10
Feeds and Feeding Management

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KEY TERMS

Feed ingredients—components of the ration that when eaten will provide nutrients or energy for animals.
Forage—plant materials rich in fiber that are included in diets.
Concentrates—ingredients rich in energy or protein included in diets.
Manufactured feeds—mixtures of ingredients that often include agro-industrial by-products, urea, and binders.
Polyethylene glycol (PEG)—a tannin-neutralizing compound.
Diet—mixture of feed ingredients consumed by an animal.
Ration—amount of a diet consumed by an animal.
Feeding Management—practice instituted by man to provide feeds to animals.
Feeding System—interactions among animals, plants, and the environment designed to provide feed to sustain life and productivity.
Intensive Feeding System—feeding system for animals fed in confinement.
Extensive Feeding System—feeding system where animals browse or have free range with little or no supplemental feeds.

OBJECTIVES

By completing this chapter, the reader will acquire knowledge on:

- Different feeds
- Feed composition
- Management practices involved in feeding goats
- Differences in nutrient needs of animals based on their physiological status including growth, pregnancy, and milk production
- Feeding management for maintenance and growth
- Feeding management for meat production
- Feeding management for milk production
- Feeding management for fiber production
- Feeding system

INTRODUCTION

The single greatest cost in any livestock enterprise is the cost of supplying feeding. With intensive feeding systems, feed cost averages 64% of the variable cost of an operation (excluding labor) or some 45% of the variable cost of an operation including labor. Management practices that reduce the cost of feed and feeding will improve profitability of a livestock enterprise. The major points in the feeding management of goats will be discussed to help readers understand differences among feeds and feeding practices that are humane, promote good health, and encourage strong immune function of goats with emphasis on efficient and economical production of meat, milk, and fiber.

FEEDS

Specific feeds are not required. Instead, the nutrients from feeds, for example, protein, energy, minerals, and vitamins, are required and must be provided by feed ingredients provided in the diet. Feed ingredients include those provided by humans as well as feed components gleaned by animals from available forage or browse. First, protein is needed. Protein may come partly from nonprotein nitrogen sources like urea. Next, energy is required; that typically is obtained from dietary carbohydrates (sugars, starches, and fiber), fats, and to a lesser degree, excess protein. Accurate feed management is a three-step process. First, nutrient requirements of the animal must be estimated; second, the composition of available feeds must be assessed; and third, one seeks to provide appropriate amounts of nutrients from specific feeds to meet the nutrient requirements. Nutrient requirements of goats for maintenance, growth, pregnancy, and production of meat, milk, and fiber are published in the NRC (2007). For practical purposes, selected nutrient requirement tables are provided in Appendix B.

Feed analysis is usually based on chemical analysis of a representative sample of forage, supplements, or concentrate feeds. Preferably, feeds should be analyzed individually. Feed analysis laboratories use specific chemical procedures to assay feeds. Typical measurements include dry matter (100 minus moisture), nitrogen, ether extract, and ash, all of which are determined by "proximate analysis." The carbohydrate portion of feeds often is assayed by detergent fiber analysis (Van Soest et al., 1991) where cell contents are separated from cell wall constituents. Cell wall constituents, also called neutral detergent fiber (NDF), include cellulose, hemicellulose, and lignin. Because of their bulkiness and slow rate of digestion, feed intake will be reduced when diets rich in NDF are fed. Acid detergent fiber (ADF), cellulose plus lignin, usually is proportional to digestibility of a feed because lignin is indigestible and cellulose is fermented slowly. A general scheme outlining chemical composition for typical feedstuffs is illustrated in Figure 10.1.

Feeds for goats can be divided into two groups: forage/roughage and concentrates. The ideal proportion of forage to concentrate in the diet depends on an animal's physiological stage and the desired level of performance. Goats managed for milk production have higher nutritional requirements and usually are fed higher amounts of grain to maintain milk production for 9–10 months when compared to goats managed for meat production (only 3–4 months of milk production for the kids).

Goats consume a wider spectrum of plants than other ruminants. As selective browsers, this grazing behavior facilitates the ability of goats to survive under harsher, semiarid conditions than either sheep or cattle. Goats selectively consume and digest a wide variety of shrubs, woody plants, weeds, and briers.

Forage/Roughage

Forage/roughage generally is rich in fiber (18% crude fiber or more) and low in energy, adds bulk to the goat's diet and thus enhances passage, and increases the butterfat content of the goat's milk. Most forage/roughage consists of the green vegetative parts of the plants though some are by-products (straw, hulls). Forage feeding often is economical and in such cases should be maximized in practical goat-feeding operations. Forage/roughage includes both wet forage/roughage (pastures, green chop, trees, shrubs, and silages) and dry forage/roughage (hay, pelleted forage, and some by-products).

