Backyard Goat Nutrition

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Introduction

Goats (*Capra hircus*) were domesticated more than 10,000 years ago and have been used for nutrition (meat and milk), clothing (hair and skin), folk art, pack transport, draught power, and brush control (Devendra and Solaiman, 2010). In the United States, goats are increasingly becoming part of the backyard hobby farm and in many cases being treated more like pets than livestock.

While goats are ruminants, they are not small cows or just like sheep. Goats are browsers and have different preferences than other ruminant livestock, and at the same time require similar nutrients. The objective of this paper is to share basic information about goat breeds, basic goat nutrition and common nutritional health challenges.

Goat Breeds

Goat breeds are separated by their primary uses (meat, milk, fiber, other), although many are multi-purpose. Table 1 provides a list of the most common goat breeds and typical weight ranges. One of the most important aspect of nutrition is knowing how much the animal weighs. The Nigerian Dwarf goat, the most registered breed in the American Dairy Goat Association (www.adga.com), and miniature breeds of the standard breeds are becoming popular for the backyard farm or as pets.

Basic Goat Nutrition

As mentioned, the goat is a ruminant and has three chambers (rumen, reticulum, omasum) before the true stomach (abomasum). Unlike cattle (grazer) and sheep (intermediate grazer), goats fall into the intermediate browser feeding type (Van Soest, 1994). Intermediate browsers are animals that will consume both grass and browse but prefer browse. While there is this image of goats consuming tin cans because they will eat anything, goats are actually picky. Goats will consume pasture plants (forbs) and browse (woody shrubs) that are not consumed by sheep and cattle. Like other ruminants, goats have a symbiotic relationship with the microbes (bacteria, protozoa, fungi) in the rumen allowing them to utilize feeds containing fiber that monogastric animals cannot. Goats have the same six required nutrients (water, protein, fat, carbohydrates, minerals, vitamins) as other livestock.

<u>Water</u>: Water is the most overlooked nutrient and often the most important. The goat's water requirement can be achieved through drinking (free water), its food (pre-formed water) and through metabolism of nutrients (metabolic water). Water intake of penned animals can be estimated based on the goat's dry matter intake (DMI) [Equation 1] or its body weight (BW) [Equation 2] if DMI is not known (adapted from NRC, 2007).

[Equation 1] Water intake (L/day) = 3.86 x (DMI, kg/day) – 0.99

[Equation 2] Water intake (L/day) = 0.0795 x (BW, kg) + 0.4907

In some cases, if the goat is consuming high quality pasture, browse, or both, it could satisfy its daily water requirement due to the high-water content of the diet. Additionally, the estimated water requirement would need to be adjusted for the effects of season, ambient temperatures, breed, growth and reproductive status (Solaiman and Owens, 2010). Gestation will increase water intake an average of 126% with a single kid and further increase water intake with twins or triplets. Milk production will increase water intake 2 gallons for every 1 lb of milk produced (3.5 L water per kg of milk; Solaiman and Owens, 2010). Regardless of the amount, it is important to provide clean, fresh available water daily.

<u>Protein</u>: Goats, like most ruminants, do not have a crude protein (CP) requirement, per se, but their crude protein requirement is a proxy for their nitrogen and amino acid requirement. The protein and non-protein nitrogen consumed by goats is either digested/fermented in the rumen by microbes (degradable intake protein, DIP) to make microbial proteins or bypasses rumen digestion (undegradable intake protein, UIP) to be digested in the abomasum. The sum of the microbial protein plus the UIP is metabolizable protein (MP). Protein requirements traditionally expressed as CP are transitioning to MP to provide a more accurate estimate. Feeds still list CP on the tag, but MP of a feed can be estimated from CP (NRC, 2007) [Equation 3].

[Equation 3] Metabolizable protein (%) = CP (%) x 0.7

Goats are efficient utilizers of low protein feeds and recycle 18-85% of the blood urea back to the rumen via saliva or directly via diffusion through the rumen wall (Solaiman and Owens, 2010). Meat goat breeds have a greater protein requirement for weight gain than dairy goat breeds due to the increase in muscle deposition and capacity for growth. Protein concentration of the complete diet should be 15 to 18% CP, 12 to 16% CP, and 10-12% CP (as-fed basis) for kids from birth to weaning (8 weeks old), growth (8 to 16 weeks old), and finishing (> 16 weeks old), respectively.

