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SHEEP PHOSPHORUS REQUIREMENTS AND MANAGEMENT CONSIDERATIONS FOR INTERMOUNTAIN WEST RANCHERS

Sheep operations vary drastically in management throughout Utah, Wyoming, and much of the western United States. An estimated 624,000 sheep across Utah and Wyoming are from operations with more than 100 head. In addition, many of these ranches are extensively managed sheep operations on rangelands. In contrast, approximately 2,300 or 83 percent of Utah and Wyoming operations have less than 100 head of sheep, and more typically use confined shelter and feeding resources, including more reliance on harvested feeds. Regardless of this variation in operation characteristics, efficient sheep production systems all use affordable and readily available feed resources.

Extensively managed range sheep operations may depend on the naturally grown forages on winter range of the

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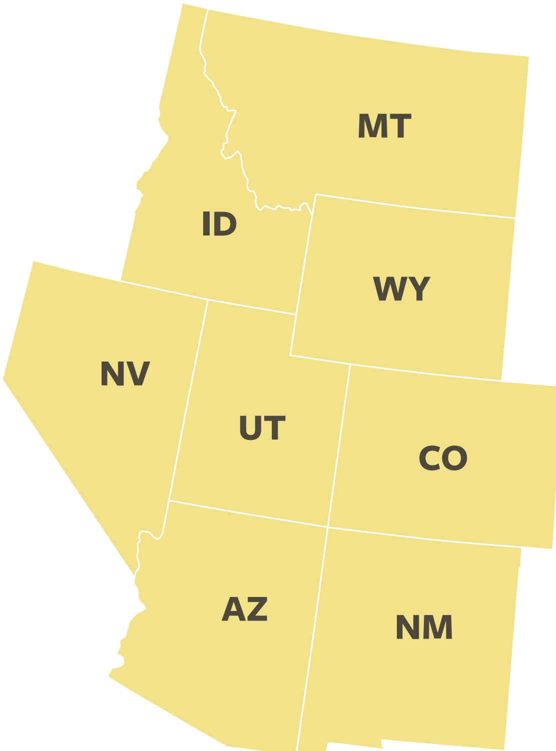

Figure 1. The Intermountain West states of Montana, Idaho, Wyoming, Nevada, Utah, Colorado, Arizona, and New Mexico.

Red Desert, the sagebrush steppe of the Uinta Basin, or a variety of forbs and perennials in the subalpine range of the Wasatch. In contrast, a large percentage of smaller operations may utilize rotational grazing on irrigated pastures, operate small feedlots, or increase production by lambing several times a year. The type of sheep raised and feed consumed across these diverse operations make providing a one-size-fit-all recommendation to clients difficult, and recommendations for feeding specific minerals and nutrients is no exception.

In general, many areas of the Intermountain West, Figure 1, tend to have alkaline soils (pH greater than 7). The far Western, Midwest, and Eastern United States that experience higher rainfall will often have soils with more neutral or acidic pH values. Alkaline soils are on the high end of a pH scale with many soils decreasing the amount and type of macronutrients plants that are available for plants to uptake through their roots starting around a pH of 7.5. Phosphorus becomes limited for plant availability around a pH of 7.5 and becomes extremely limited to plants with a soil pH of 8.5.

Table 1. Approximate phosphorus (P) requirements of sheep at various stages of production (NRC, 2007).

Sex	Stage of Production	Weight (lbs.)	P requirement (g/day)
Ewes	Maintenance	154	2.0
		176	2.2
	Early gestation (w/twins)	154	4.6
		176	5.1
	Late gestation (w/twins)	154	5.3
		176	5.8
	Early lactation (w/twins)	154	6.9
		176	7.4
	Late lactation (w/twins)	154	4.6
		176	5.1
Rams	Growing (0.88 lbs./day)	110	5.1
		154	6.1
	Maintenance	275	3.7
		330	4.3
	Pre-breeding	275	4.1
		330	4.7
Lambs	Growing (0.44 lbs./day)	44	2.5
	Growing (0.66 lbs./day)	88	4.3

Phosphorus (P) nutrition in sheep is a challenging topic when addressing producers from diverse sheep management systems. Still, P is an essential nutrient despite location or type of management system because P is noted to be the most limiting mineral for grazing animal productivity globally (Holechek et al., 1995). P is the second-most abundant mineral in the body of an animal, with roughly 80 percent of P in bones and teeth. The remaining 20 percent of P is distributed throughout the body in fluids and other tissues. At the cellular level, P is an essential component of DNA and RNA, energy storage and release (ATP, ADP), cell membrane integrity, nerve tissue and more. Long story short, sheep cannot live without P.