Fresh forage may be grazed or fed to goats in stalls in a zero grazing system. Goats consume large amounts of forage when grazing, but intake may be even greater when fed forage in a cut-and-carry feeding system. Goats select long hay over chopped hay and leaves over stem portions of forage. Fresh forage often is preferred, followed next by hay, and finally by silages. When goats graze pasture or browse, they typically choose a higher quality diet than that offered in the trough. When given a choice, per unit body weight (BW), goats consume more legumes than grasses, more alfalfa than clover, and more Italian ryegrass or corn and sorghum than orchardgrass and fescue. Within each plant species, voluntary intake will vary with stage of plant growth. Intake is maximum 1–2 weeks before grain production with grasses and 1 week before budding with legumes. The relationship between the nutritive value of forage and its voluntary intake is well

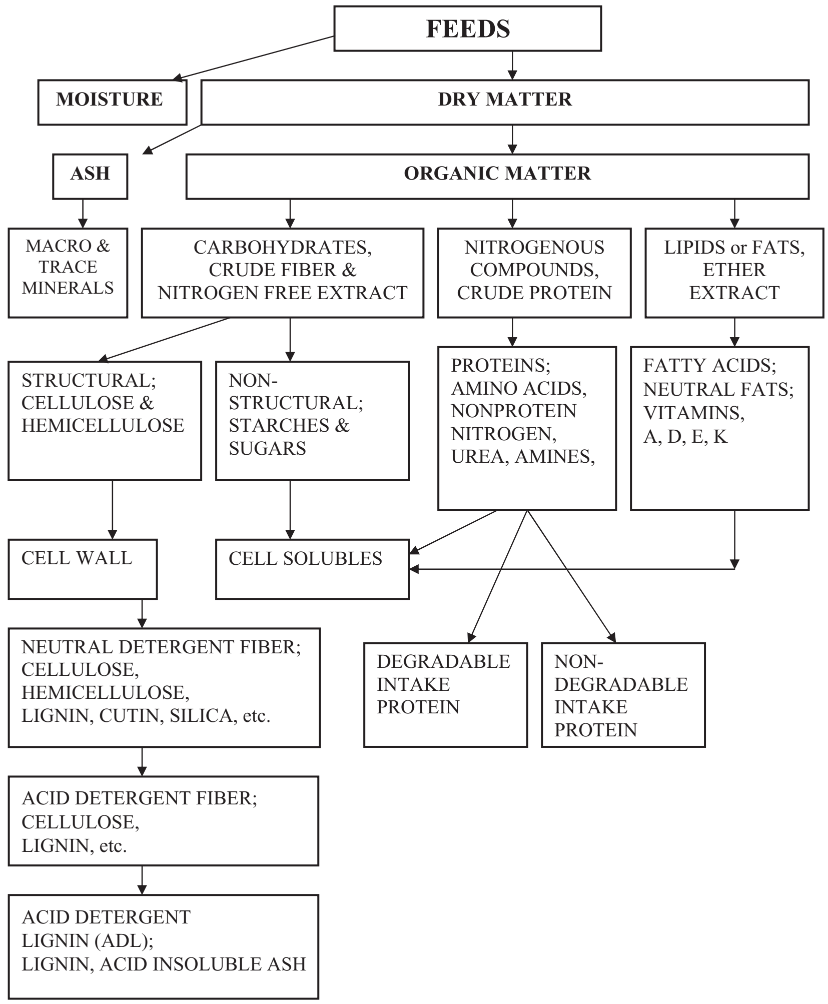

Figure 10.1 Analytical scheme for determining nutrient content of feeds.

established. Forage preference is positively correlated with organic matter digestibility of the individual forage whereas it is negatively related to the fiber characteristics (NDF, ADF, ADL). When dry matter (DM) is less than 10–12%, low forage DM may limit intake.

Amount of refused feed also will alter intake of forage by goats. Goats will eat more forage (depending on type of forage) when the allowed refusal is larger because they have greater selection opportunity. Mixed fresh forage along with dry forage usually is preferred over a single forage, but performance will vary with feeding value of the forage.

Dry Forage

Adding dry forage to high-concentrate diets will increase rumen-buffering capacity that in turn optimizes rumen fermentation and improves animal performance. Dry forage include hays, pelleted forage, and by-products like straw and seed hulls. Feeding a higher quality hay also allows diet formulators to reduce the protein content of the grain mix fed and thereby to reduce the cost of the grain mix. Factors that influence the quality of hay include date of the harvest, leafiness, lack of seed heads, absence of coarse stems, lack of foreign material, and green color. Hay intake will vary depending on the plant species and maturity stage. With roughage-based diets, hay intake is related inversely to its fiber content, and fiber content increases as plants mature. Grass hay usually is of lower quality and feeding value than legume hay. Although goats prefer long hay, feed intake is increased when hay is pelleted and chopped. Intake of pelleted and dehydrated forage will be similar to intake of good quality hay.

Table 10.1 Diet digestibility and growth of goats with sericea lespedeza meal replacing alfalfa meal in the diet.

	Sericea Lespedeza, %					*P*-value[a]		
Item[1]	0	10	20	30	SEM	Linear	Quadratic	Cubic
DM Digestion %	70.6	66.7	66.3	65.9	1.3	0.08	0.28	0.57
ADG, g	129.6	77.0	94.9	129.9	14.1	0.77	0.01	0.45
ADFI, g DM	1064.8	1082.4	1195.4	1295.6	1414.5	0.01	0.70	0.84
Gain:Feed, kg	0.12	0.07	0.07	0.09	0.009	0.09	0.002	0.32
Scrotal circum., cm	26.2	22.7	24.4	24.1	0.76	0.21	0.07	0.96
Height, cm	66.3	61.7	62.5	64.8	1.27	0.05	0.01	0.53
Heart girth, cm	98.8	93.2	98.3	93.2	2.31	0.68	0.57	0.11

[1]ADFI, average daily feed intake.
[a]Based on orthogonal contrasts for equally spaced treatments.
Source: Thomas et al., 2008.

