acid Detergent Fiber	%DM	39.3	38.4	
Neutral Detergent Fiber	%DM	65.0	59.8	
Ash	%DM	6.67	9.39	99.5
NFC	%DM	17.1	14.5	
Calcium	%DM	0.39	0.85	15.5-18.5

Parameter	Units	**Grass Hay #1** 1st cutting 2013	**Grass Hay #2** 2nd cutting 2012	Kalmbach Goat Mineral (label values)
Phosphorus	%DM	0.28	0.28	8.0
Magnesium	%DM	0.11	0.29	1.5
Potassium	%DM	2.35	2.95	1.0
Salt	%DM			18.5-22.0
Sodium	%DM	0.005	0.008	
Iron	ppm	56	98	
Manganese	ppm	33	79	
Zinc	ppm	26	51	7500
Copper	ppm	6	9	1450-1850
Molybdenum	ppm	2.25	3.09	
Selenium	ppm			26

Key to the herd's current situation, both hay samples contain lower Cu content and higher molybdenum (Mo) content, which will result in lower Cu availability from these forages. Molybdenum and sulfur in the diet or water are metabolized by the bacteria in the rumen to generate compounds termed thiomolybdates. Thiomolybdates are well known for binding (chelating) Cu and making it unavailable to the animal. To address this potential interference between Mo and Cu we would like to have the dietary Cu:Mo ratio range between 6-to-8:1 in sheep and 6-to-10:1 in goats and cattle. Ratios below 4:1 are consistent with inducing a dietary copper deficiency problem. Both hay samples have low Cu:Mo ratios of 2.7:1 and 2.9:1, respectively. This would suggest that consumption of the mineral supplement is essential to balancing the consumed total diet in meeting the daily Cu requirements of the goats.

Dietary evaluation indicated total Cu intake was below requirement for pregnant does (9.35 mg/d vs. 26.8 mg/d) as well as dietary Cu availability being compromised. Consumption of at least 0.5 oz of the mineral could improve Cu intake to requirement needs. As the owner reviewed historical information on mineral feeding and herd performance there was a strong relationship between improved reproduction and less kid losses when more finances were spent on mineral supply.

Nutritional Recommendations: The mineral product being used can adequately supply sufficient Cu to the diet to meet the daily needs of the does, but the mineral needs to be continuously consumed at sufficient quantity. A minimum of 0.5 oz/head/day would be suggested, though this may be increased to 0.75 oz/head/day for pregnant does to ensure sufficient transfer to the fetuses. It was suggested to incorporate the mineral into the grain supplement and provide a minimum amount to all the animals. Allowing free choice intake leads to highly variable intake with some animals overconsuming (not a significant issue) and others underconsuming.

Case Outcome: Owner immediately starting adding mineral to the diet of the does and called a few weeks later to state some concern that he has not seen his does in estrus. The bucks had been with the does the entire time. The following spring he experienced and overwhelming kidding period where nearly all does kidded within a 1 week period indicating all does were bred when he was not seeing estrus activity. Kid losses were negligible that kidding season. The herd regularly incorporates mineral into the grain feeding practices and offers it free choice while grazing.

Case 2: Commercial sheep and goat herd with stillborn and weak lambs and kids

This case involved a 250 ewe flock of Finn, Dorset, Suffolk and crossbred sheep with a 200% lambing crop as well as 60 Boer does with 185% kidding crop. Farm is located in west-central Ohio and is managed intensively in providing a formulated total mixed ration (TMR) throughout the year.

Presenting Problem: The flock/herd had experienced problems with animal losses and Cu related diseases (swayback, enzootic ataxia) approximately 6 years previously. Unable to correct the underlying problem resulting in ongoing losses of lambs and kids. Approximately 17-25% stillbirth or weak neonates year to year. High perinatal death loss within 3-4 days of age.

Diagnostic Process: Flock owner had reached out to a number of sheep nutritionists to help identify and resolve the problem. A number of dietary changes were made but with little improvement in the overall situation. A number of retained livers from dead lambs and kids were submitted for mineral analysis (Table 2).