Protein requirements increase 62% over maintenance during early gestation (the first 100 days) in does with twin fetuses and will increase another 56% in late gestation (the last 50 days) (NRC, 2007). Estimates of MP requirements for mature does (20 to 90 kg) and bucks (50 – 150 kg) for dairy and non-dairy breeds are provided in Equation 4 through 7 (adapted from NRC, 2007). The protein requirement for lactation above maintenance is Equation 8 (NRC, 2007). A good resource to determine a goat’s MP and metabolizable energy requirements, discussed later, is the Langston University Nutrient Requirement Calculator.

[Equation 4] Mature dairy doe, MP g/d = (BW, kg x 0.7821) + 12.86

[Equation 5] Mature dairy buck, MP g/d = (BW, kg x 0.808) + 24.2

[Equation 6] Mature non-dairy doe, MP g/d = (BW, kg x 0.7083) + 10.92

[Equation 7] Mature non-dairy buck, MP g/d = (BW, kg x 0.728) + 22.8

[Equation 8] MP requirement for lactation added to maintenance requirement,

g/d = 1450 x milk yield, kg/day

Fat: Goat diets are typically low in fat (2 – 5% DM basis). Fat (9 kcal ME/g) supplies 2.25 times more energy than protein and carbohydrates (4 kcal ME/g). Goats have a fatty acid requirement for linoleic and linolenic acid that is about 50% of the requirement of monogastric animals and is not well defined (NRC, 2007). Typically, diets should be kept under 7% (DM basis) as diets over 5% (DM basis) start to have a negative impact on rumen fermentation (Byers and Schelling, 1988).

Carbohydrates: Fermentation of carbohydrates provide the main source of energy to ruminants. Carbohydrates are divided into non-structural (sugars, starch, organic acids, and pectin) and structural (hemicellulose, cellulose, lignin) carbohydrates. The structural carbohydrates, hemicellulose and cellulose, are fermented by the rumen microbes resulting in the production of volatile fatty acids (VFAs; acetate, propionate, and butyrate), the ruminant's main source of energy, plus methane and carbon dioxide.

The structural carbohydrates are often called fiber and are analyzed as Crude Fiber, Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), and Acid Detergent Lignin (ADL). Crude fiber is still on feed tags due to state regulations, but most animal nutritionist use the detergent fiber system to classify fiber more appropriately and how it impacts the animal. A feed's NDF concentration gives an indication of gut fill. Gut fill is how much the animal can consume before its digestive tract is full and no more can be consumed. A feed that is too high in NDF may limit consumption to a point that the animal cannot consume enough to meet its energy requirement. Acid Detergent Fiber gives an indication of a feed's digestibility. As ADF increases, the feed's digestibility decreases. Acid detergent lignin is an indication of the amount of fiber that will not be digested and will pass through the digestive tract.

Minerals: Macrominerals required in gram amounts include Ca, P, K, Mg, Na, Cl, and S. The microminerals include Co, Cu, Fe, I, Mn, Se, Zn and are required in milligram amounts in the diet. Minerals have structural (bone and teeth), physiological (electrolytes, acid-base balance, nervous transmission) and metabolic (coenzymes, cofactors, components of hormones) functions. One key difference between sheep and goats is their tolerance for copper. Goats have a greater copper requirement than sheep with a dietary maximum upper limit of 40 mg Cu/kg DM (NRC, 2007).

There can be significant regional differences in soil mineral concentrations resulting in differences in the mineral concentration of feed and forages grown on those soils. It is always good to have forages routinely tested for mineral content. While serum mineral concentration can give a reasonable indication of mineral status, the mineral concentration of the liver is a better indication of status. If Ash is listed on a feed tag, that is the sum of all the minerals in the feed after the organic material was burned off. It is important to supply a trace mineral mix formulated for goats since the mineral requirements is different than cattle and sheep.