Cassava hay and peanut hay can be successfully fed to goats.

Sericea lespedeza gained popularity as forage because it reduces the parasite load of goats (Terrill et al., 2007). When sericea lespedeza meal (SLM) was fed at 30% of the total diet DM to completely replace alfalfa meal in the diet, dry matter digestibility and gain efficiency decreased. However, when goats were fed 30% SLM alone, they gained weight at a rate similar to goats fed alfalfa meal alone, and both groups gained more than goats fed acombination of alfalfa meal and SLM (Thomas et al., 2008; Table 10.1).

Straws, most hulls, and stovers have low quality (digestibility) as a feed but do not necessarily have low value when fed in a mixture. Cottonseed hulls have higher palatability and feeding value than peanut hulls and oat hulls and add bulk factor of diet (Perry et al., 1999). Soybean hulls (an exception) in combination with hay are excellent as forage for goats.

Pasture

Globally, mixed farming systems (crop and livestock) provide more than 54% of total meat and 92% of total milk production by cattle and goats followed by landless systems (feedlots); grazing systems (no crop) provide less than 10% of the world's production of meat and milk. However, grazing systems are important in certain areas of the world such as Central America and South America where population density is low, and within the U.S. Most of the livestock in Asia is found in mixed farming systems. In the future, more livestock likely will be produced in grazing systems and mixed farming systems.

The soil and climate in most Southeastern states, in California, and in the Midwest regions of the U.S. are favorable for production of high quality grasses and legumes suitable for grazing. Pasture management, either under continuous or rotational grazing, is discussed below. Warm or cool season grass/legume pastures are site specific, so readers wishing deeper discussion of this topic should study pasture and grazing management manuals.

Continuous Grazing

Under a continuous grazing system, animals are allowed to graze the pasture throughout the grazing season. The number of animals grazing per hectare (grazing intensity) is predetermined so that plants have sufficient time to regrow. This system of grazing over time results in an accumulation of less-desirable plant species. This is the result of selective consumption of more-desirable plant species and reduced regrowth of those species. Understocking and overstocking may alter total output in terms of animal production and pasture quality. Understocking results in more mature plant stands in the pasture with higher fiber content and lower protein and energy contents that result in low digestibility of plants and lower quality pastures. Trampling loss associated with understocked pastures also increases waste of herbage.

Overstocking, on the other hand, reduces available forage per animal and will not sustain optimum animal production. In addition, parasite management for goats must be intensified using an overstocking system of grazing. The parasite burden will increase if proper measures are not practiced. The proper stocking rate in terms of maximum animal gain usually is not the same as that to

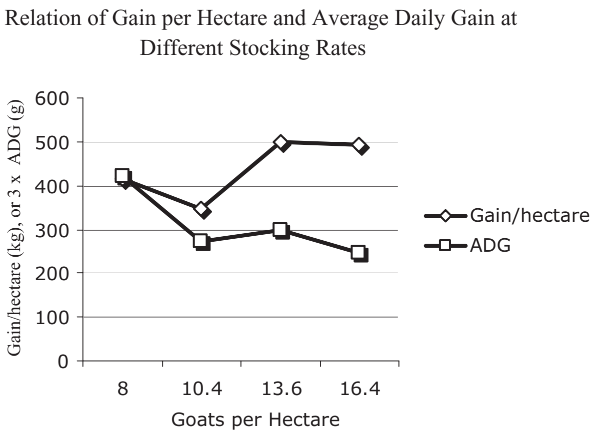

Figure 10.2 Average daily gain and gain per hectare for goats grazing continuously annual ryegrass pastures at different stocking rates. Source: Solaiman et al., 2006.

produce the maximum gain per hectare. Higher stocking rates often will reduce average daily gain (ADG) even though gain per hectare will be increased as illustrated in Figure 10.2 (Solaiman et al., 2006).

Because investments in fencing and watering systems are small with continuous grazing, it is not capital intensive and requires few management decisions because animals are not moved from pasture to pasture. Research data on optimum stocking rates for pastures continuously grazed by goats are lacking, and most of the available information has been transferred to goats using cattle data considering that five or six goats are equal to one animal unit. However, parasite management is difficult with continuous grazing systems and warrants further investigation. Also, forage preferences and accumulation of undesirable plant species may be greater with goats than cattle due to greater plant selectivity by goats.

Rotational Grazing

Rotational grazing or controlled grazing is an economical way to provide forage for goats, but this system requires careful planning, fencing, and more intensive animal and pasture management. This also is called management-intensive grazing where goats are allowed to rigorously graze one pasture before being rotated or transferred to another similar pasture. Rotational grazing permits plants to regrow on the grazed pasture and is helpful for parasite management. With this system, multiple paddocks are needed so that grazing animals can be rotated among pastures. The timing of animal rotation is based on the growth characteristic of the forage in the pasture and occasionally may depend upon the stage of the parasite cycle prevailing in that environment.

Table 10.2 Grazing efficiency or utilization rate.

Number of Paddocks	Approximate Days on Each Paddock	Grazing Efficiency includes Maintaining Minimum Stubble
Continuous	—	40% or less or (80% overgrazed, low yield)
4 to 6 paddocks	7 to 9 days	40 to 55%
8 to 10 paddocks	4 day	55 to 65%
24 to 45 paddocks	1 day or less	70 to 80%
Hay	—	70 to 80%

Source: Brann, 2005.