Table 2. Hepatic copper and molybdenum concentrations in population of kids, lambs and ewes from affected flock.

Liver Minerals	Kids, n=9	Lambs, n=4	Ewes, n=3
Cu, µg/g DW	28.6 ± 22.2	36.3 ± 16.7	18 ± 13.1
Mo, µg/g DW	3.6 ± 1.1	1.9 ± 0.6	3.3 ± 1.6
Cu Reference	75-300 µg/g DW	60-300 µg/g DW	60-300 µg/g DW
Mo Reference	1.5-3.0 µg/g DW		

In recognizing the issues of copper and molybdenum in the liver samples, forage samples were submitted. Table 3 summarizes forage testing results for copper and molybdenum over the past 5 years on the farm. Water tests from the farm indicated high sulfur (>500 ppm) and iron (>1 ppm). All forages are grown in the local area.
Table 3. Forage copper and molybdenum concentrations in farm forages over the past 5 years.

Forage Crop	Year	Cu, ppm DM	Mo, ppm DM
Clover hay	2011	5.1	2.52
Corn silage	2011	14.8	0.51
Clover hay	2011	9.8	5.04
Corn silage	2012	6.6	5.48
Oatlage	2012	7.4	5.31
Corn silage	2013	7.0	5.33
Oat forage	2013	7.0	5.77
Clover silage	2014	14.8	1.5
Clover hay	2015	12.5	8.43
Corn fodder	2015	6.5	2.97
Corn silage	2015	3.6	7.15
Corn silage	2015	4.3	6.87
Oat baleage	2015	8.4	2.47

Nutritional Recommendations: The primary assessment was inadequate dietary Cu availability based on forage testing and liver mineral concentrations. A custom premix used in the TMR formulation was modified to increase

Cu content to account for dietary Mo to achieve a total dietary Cu:Mo ratio of 6-8:1. Due to the excessive Mo in the forages the total dietary Cu content was an amazing 43 ppm DM, extremely above any recommendations for feeding sheep.

Case Outcome: New diets with high Cu were provided to early and late gestating rations. The following lambing and kidding season saw tremendous improvement in lamb and kid survival and ewe health. Diets were reformulated with the same approach the ensuring years following forage nutrient analysis to account for Cu and Mo. The third lambing season since adding the higher Cu diets starting with a horrific lamb loss of 40 out of 80 lambs born. A number of lambs or liver samples were submitted for mineral analysis (n=13) and necropsy (n=4). Again liver Cu concentrations were low in all samples that had not been treated with injectable mineral supplements. A new alfalfa hay had been purchased and fed in the gestation diets and subsequent nutrient analysis showed a Cu and Mo content of 15.4 and 22.1 ppm DM, respectively. The forage was removed from the diet and the TMR reformulated as previously to properly balance Cu and Mo. Lamb losses were resolved following the change for the latter lambing ewes.

Another interesting side note to this situation was an unexpected group of ewes lambing due to some rams not be removed. This ewe group was fed the maintenance diet and never exposed to the late gestation diets since it was not recognized they were pregnant. There were a number of issues with lamb viability in this group. The maintenance diet did address the Cu availability issue, but was not formulated to account for lower intake capacity and higher energy and protein needs. It was a testament to what a difference proper nutrition during critical periods makes for animal performance and health.

Case 3. Sheep flock experiencing high lamb losses

In this situation there were two adjacent farms owned by a father and his daughter and son-in-law. The farms were located in western Pennsylvania and the family has been in the sheep industry for multiple generations and active in 4-H showing of sheep. Both flocks are predominately grazed on cool season grass pastures on the respective farms and hay is harvested from these pastures and other fields to provide forage during the winter non-grazing period. A custom grain mix is provided at 1 lb/head/day for late gestating ewes. Trace mineral salt is provided free choice.

Presenting Problem: On the daughter's farm they experienced high stillbirth and neonatal lamb losses (>25%). Twenty four of 25 2-year old ewes died and no lambs from these ewes survived. The affected ewes were described as reducing feed intake and segregating from the flock, looking thin to cachexic and then found dead within 1-3 days from first signs. There were no lamb or ewe losses on the father's farm.