PHOSPHORUS SOURCES AND POTENTIAL DEFICIENCIES

Poor skeletal growth, depraved appetite, and infertility are clinical signs of P deficiency. Poor skeletal growth can be an arbitrary observation. Since both calcium (Ca) and P are involved in bone mineralization, and the relative ratio of Ca:P is important, there are similarities in the bone deformations, such as rickets (bent leg) in growing sheep. Young sheep can adapt to clinically low levels of P through changes in bone mineralization. Less noticeable signs such as soft bone and the more rapid breakdown of teeth can contribute to greater ewe turnover, requiring a greater ewe lamb replacement rate. Poor appetite and subsequent growth rates can go unnoticed in extensive range operations where sheep aren't checked daily. But lighter weaning weights, more dry ewes at lambing, and a less thrifty animals over time might indicate a need to evaluate the P supplementation strategies for the flock.

P deficiencies found under range conditions can be a result of low P and high Ca diets. P reserves are diverted away from leaf tissues into seed formation as a plant reaches maturity. Many western US sheep operations grazing rangelands will notice a rapid decline in P content of grasses as the growing season progresses. Cool season grasses like Idaho fescue (*Festuca idahoensis*) or sheep fescue (*Festuca brachyphylla* subspecies *coloradoensis*) will reach maturity by mid-summer and then experience a nutritional decline. Data from clippings taken from rangelands in northeast Wyoming showed a 50 percent reduction in P from August to December (0.14 – 0.03 percent; data unpublished). Another recent Idaho study showed a 25 percent reduction of P across irrigated pastures and rangelands from summer to fall (Sprinkle et al., 2018). In this study, P concentrations on range and irrigated pasture were rarely adequate to meet requirements during summer or fall. P deficiency can occur when pastures contain less than 0.16 percent P or 0.2 percent P with pregnant ewes. Late summer through winter, or whenever sheep are managed on lower quality grasses, present time points to provide supplemental P in the mineral.

This illustrates the increased reliance on other dietary sources of P on many rangelands and even pasture-based sheep operations during late-season grazing summer through fall. When compared to critical

Table 2. Phosphorus (P) content of common feed ingredients and rangeland plants.

Commonly harvested feeds[1]		Commonly grazed forages[2]	
Feed Ingredient	**% Phosphorus DM basis**	**Forage**	**% Phosphorus DM basis**
Alfalfa Grass Hay Mix	0.19	Big Sagebrush	0.18
Alfalfa Hay Full Bloom	0.24	Black Sagebrush	0.17
Crested Wheatgrass Hay	0.14	Meadow Fescue	0.42
Corn	0.30	Needle-and-thread	0.06
Soybean Meal 44% CP	0.71	Orchardgrass	0.39
Cottonseed Meal 41% CP	1.19	Timothy	0.28
Dicalcium Phosphate	0.18 – 0.22	Winterfat	0.12

[1] Values obtained from: Small ruminant NRC, 2007
[2] Values obtained from: United States-Canadian Tables of Feed Composition, third revision

production stages, P concentrations decrease in forages at the same time sheep requirements increase in many operations (Table 1, page 2). Rams and ewes have higher P requirements leading into the breeding season and the ewe throughout pregnancy, which coincides with when dormant grasses low in phosphorus are grazed. Even for those that lamb in fall, remember that P concentrations will be low when requirements are highest during lactation.

Requirements are greater for forage-based diets, with the assumption of increased salivary P output and more P lost in the feces. Additionally, growing lambs exhibit greater P absorption than adults (90 percent vs. 55 percent). Many replacement ewe lambs are developed to be bred at 18 months and are minimally developed on rangelands, often with little additional supplementation. Such critical periods of reproductive development in replacement ewes especially warrant provision of a P-containing mineral or supplement as decreased conception rates have occurred due to inadequate P. Attributing reproductive losses solely to P deficiencies, because energy and protein drive reproduction, is difficult, yet, at the cellular level, an absence of P can bring metabolism to a halt.