The size of the paddocks dictates the need for fencing and the design of the water supply system. Paddock size is positively correlated with animal numbers, animal size, level of intake, and days on pasture, but negatively correlated with available forage and grazing efficiency. The equation below can be used to determine paddock size for a rotational grazing system.

$$\text{Hectare/Paddock} = \frac{\begin{array}{l}(\text{No. Anim.}) \times (\text{Anim. Wt.}) \times \\ (\text{DMI, \% BW}) \times (\text{Freq. of Rotation})\end{array}}{\begin{array}{l}\left[\begin{array}{l}(\text{cm of forage}) \times (\text{kg per ha, cm}) - \\ (\text{DM from grain mix})\end{array}\right] \\ \times (\text{\% GE})\end{array}}$$

Where, DMI = dry matter intake; BW = body weight; GE = grazing efficiency.

Dry matter intake for goats on pasture will range from 3.5–4% of body weight. If grain supplement is provided on pasture, dry matter contributed from grain mix can be deducted from total forage DM required. Frequency of rotation (days on paddock) is a managerial decision, but grazing for 3–7 days per pasture usually is recommended. Grazing efficiency (utilization rate) of pasture varies depending on number of paddocks used and height of grazed forage (Table 10.2). The recommended grazing height and rest days for pasture are listed in Table 10.3. For goats, it is highly recommended to move goats out of pasture when vegetation height approaches 13 cm (5 in.).

Table 10.3 Recommended grazing heights and rest periods.

Forage Type	Begin Grazing Height, cm	End Grazing Height, cm*	Rest Time Days
Tall fescue, orchard grass, and legume, annual ryegrass, or small grains	20 (8″)	10 (4″)	14–45
Bermudagrass crabgrass	13–20 (5–8″)	7.6 (3″)	14–45
Alfalfa	30–38 (12–15″)	7.6 (3″)	24–32
Sudan grass, pearl millet	30–46 (12–18″)	20 (8″)	14–30
Native warm season grasses	30–46 (12–18″)	20 (8″)	30–50

*Due to parasites and desired intake it is recommended that goats not graze below a height of 13 cm (5″). Rotation timing should be based on minimum forage height, not days grazing (adjusted for goats by Ann Peischel).

Source: Brann, 2005.

Stocking rate usually is determined by the availability of forage and number of paddocks. Overstocking and understocking rules apply in this system, too, so the optimum stocking rate must be predetermined for a specific type of forage and environmental conditions that alter forage availability.

Strip grazing has gained popularity in goat production systems. In this system, goats are allowed to graze a strip of pasture a few hours each day to partially meet their daily needs. This system requires less land, but it requires more intensive management and labor. Perimeter fences are required to hold animals in pastures and to protect them from predators. Rotational and controlled grazing and strip grazing require temporary or interior fencing to subdivide the pasture into paddocks for rotation. For proper fencing and watering on pasture, the reader is referred to more specialized fencing manuals and Chapter 17, Housing Requirements.

Browse

Browse materials, shoots, leaves, and very high quality parts of shrubs, forbs, and trees, often are the goat's staple food. Goats prefer foliage from trees and shrubs. These novel dietary ingredients are rich in nutrients even though they often contain high levels of plant toxins and antinutritive factors. The chemical composition of browse differs from that of grasses. Grasses are rich in a relatively unlignified cell wall (NDF = 50–70%) that is readily available for cellulolytic fermentation in the rumen, whereas browse materials have a relatively lower cell wall (NDF = 30–50%) that is highly lignified but is rich in readily fermented cell contents. Browse materials also contain secondary plant metabolites (SPM) that are absent in most grasses. These biologically active compounds help protect plants from herbivore and insect damage. Some SPMs of interest include tannins that limit the nutritive value of plants by forming complexes with proteins and carbohydrates, phenolic acids and terpenes that disturb rumen fermentation, and pyrrolizidine alkaloids that are hepatotoxins. One possible collateral benefit of consuming browse is that these materials contain secondary compounds that may reduce internal parasite infestations. Goats select tree foliage, shrubs, forbs, flowering parts, seeds, and nuts when they are available. Available browse can serve as a supplement in pasture-based feeding systems when forage declines in quality, and this can help sustain grazing animal performance. Conversely, pastures that are predominantly browse can be improved by supplementing animals with conventional feeds (e.g., corn, barley) to dilute secondary compounds and provide limiting nutrients.

Goats are resistant to many plant toxins and antinutritive factors. Thereby, goats can readily defoliate most plant species, many of which cattle will not use. Although the proportion will vary with availability, goats typically consume a diet that is predominantly browse (65–70%) with smaller amounts of grasses (20–25%) and forbs (5%). Goats prefer woody plants like blackberry and raspberry bushes and use their upper mobile lips to select the tender, more digestible young leaves and leave the less digestible branches and thorns. Browsing by goats with proper management can prune and stunt bushes, and this helps to encourage grass growth. However, many browse plants contain antinutritional factors like high lignin content, silica, and terpene-based organic compounds, tannins, and other alkaloids. High levels of tannin compounds reduce the availability of protein; however, when a diet is supplemented with polyethylene glycol (PEG), it reduces the antinutritional effects of tannins by improving protein availability (Decandia et al., 2000) that in turn will increase ovulation rate (Lassoued et al., 2006) in goats. Animal performance should be monitored closely. Condensed tannin-containing browse can help control anthelmintic-resistant gastrointestinal parasites. Tannins decrease fecal egg counts in sheep and goats and may decrease hatch (Min and Hart, 2003). Mimosa, fed as a cut-and-carry forage, had no anthelmintic activity when fed for 21 days to goats as compared to fresh soybean leaves. However, when goats browsed on mimosa fields, they required less parasite control than when they grazed bahaigrass pastures (Solaiman et al., 2006).