Diagnostic Process: Stillborn lambs were submitted for necropsy with a similar finding of no infectious agents or other obvious cause for their demise. Liver mineral concentrations showed low Cu, but no other issues. Two-year old ewes also had no significant findings accounting for their demise. Liver mineral concentrations of these ewes showed normal Cu, but very elevated Mo (6.68 µg/g DW; Reference 1.5 – 3.0 µg/g DW). The farms were visited to review management and feeding programs and evaluate the ewes. Forage samples were collected on each farm for nutrient analysis (Table 4). Water samples were submitted from both farms and from various sources within each farm. A sample of a new limestone product used to lime all fields on the daughter's, but not the father's, farm was collected. This product is a byproduct of the steel polishing industry from Pittsburgh and sold at a low cost compared to traditional agricultural limestone products.

Table 4. Comparison of forage copper and molybdenum content for the two farms.

Forage	Cu (ppm)	Mo (ppm
Daughter's Farm		
Baleage	13	7.81
1st Cut Hay	8.0	3.46
1st Cut Round Bale	7.0	5.66
2nd Cut Round Bale	11.0	7.15
Grain mix	6.0	1.9
Father's Farm		
1st Cut Hay	12.0	1.45
2nd Cut Hay	11.0	2.13
Grain mix	7.0	1.62

Nutritional Recommendations: The forage test results indicated a significant difference in Mo content between farms. No significant issues were identified in water samples from either farm. The daughter's farm had a new gas well drilled 2 years ago. Results of the limestone product analysis showed a high Mo content (21 ppm), which was confirmed by further DEP analysis on the farm as requested by the Pennsylvania Department of Agriculture once they were aware of the animal loss issues. A group of affected ewes were moved from the daughter's to father's farm and fed only forages from the father's farm. The remaining ewes were provided a 2 g CuO pellet for the remainder of the grazing season as it was decided a high Cu free choice mineral would not be a workable solution. Copper content of the premix incorporated into the grain mix was increased for the daughter's farm.

Case Outcome: There were no further animal losses for the remainder of the grazing season and all ewes seemingly were bred for early February lambing. Serum Cu concentrations were determined in 3 groups of 18 ewes to assess Cu status 6 months after dietary changes (Table 5). Lambing season went well with no lamb losses and good viability. The last 2-year old ewe and 2 other ewes died after all lambs were weaned. Liver mineral concentration showed a higher Cu (352 µg/g DW) and high Mo (6.8 µg/g DW) in this ewe. Ewes on the daughter's farm were given another 2 g CuO bolus for the grazing season. Forage testing is being completed to monitor the Mo status. How long it will take for the Mo to be removed from the soil and forages remains uncertain. Ongoing Cu status monitoring is shown in Figure 1.

Table 5. Comparison of ewe serum Cu concentrations.

Group	Serum Cu (µg/mL)	
	Mean	Range
Home farm	1.09 ± 0.20^a	0.82 – 1.46
Transferred	0.87 ± 0.13^b	0.63 – 1.26
Boluses	0.60 ± 0.28^c	0.26 – 1.01
Blood collected in December from 18 ewes for each group		
25% of "Bolus" ewes had serum Cu < 0.3 µg/mL		

Take Away Points to the Case Studies

These case studies all suggest a new clinical presentation of copper deficiency in sheep and goats characterized by stillbirths and weak, unthrifty neonates. This has not been a recognized consequence of copper status documented in any nutrition text. Other trace minerals, especially selenium, zinc and manganese, may also be involved in such clinical issues. Recent and past research has suggested lower hepatic trace mineral status in aborted and stillborn fetuses, but no direct cause and effect relationship has been documented. These cases also underscore the critical need for timely forage analysis to recognize potential nutritional issues. Many small ruminant clients do not utilize this diagnostic resource, but it is critical to identifying potential nutritional risks. Mineral analysis of forages must be completed using wet chemistry and not near infrared spectroscopy (NIR) methods. One should always include molybdenum analysis with copper and possibly sulfur to ascertain potential for dietary copper availability.