Vitamins: In most cases, goats only have a dietary requirement for the fat-soluble vitamins A, D, and E. Vitamin A is provided by beta-carotene in browse and forages or added in the diet. Vitamin D needs to be added to the diet if the animal is indoors without adequate sun exposure. Vitamin E is supplied from fresh pasture or browse and in many cases also supplemented in the diet. Vitamin K is the other fat-soluble vitamin and can be synthesized by rumen microbes. The water-soluble vitamins include vitamin C and the B vitamins (biotin, choline, cyanocobalamin [B_{12}], folic acid, niacin, pantothenic acid, pyridoxine [B_6], riboflavin [B_2], and thiamine [B_1]). Goats have the enzymatic pathway to synthesize vitamin C and can synthesize choline endogenously. The remaining B vitamins are synthesized by microbes in the rumen. Cobalt is required for vitamin B_{12} synthesis and sulfur is needed for thiamine and biotin synthesis (Solaiman and Owens, 2010). Polioencephalomalacia can result from a thiamine deficiency. Thiamine synthesis can be decreased due to excessive dietary sulfur, ruminal acidosis, and feedstuffs with thiaminase activity (bracken fern, Italian ryegrass, fresh fescue) (NRC, 2007).

<u>Energy</u>: Energy is not a nutrient but is derived from nutrients (protein, fat, carbohydrates). Energy can be classified in multiple ways. Gross energy (GE) is all of the energy that is combustible in feed, but not all GE is digestible. Digestible energy (DE) is the amount remaining after accounting for energy in the feces (fecal energy). Metabolizable energy (ME) is what remains after accounting for the amount of energy lost in urine and gas. A goat's energy requirement is determined using ME. The ME in feed can be estimated from Total Digestible Nutrients (TDN) and DE [Equation 9 and 10].

[Equation 9] $\text{DE, kcal/g} = (\text{TDN, \%} / 100) \times 4.4$

[Equation 10] $\text{ME, kcal/g} = \text{DE} \times 0.82$

Table 2 provides formulas to calculate the maintenance energy requirement for meat- and dairy-type goats. Estimates for the additional energy needed for growth, gestation and lactation are provided. To estimate the energy requirements of Angora goats, see NRC (2007) or the Langston University Nutrient Requirement Calculator.

Common Metabolic Disorders

Pregnancy toxemia, milk fever, and urinary calculi are three common metabolic disorders that occur in goats. For additional metabolic disorders, not discussed, please reference The Meat Goat Production Handbook, 2nd edition (2015), the Dairy Goat Production Handbook (2016), Goat Science and Production (2010) and The Nutrient Requirements of Small Ruminants (2007).

<u>Pregnancy toxemia (ketosis)</u>: Occurring mostly during late-term gestation (the last 4 to 6 weeks) with multiple fetuses, pregnancy toxemia is a result of the doe's inability to consume enough energy to meet its demand (Boileau and Dawson, 2015, NRC, 2007). The uterus, fetuses, and placenta take up an increasing amount of space in the abdominal cavity allowing less space for feed consumption. The condition is exacerbated if the doe is over-conditioned. Since feed intake is inadequate, the doe breaks down its fat stores for the needed energy. Ketones are generated from the metabolism of fat. While the ketones can be used for energy, the excessive amounts lead to clinical signs including separation, dullness, poor appetite, and not moving, progressing to severe depression, muscle tremors, teeth grinding, head pressing, stargazing and blindness (Boileau and Dawson, 2015).

To help prevent pregnancy toxemia, the body condition score of the doe should be monitored during gestation and should be 3 to 3.5 (5-point scale) prior to kidding. As does approach the last third of gestation start transitioning them to a diet with increased energy density to meet the demand of growing fetuses. If possible, identify those does carrying three or more fetuses, monitor and feed accordingly.

Milk fever (hypocalcemia): Milk fever often occurs in the last 2 weeks of gestation through the first 2 weeks of lactation. It is most common in high producing dairy goats or older does, during gestation, carrying three or four kids. The hypocalcemia occurs when there is insufficient blood calcium to meet the high calcium demand for the developing fetuses or milk production. Does may isolate themselves, have muscle tremors, and/or an unsteady gait. Some animals will be unable to stand or too weak to deliver kids. The condition is considered a medical emergency.