The value of browse as a partial fulfillment of a goat's diet is not fully understood. Several factors can influence its effectiveness as a part of a feeding system including selection opportunity, nutritional quality, diversity of browse to keep goats entertained, and the height where parasite larvae cannot reach. Availability of browse should be managed closely by monitoring the percentage of plant defoliation that can secure rejuvenation rather than elimination of plants; each plant can tolerate a certain percentage of defoliation before it is eliminated. Goats tend to have higher blood urea nitrogen when allowed to browse. This might reflect insufficient consumption of carbohydrates or carbohydrates and protein being bound by tannins. Also, the size of animals in comparison to height of the canopy, and number of animals per unit area must be considered when considering the availability of browse plants. Obtaining reliable browsing data requires an extensive commitment of time with very limited applicable information. Browsing studies are rare, and variation in the browse species and in their composition within season and between years complicates application to other conditions.

Silage

Silages include partially fermented grass or legume forage, and they should be free of molds. Silage or haylage produced from legumes has a higher DM and protein content and a lower cell wall content than silage produced from grasses. High dietary concentrations of silage have been associated with metabolic and other problems (acidosis, demineralization, cortical necrosis, enterotoxemia, and listeriosis) of goats. Silage should be introduced into the goat's diet gradually. However, grass silage has been used successfully in the goat diet (Trodahl et al., 1981). Also many food industry by-products such as waste from beets, apples, potatoes, banana leaves (Pieltain et al., 1998), and cassava leaves (Marjuki et al., 2008) have been successfully used as silage for goats. Ensiling cassava leaves reduced the content of cyanide (HCN), a poisonous compound for livestock normally found in cassava leaves (Tewe, 1992). When fed silage, goats tended to eat less and produced less milk than when fed either palatable green or pelleted forage. Corn silage is a good source of energy, but its intake must be limited to avoid excessive fat deposition. Supplying hay with silage helps reduce digestive and metabolic problems, and increases feed intake and milk production.

Other Roughage

Goats readily consume garden by-products. Later discussion is based on experience with limited scientific documentation but may provide some guidance for goat producers.

Rape, kale, or beets commonly are added to diets for goats. Under controlled feeding, goats adapt well to by-products and surplus feeds including discarded produce. Some surplus or damaged produce like carrots, artichokes, and turnips should be used with caution. Because crucifers like cabbage contain goitrogens that interfere with thyroid hormones, their use in diets for goats should be limited. Avoid feeding clippings from rhododendron or branches pruned from cherry, apricot, or peach trees because when wilted, they may prove toxic to goats. Sweet potato forage and its mixture with grasses provide an inexpensive source of nitrogen in the diet for growing goats (Aregheore, 2004). Little is known about the effects of pine needles in grazing species other than cattle where they may prove toxic. Sheep and goats may not abort if they consume pine needles (Short et al., 1992).

Grains and Concentrates

Concentrate feeds are low in fiber but rich in energy, protein, or both. In addition to the roughage, grain mixes typically are added to diets for growing and nursing goats. This is the most expensive portion of the diet to purchase from outside the farm or ranch. Concentrate mixes are composed from high energy or high protein feeds. Although the majority of a goat's required nutrients often come from forage, when forages are not available or when forages are insufficient in protein and energy to support desirable performance, supplements should be provided. Supplements should be designed specifically to match dietary shortages. When protein is deficient, feeding a low-protein, high-energy supplement will not increase total nutrient intake, but a relatively small amount of a high-protein supplement may prove beneficial. Feeding grain often decreases both forage consumption and digestibility; however, with low quality forage, a grain concentrate may have a positive associative effect on forage intake (Huston, 1994). Goats may refuse to eat concentrates in an abnormal physical form, particularly if the feed is dusty. Goats prefer cubed, pelleted, or coarse feed compared to finely ground feeds. Even more than cattle and sheep, goats may refuse to eat moldy or fermented feeds. Cereals, cereal by-products, and oil seed meals are readily acceptable. However, goats may refuse to eat rapeseed meal, dehydrated alfalfa, flour meal, or animal fat.

Energy Concentrates

Energy concentrates are defined as feeds with less than 20% protein and less than 18% fiber. High-energy feeds include all cereal grains, some root crops, flourmill and bakery by-products, and many other food manufacturing by-products such as beet pulp and citrus pulp.