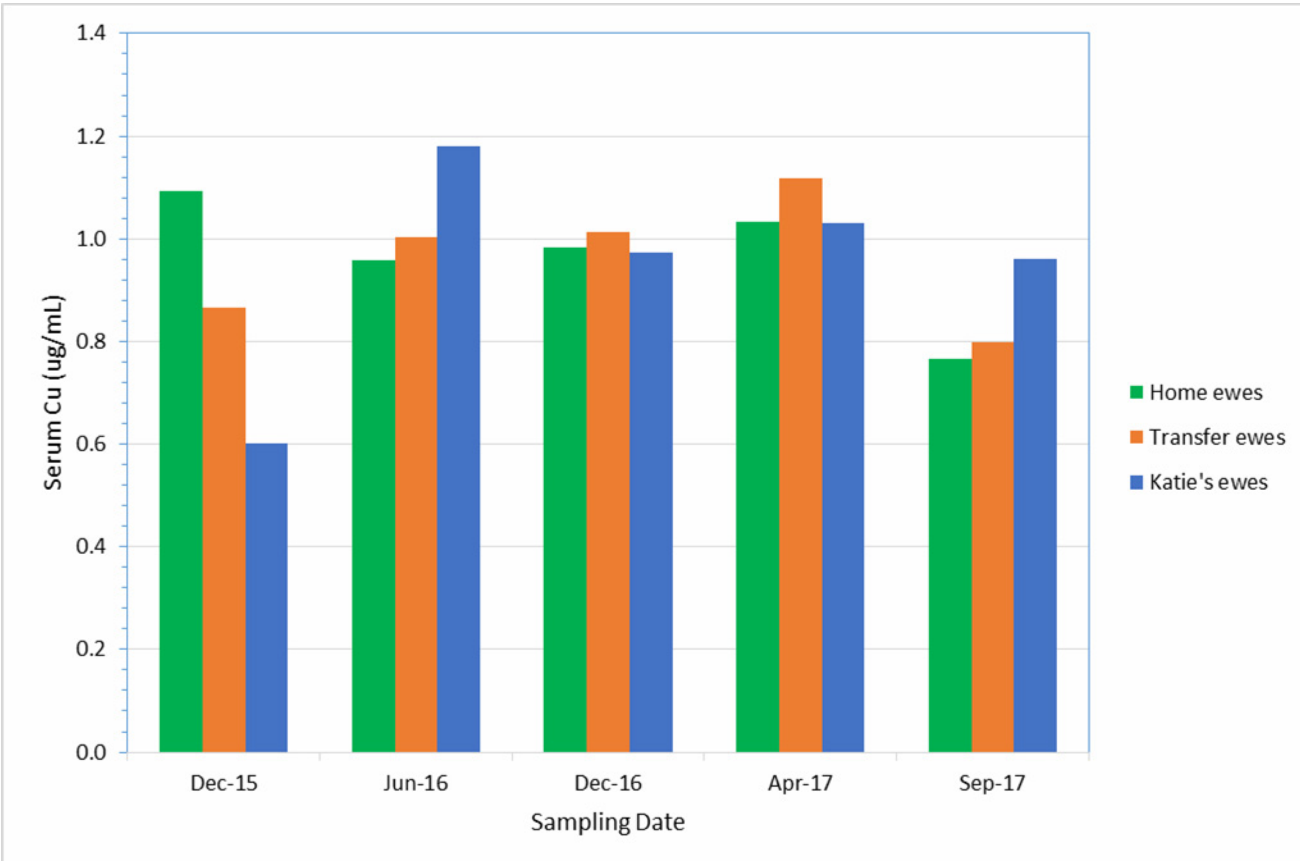

Figure 1. Comparison of serum Cu concentrations over time for three groups of ewes with different expsoure to high forage molybdenum. Katie's ewes group was administered 2 g CuO boluses at three time points.