PHOSPHORUS CONTENT OF FEED

Forages are generally high in Ca and low in P. In contrast, grains and by-products generally are high in P and low in Ca. In terms of forage P composition, generally legumes contain more P than grasses. Confinement sheep operations that feed a large amount of grain by-products can easily meet P requirements from the feed, whereas forage-based operations might be more reliant on mineral supplementation to meet animals' needs. A feed composition table can be useful to provide an estimate of P content in feedstuffs but can't replace the site-specific accuracy of a lab analysis.

Range Sheep Phosphorus (P) Scenario

Let's consider a region-specific example of an extensive range operation in the Wyoming Red Desert to calculate if our animals' P requirements are met. Assume we have a 150-lb. Rambouillet ewe in early gestation carrying twins in the uterus is grazing dormant winter range with a P content of 0.14 percent. Assuming this ewe can consume 2.5 percent of her body weight, she will consume 2.3 g/day of P or only 50 percent of her 4.6 g daily P requirement. On the other hand, if we provided the ewe with a typical 8 percent P-containing mineral, assuming 1 oz. of mineral is consumed, she will have a combined P intake of 4.5

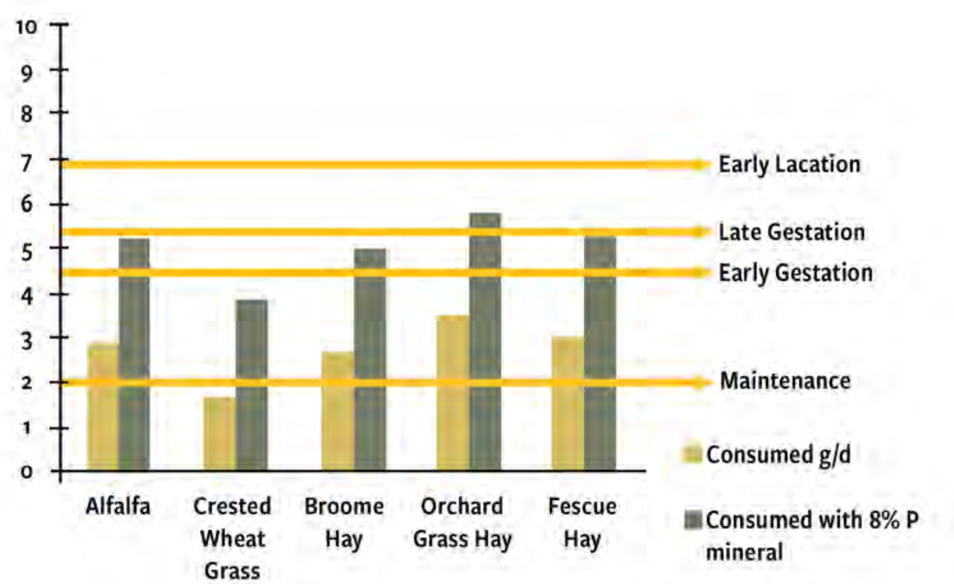

Figure 2. Estimated phosphorus (P) consumption of 150 lb. ewe 1) from forages only, and 2) forages + mineral contribution, assuming 8 percent P mineral consumed at 1 oz/day (NRC, 2007).

g/d. She will consume 98 percent of her 4.6 g daily P requirement.

Farm Flock Phosphorus Scenario

In contrast, a small farm flock with a 175-lb. Suffolk ewe in early gestation with twins in the uterus is consuming 3 lbs. of alfalfa hay (0.19 percent P) and 1 lb. of soybean meal (0.71 percent P) will roughly consume 5.8 g/d or 114 percent of her required 5.1g of daily P. An additional ounce of 8 percent P-containing mineral would result in the consumption of 157 percent of her daily P requirement. This larger Suffolk ewe's increased P requirement is easily met by feeding soybean meal. Feeding hay alone would only meet 68 percent of her 4.6 g daily P requirement. While these are generic examples, they illustrate the need and approach to look at P requirements by stage of production and management system.