When forage or browse crops are low in digestible energy content, 0.25–0.50 kg shelled corn or whole cottonseed per goat daily often is provided to supplement the diet with digestible energy. Whole cottonseed contains high levels of CP and TDN and requires no processing, which makes it a very desirable by-product feed. The energy in WCS is primarily from fat. Whole cottonseed also contains gossypol, a polyphenolic yellow pigment that has deleterious effects on male reproduction. Adding whole cottonseed to medium- or low-quality forage diets for growing male goats has had detrimental effects on animal production; however, when limited to 15% of diet DM, whole cottonseed consumption improved dry matter digestibility and passage and had no adverse effect on growth or sperm quality in growing male goats (Solaiman et al., 2009; Table 10.4). The difference among corn, milo, barley, and wheat in energy content for goats is small, so cost per unit of energy usually determines which grain should be used. Although it is not recommended, pearl millet grain can substitute successfully for corn in complete diets for lactating dairy goats but not for growing animals according to Glaye et al. (1997). Metabolizable energy of pearl millet is only 90% of that for corn for mature goats, and its protein is not used efficiently (Terrill et al., 1998). Milo may promote urinary calculi if not balanced with proper minerals and should be used with caution for male goats. Being very rapidly fermented, wheat should not constitute more than 50% of the grain mix. Oats usually are not cost effective. Grinding promotes dustiness (undesirable for goats) and increases feed cost. Yet, cracking exposes the endosperm and improves the digestion of feed grains. Vegetable oil or animal fats also are fed to increase the energy density of the diet. However, feeding more than 7–8% fat in the diet may negatively impact rumen fermentation and depress fiber digestion.

Protein Concentrates

When forage is low in protein content or availability, additional protein supplements are needed for maximum production or performance. Protein concentrates usually contain at least 20% crude protein. High-protein feeds include alfalfa hay, alfalfa meal or cubes, and other high-protein concentrates such as oilseed by-product meals (cottonseed, peanut, soybean, etc.). Corn gluten meal has a

Table 10.4 Growth performance, scrotal circumference, and semen quality of goat kids fed diets with different amounts of whole cottonseed.

	Whole cottonseed, % DM				*P*-value[a]	
Item	0	15.7	32.7	SEM	Linear	Quadratic
Average daily gain, g	81.4	109.8	85.7	6.83	0.66	0.01
Average daily feed intake, g	948.3	1,295.6	1,084.7	103.0	0.37	0.05
Gain:Feed (G:F)	0.09	0.09	0.08	0.01	0.70	0.84
Scrotal circumference, cm	23.1	22.3	20.4	0.31	0.0001	0.22
Sperm quality						
Normal, %	81.0	73.9	71.5	6.1	0.30	0.76
Gross motility (scale 0–5)	4.90	4.52	4.56	0.11	0.05	0.16
Progressive motility, %	72.3	67.2	59.2	5.89	0.14	0.84
Head abnormality, %	8.24	4.56	15.41	5.80	0.40	0.33
Mid-piece abnormality, %	9.49	10.6	12.1	2.84	0.54	0.96
Tail abnormality, %	2.52	2.83	4.62	1.36	0.32	0.67

[a]Based on orthogonal contrasts for equally spaced treatments.
Source: Solaiman et al., 2009.

poor balance of amino acids, whereas fishmeal and heat-treated soybean meal provide a desirable mix of amino acids in ruminally bypassed protein. Protein derived from ruminants, and poultry litter (potentially contaminated with ruminant derived protein) must not be fed to goats in the U.S. even though animal protein sources like blood meal, or meat and bone meal can be useful sources of high quality protein. Because these materials may transfer prions (BSE) and cause human health problems, their use is prohibited in the U.S. The most common protein sources fed to goats are the oilseed meals: cottonseed meal and soybean meal.

Urea is a nonprotein-nitrogen source hydrolyzed to ammonia by rumen microorganisms. Ammonia can be efficiently used by microorganisms of the rumen during fermentation for synthesis of microbial protein, provided sufficient energy is available for the microbes to grow. When used correctly in goat feed, urea can provide an excellent, cost-effective source of nitrogen. As a thumb rule, the amount of urea to be fed should be no more than 25% of the required protein in rations for milking does. Because urea does not provide energy, it is useful only when the supply of fermentable carbohydrates is adequate. This means that its value and usefulness with low quality forage will be nil unless sources of readily available energy, such as molasses, are provided. Urea should not be fed to young ruminants before the rumen is fully functional. Ammonia toxicity can occur when a large amount of urea is introduced abruptly into the ration or intake is excessive due to diet formulation errors or improper diet mixing. With adaptation to urea, rate of ammonia production is reduced, so ruminants should be adapted to diets containing high levels of urea over several days or weeks.

Commercial protein supplements are available in many forms: meals, pellets, liquid supplements, and liquid blocks. Typically protein is the most expensive portion of the diet purchased off the farm. Therefore, when supplementing protein, cost comparisons, the presence of other dietary components, palatability of the product, ease of handling, feeding facilities, labor cost/convenience, and the need for uniform intake should be considered carefully. Because goats are skilled at sorting feed components being fed, diets should be formulated and feeding methods should be employed to reduce or prevent sorting. Sorting typically is most prevalent when (1) feed components differ in particle size, (2) components differ in density, and (3) a surplus of feed is provided. Therefore, protein supplements selected should have a particle size and density similar to other diet ingredients, and the supply of feed or time of access to feed should be limited.