During gestation, it is advisable to feed an adequate amount of calcium, but not excessive amounts such as feeding legume hay. Feeding an acidic diet during late gestation may be beneficial to help prepare for the mobilization of bone reserves and increase the efficiency of urinary and intestinal calcium transport (Solaiman and Owens, 2010). After kidding, the amount of dietary calcium should be increased through supplementation or the addition of legume hay.

Urinary calculi (urolithiasis): Urinary stones are a problem in males more than females probably due to the longer, smaller urethra, and the sigmoid flexure in males (NRC, 2007). The concern arises when the stones become large enough to block the urinary tract and prevent urination. There are five types of stones that might occur (complexes of calcium-magnesium-phosphorus, silica, calcium oxalate, calcium carbonate, and ammonium phosphate) based on region and feeds consumed (Boileau and Dawson, 2015). Early castration (less than 3 months of age) decreases urethra diameter growth and thus increases the probability of clinical signs. Pygmy goats seem to display a greater incidence of urinary stones than larger breeds. Dietary predisposition includes high grain diets, a calcium to phosphorus ratio less than 2, and insufficient water consumption.

Dietary factors that can help decrease the chance of a goat developing urinary stones include feeding a high forage diet, ensuring the calcium to phosphorus ratio is greater than 2, providing salt to stimulate water intake, providing clean fresh water, avoiding feeds high in silica and oxalates, and over-feeding legumes. Adding a urinary acidifier such as ammonium chloride or ammonia sulfate is recommended. Crookshank (1970) demonstrated that 0.5% ammonium chloride and 0.9% ammonia sulfate in the diet was effective in reducing the total number of cases (clinical cases, stones found at slaughter, and stones found in the urine) of urinary stones in wether lambs. Alternatively, it is recommended that 100 to 200 mg/kg BW of ammonium chloride or ammonia sulfate is fed to help acidify the urine to prevent stone formation (NRC, 2007).

Conclusion

It is important to feed goats differently than cattle and sheep due to their intermediate browser feeding type. There are a range of breed sizes that are becoming popular and depending on their breed-type have different nutrient requirements. Nutrient requirements are not static throughout the year but will fluctuate given the goat's maturity and reproductive status. Understanding the goat's nutrient requirements and supplying the required nutrients in the required amounts to meet the goat's needs is critical to maintain the goat's overall health.

Further Reading

Meat Goat Production Handbook, 2nd Edition. 2015. American Institute for Goat Research, Langston University, Langston, OK.

Dairy Goat Production Handbook. 2016. American Institute for Goat Research, Langston University. Langston, OK.

Goat Science and Production. 2010. Wiley-Blackwell, Ames, IA.

Langston University Nutrient Requirement Calculator (luresext.edu/?q=Nutrient-Calculators)

Nutrient Requirements of Small Ruminants. 2007. National Academy Press, Washington, DC.

Literature Cited

Boileau, M. and L.J. Dawson. 2015. Meat goat herd health. Pp. 115-141 in Meat Goat Production Handbook, 2nd Edition. R.C. Merkel, T.A. Gipson, and T. Sahlu eds. American Institute for Goat Research, Langston University, Langston, OK.

Byers, F.M. and G.T. Schelling. 1988. Lipids in ruminant nutrition. Pp. 298-312 in The Ruminant Animal Digestive Physiology and Nutrition. D.C. Church, ed. Prentice Hall, Englewood Cliffs, NJ.

Crookshank, H.R. 1970. Effect of ammonium salts on the production of ovine urinary calculi. J. Anim. Sci. 30:1002-1004.

Devendra, C. and S.G. Solaiman, 2010. Perspectives on goats and global production. Pp. 3-20 in Goat Science and Production. S.G. Solaiman, ed. Wiley-Blackwell, Ames, IA.

[NRC] National Research Council. 2007. Nutrient Requirements of Small Ruminants. National Academy Press, Washington, DC.

Solaiman, S.G. and F.N. Owens. 2010. Digestive physiology and nutrient metabolism. Pp. 157-178 in: Goat Science and Production. S.G. Solaiman, ed. Wiley-Blackwell, Ames, IA.

Van Soest, P.J. 1994. Nutritional Ecology of the Ruminant, 2nd ed. Cornell University Press, Ithaca, NY.

Table 1. Body weight ranges for goat breeds common in the United States.