CALCIUM TO PHOSPHORUS (Ca:P) RATIOS AND URINARY CALCULI (i.e., WATER BELLY)

It is important to consider Ca levels in the diet concurrently when discussing dietary P concentrations and requirements. Complications can arise when the appropriate Calcium-to-Phosphorus (Ca:P) ratios are not met, with water belly or urinary calculi being one of the clinical outcomes of this imbalance in sheep. For example, early castrated ram lambs have been suspected to be more prone to water belly, since removal of hormonal influences necessary for maturation result in a smaller urethral process than intact rams. In general, water belly is largely a nutritional disorder more than anything. Urinary calculi becomes a greater challenge in high P diets, which generally are high concentrate diets (Table 1). This obstruction of the urethral process from phosphate-calcium stones results in clinical cases that seldom end well. The problem with P excess or imbalances is generally spoken of in regard to the Ca:P ratio, where an impaired absorption of calcium and phosphorus occurs in instances when this ratio is > 7:1 or < 1:1. Yet, we all have seen many exceptions to the rule where we have greatly exceeded the ideal 2.5:1 Ca:P ratio. We often hedge these ratios with addition of 0.5 percent ammonium chloride (8-10 lb./ ton of feed) or adding Ca sources (limestone) to the diet, yet these are not always perfect at eliminating urinary calculi. Maintaining a Ca:P ratio of 2.5:1 in high concentrate diets is a challenge where high grain diets more closely resemble 1:4 to 1:6. Nutritionists under these circumstances will reduce phosphorus or add limestone from a mineral

Table 3. Published literature discussing Ca:P ratio and its relationship with urinary calculi (water belly) in rams.

Source	Animals	Feedstuff	Ca:P ratio	Effects
Emerick and Embry, 1963	Texas wether lambs	67% corn silage, 28% ground corn, 5% soybean meal	1.3:1 with increasing phosphate concentrations	Decreased Ca:P ratio or high P diets increase incidence of urinary calculi up to 31% and could be reduced by adding limestone to the diet.
Bushman et al., 1965	Lambs	77% ground corn, 20% ground alfalfa hay, 3% soybean meal	Basal diet 1.5:1 High P diet 1:1/5 or .55% P	Basal diet had ~2% incident of urinary calculi while high P had ~42% of lambs with urinary calculi.
Godwin and Williams, 1982	Merino wether lambs	Oaten chaff, Lucerne chaff, and increasing Wheat grain	Ca:P ratios in 5 diets range from 3.3:1 to 0.3:1	Decreasing Ca:P ratio lead to greater incidence of urinary calculi.
Stewart et al., 1989	Hampshire and Targhee wether lambs	50% grass hay, 49.7% oat grain, .3% veg. oil and mineralized salt	Control diet 1.2/1 High Ca diet 2.4:1 and 3.38% SiO_2	Stone formation was greater with high silica diets and having high Ca:P ratio compared to control diet.

premix to maintain the ideal Ca:P ratio. Incidence of urinary calculi from rams in the Wyoming Ram Test was drastically reduced when the pelleted diet was switched from a high P-byproduct diet to an alfalfa-based pellet lower in P.

Often times excessively high P in diets is the culprit for water belly; however, inadequate water intake, silicate in range grasses, and oxalate content all can contribute to incidence of urinary calculi. Decreased water intake, whether a result of extremely cold temperatures or palatability issues like excessive total dissolved solids and sulfates, will reduce water flow needed for kidney filtration. Precipitation of stones can occur under these low water intake conditions. Efforts to add more effective fiber to ram diets to increase rumination time and salivary flow has decreased incidence but is no substitute for adequate water intake. Efforts to ensure optimal water intakes are important year-round but especially during winter months in high-quality feedlot diets.

Similarly, in the western U.S. high levels of silicate (sand) in range grasses grown on sandy soils can contribute to silica calculi. In the arid regions of the west, oxalates,

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which can accumulate in fast growing annual plants such as kochia and halogeton, will bind Ca in the rumen reducing the Ca:P ratio. Most often, the oxalate example has been where the bum lambs/ram lambs were turned into the kochia patch outside the corral while still consuming the high concentrate pellet, and a small percentage come down with water belly. These cases are hard to plan for and aren't frequent.

Covering all the scenarios of when and how much to supplement with P is difficult, but we have had an increasing number of producers asking whether they should remove P from their mineral. The best response is often "it depends," based on the discussion above. Remember that with ever-increasing access to information, we should learn to separate anecdotes from research-based information and learn to determine if the information is relevant to our region and management system. Each of the diverse management systems talked about earlier throughout the Intermountain West need a separate plan of attack when making dietary P decisions in a flock. A century of scientific investigations and advancements in animal nutrition have refined P recommendations, and if used by producers and nutritionists alike, can maintain or improve the production and health of their flock.

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