Manufactured Feeds and By-Products

Manufactured feeds are mixtures of feeds that often contain agroindustrial by-products, urea, binders, and preservatives that either are complete diets (providing all the nutrients required) or supplements (providing nutrients otherwise deficient within the basal diet ingredients). The products used and their proportions in manufactured feed will differ with cost and availability of by-products at the local level. Supplements that provide missing nutrients generally will increase digestibility of low quality forage and thereby will increase the rate of body weight gain. For example, olive cake–based feed blocks enriched with squeezed cactus fruits provide a cost-effective supplement to a kermes oak-based diet in olive-producing areas of the world. Such blocks substantially increase the nutritive value of kermes oak-based diets by partially neutralizing tannins (Ben Salem et al., 2003). Feed blocks are efficient carriers for macro- and micronutrients, tannin-neutralizing reagents (for example, polyethylene glycol), and anthelmintic products for small ruminants. Grain-based commercial supplements may not prove economical for growing and finishing meat goats if not properly formulated for goats. Many high-starch supplements traditionally fed to cattle when fed to goats may reduce ruminal pH and fiber digestibility. Typically, diets for growing and finishing goats and sheep contain considerably higher amounts of roughage than diets fed to cattle.

Certain by-product feeds contain fiber that is quite digestible. Such fiber sources should provide adequate rates of gain without causing the digestive problems associated with high-starch (high-grain) diets. Such feeds would include soy hulls, corn gluten feed, and wheat middlings (Moore et al., 2002). Ensiled green tea waste also has potential as a protein supplement (Kondo et al., 2004). Dehydrated citrus pulp can replace corn up to 40% in the diet and can maintain high performance of goats (Bueno et al., 2002). Mustard seeds contain about 30–35% oil and 34–39% protein. The oil-extracted mustard seed, mustard cake has a good balance of essential amino acids and a relatively high methionine content, and it can replace peanut cake completely with no adverse effect on performance (Anil Kumar et al., 2002). Olive leaves traditionally have been used in Mediterranean countries as a source of nutrients for small ruminants during periods of scarce feed supplies. Because olive leaves contain condensed tannins, they should be supplemented with barley, faba beans (Yanez et al., 2004), or PEG for optimum utilization. Condensed tannins will form complexes with dietary proteins, carbohydrates, and microbial enzymes and decrease protein availability. Good palatability and high-energy content make unripe banana fruits a suitable feed for goats that appears similar to barley but with lower protein content. Seed harvested cowpea vines are low-quality forage that can be improved by ensiling (Solaiman, 2007), and poultry waste has also been used as feed for goats in some regions of the world. Replacing alfalfa meal with broiler litter at 25% of the dietary DM in a total mixed ration reduced dry matter digestibility in goats but still yielded an acceptable diet (Bartlett, 1989; Table 10.5) while reducing diet cost. Whole cottonseed is high in energy and protein; fed at up to 15% of dietary DM, it improved average daily gain with no adverse effect on reproductive performance of goats (Solaiman et al., 2009). The distillers dried grains with solubles (DDGS), a by-product of the ethanol industry, can be successfully used in the diet of growing goats (Gurung et al., 2009; Table 10.6). This is a unique feedstuff providing protein, energy, highly digestible fiber, and minerals to goats.

Table 10.5 Nutrient digestibility of diets with broiler litter replacing alfalfa meal in total mixed diets fed to goats.

	Broiler Litter, % DM			
Digestibility, %	0	12.5	25.0	SEM
Dry Matter	75.7[a]	70.6[b]	67.2[c]	0.52
Crude Protein	71.6[a]	64.1[b]	59.1[c]	0.92
Neutral Detergent Fiber	55.7[a]	51.0[ab]	48.2[b]	1.48
Acid Detergent Fiber	48.1	49.8	45.1	1.65
Cellulose	54.2[b]	53.5[b]	60.2[a]	1.37
Hemicellulose	65.2[a]	52.2[b]	52.6[b]	4.11
Ash	46.9[a]	22.2[b]	18.7[b]	4.25

[abc]Means with different superscripts differ ($P < 0.05$).
Source: Bartlett, 1989.

Mineral and Vitamin Supplements

Minimum requirements of minerals and vitamins must be provided for optimum goat performance, but the need for supplements will vary with composition of diet ingredients. Mineral supplements can be as simple as salt alone or may be a complex mix consisting of several macro and trace elements plus vitamins provided free choice in the form of either a loose mixture or a block. Some mineral/vitamin mixtures can be included in a total grain mix to be fed as part of a totally mixed ration (TMR). Generally calcium, phosphorus, and sodium are supplemented to diets for goats, but the need for each will differ with the diet ingredients being fed. Normally, calcium is present at adequate levels in most forage for gazing ruminants, but salt (or some source of sodium) must be supplemented. Phosphorus may be deficient in forage at certain times of the year, and a phosphorus deficiency can reduce reproductive performance. If grass tetany is a regional problem with forage, seasonal supplementation with magnesium may be necessary. In early spring or when animals are consuming fresh green and rapidly growing pastures fertilized with N, P, and K, high levels of potassium and nitrogen with low levels of magnesium and salt may lower the ratio of magnesium : potassium and provoke grass tetany. Trace mineralized salt provides a mixture of micro minerals, and vitamins A and E are supplemented in vitamin premixes.

Soils in many areas of the U.S. are deficient in copper, so feeds produced in those areas also will be deficient in copper. Adding a mineral supplement to the diet that has

Table 10.6 Average daily gain and dry matter intake of Kiko × Spanish crossbred growing male goat kids fed different amount of distillers dried grains with solubles (DDGS).