	Mature body weight, lb (kg)	
Use and Breed	**Bucks**	**Does**
Meat Breeds		
Boer	240 – 300 (109 – 136)	200 – 225 (91 – 102)
Kiko	250 – 300 (114 – 136)	100 – 180 (45 – 82)
Savanna	200 – 250 (91 – 114)	125 – 200 (57 – 91)
Spanish	200 – 250 (91 – 114)	100 – 150 (45 – 68)
Myotonic (Tennessee Fainting)	130 – 175 (59 – 79)	80 – 130 (36 – 59)
Milking Breeds		
Alpine	198 (90)	164 (74)
Guernsey	> 150 (> 68)	> 120 (> 54)
LaMancha	160 (73)	130 (59)
Nigerian Dwarf	75 (34)	75 (34)
Nubian	175 (79)	130 (59)
Oberhasli	150 (79)	120 (54)
Saanen	220 (100)	145 (66)
Toggenburg	160 (73)	120 (54)
Fiber		
Angora	180 – 225 (82 – 102)	70 – 110
Cashmere	150 (68)	100
Other		
Pygmy	40 – 60 (18 – 27)	35 – 50 (16 – 23)
Mini Alpines		135 (62)
Mini Nubians		< 100 (< 45)
Kinder (Pygmy x Nigerian Dwarf)		100 – 150 (45 – 68)
Pygora (Pygmy x Angora)	75 – 95 (34 – 43)	65 – 75 (30 – 34)
Nigora (Nigerian Dwarf x Angora)		70 (32)

Adapted from: American Dairy Goat Association (www.adga.com), Oklahoma State University Breeds of Livestock - http://afs.okstate.edu/breeds/goats, www.animalbliss.com/4-types-of-miniature-goats/, and https://pethelpful.com/farm-pets/15-Best-Pet-Goat-Breeds-for-Pets.

Table 2. Metabolizable energy estimates for meat- and dairy-type goats during maintenance, growth, gestation, and lactation.

Breed Type	Age/Stage	Sex	Formula[a]
Maintenance energy requirement, kcal ME/day			
All	Suckling/Preweaning	Intact males	$125 \times BW^{0.75}$
	Suckling/Preweaning	Females & wethers	$107 \times BW^{0.75}$
Meat	Growing	Intact males	$126 \times BW^{0.75}$
	Growing	Females & wethers	$108 \times BW^{0.75}$
	Mature	Intact males	$116 \times BW^{0.75}$
	Mature	Females & wethers	$101 \times BW^{0.75}$
Dairy	Growing	Intact males	$149 \times BW^{0.75}$
	Growing	Females & wethers	$128 \times BW^{0.75}$
	Mature	Intact males	$138 \times BW^{0.75}$
	Mature	Females & wethers	$120 \times BW^{0.75}$
Energy required for growth, kcal ME[b]			
All	Suckling	All	3.20 x ADG
All	Growing	All	5.52 x ADG
All	Mature	All	6.81 x ADG
Energy for gestation, % added to maintenance energy requirement			
Meat	Early Gestation[c] - Singles	Females	17
	Early Gestation – Twins	Females	26
	Early Gestation – 3 or more	Females	40
	Late Gestation[d] - Singles	Females	48
	Late Gestation – Twins	Females	66
	Late Gestation – 3 or more	Females	91
Dairy	Early Gestation - Singles	Females	14
	Early Gestation – Twins	Females	31
	Early Gestation – 3 or more	Females	35
	Late Gestation - Singles	Females	41
	Late Gestation – Twins	Females	58
	Late Gestation – 3 or more	Females	78
Energy required for Lactation, kcal ME[b]			
All	Mature	Females	1248 x Milk Yield[e]

[a]BW in kg and ADG in g/day. Adapated from NRC, 2007.

[b]Added to daily maintenance ME requirement.

[c]First 100 days of gestation.

[d]Last 50 days of gestation.

[e]If milk yield is not determined, average milk yield for meat goat does is 0.93 kg, 1.55 kg, and 2.13 kg for does with singles, twins, or triplets plus, respectively. For dairy goat does milk yield averages 1.27 kg, 2.67 kg, and 4.18 kg for does with singles, twins, or triplets plus, respectively.