	Distillers dried grains with solubles, % DM			
Item[1]	0	10.3	20.6	31.0
Initial BW, kg	27.9 ± 0.94	29.8 ±± 0.73	27.8 ±± 0.82	29.5 ±± 0.73
Final BW, kg	38.5 ±± 1.63	39.8 ±± 1.26	36.4 ± 1.42	38.3 ± 1.26
ADG, g/d	141.0 ± 18.4	134.1 ± 14.2	115 ± 16.0	117 ± 14.2
Total DMI, g/d	1,017 ± 87.3	1,138 ± 77.5	1,106 ± 93.1	1,003 ± 87.0
Concentrate, g/d	519 ± 41.9	591 ± 37.2	575 ± 44.7	520 ± 41.8
Hay, g/d	499 ± 45.8	547 ± 40.7	531 ± 48.5	483 ± 45.7
Gain:Feed	0.12 ± 0.01	0.12 ± 0.01	0.11 ± 0.01	0.12 ± 0.01

[1]No differences were observed ($P > 0.10$).
Source: Gurung et al., 2009.

an adequate amount of copper can eliminate most symptoms of deficiency. Copper deficiency is sporadic throughout the U.S. Soils in and feeds from the upper coastal areas on the West Coast (including California) tend to have higher copper and other trace minerals than the East Coast; the Southeast and major parts of the Midwest are deficient in copper and many other trace elements according to U.S. geochemical soil maps. However, animals raised in Western states often have lower serum copper than those raised in Southeastern and Midwestern states. In some states, copper levels in soil may be sufficient, but other minerals present in feeds (molybdenum or sulfur) may reduce copper availability. The addition of 5 or 10 mg of molybdenum to the diet can deplete copper in the liver and negatively impact immune response in goats (Solaiman et al., 2008; Table 10.7).

Soil copper concentrations may vary from location to location within a state. Therefore, it is recommended to check soil or forage mineral levels for copper, molybdenum, and sulfur. Copper deficiency symptoms vary depending on the severity of the condition. Symptoms can include frequent staphylococcus lesions on the body, a thin and faded hair coat, bald tail tips, twisting and bending of the front legs, spinal cord injuries, and anemia. Generally, the immune system loses effectiveness with a copper deficiency leaving animals more vulnerable to diseases and parasites. Although most symptoms of copper deficiency can be reversible by feeding adequate copper, other symptoms like swayback in young kids (caused by copper deficiency in pregnant does), and spinal cord injuries are not reversible. Goats are more tolerant to high levels of copper than sheep or cattle (Solaiman et al., 2001). Feeding as high as 100 mg of copper per day for 100 days improved daily weight gain and immune function of goats (Table 10.8; Solaiman et al., 2007). This confirms previous recommendations of other producers and goat experts. However, copper is accumulative, and high levels of copper are not recommended for long-term use. Dietary levels of copper above 40 ppm are not recommended for dairy goats. For more information on soil copper, the reader is directed to the USGS map for copper at http://tin.er.usgs.gov/geochem/doc/averages/cu/usa.html.

Internal parasites, either through altering GI pH and copper absorption or by increasing blood loss, can contribute to copper deficiency; conversely, parasites are more prevalent in copper-deficient animals, and parasite infestation can be managed more readily when animals are kept at optimum copper status. Other minerals can interfere with copper status. These include diets with high levels of either sulfur (>0.35% of diet dry matter), molybdenum (more than 2 ppm in feed), iron (more than 250 ppm), calcium, zinc, manganese, or cobalt. Such diets can reduce copper absorption and deplete liver copper. Soils that are heavily limed or have a high pH will render the copper unavailable. The concentration of copper in the liver is the most reliable index of copper status of the animal. Although

Table 10.7 Mineral concentration in the liver and immune response of goats fed high amounts of molybdenum.

	Added Molybdenum, mg				*P*-value[a]	
Item	0	5	10	SEM	Linear	Quadratic
Liver, DM						
Copper, ppm	380.0	152.1	120.0	5.24	0.003	0.15
Molybdenum, ppm	5.17	4.93	6.03	0.32	0.07	0.11
Iron, ppm	190.0	136.7	131.7	10.9	0.002	0.09
Zinc, ppm	94.7	88.3	101.7	7.24	0.50	0.28
Humoral Immune Response						
Antibody Titer[b]	86.7	46.7	33.5	11.5	0.002	0.35
Cell-Mediated Immune Response						
Skin Fold Thickness[c], cm	4.63	4.06	3.84	0.14	0.002	0.30

[a]Based on orthogonal contrasts for equally spaced treatments.
[b]Antibody titer to ovalbumin injection; a higher titer reflects a stronger immune response.
[c]Skin fold thickness in response to PHA injection; greater thickness reflects a stronger immune response.
Source: Solaiman et al., 2008.

Table 10.8 Effects of supplemental copper on growth and immune function of growing kids.

	Dietary Copper, ppm				*P*-value[a]	
Item	0	100	200	SEM	Linear	Quadratic
Average daily gain, g	131	147	117	6.09	0.11	0.01
Average daily feed intake, kg	1.21	1.11	1.03	0.06	0.05	0.90
Gain:Feed (G:F)	0.11	0.13	0.11	0.01	0.67	0.02
Scrotal circumference, cm	23.1	22.3	20.4	0.31	0.0001	0.22
Serum copper, mg/dL	0.82	0.78	0.86	0.03	0.35	0.14
Liver copper, mg/kg DM	206	504	778	59.0	0.001	0.87
Immune response[b]						
Antibody titer to ovalbumin						
Day 72	0.26	0.31	0.32	0.03	0.08	0.46
Day 98	0.19	0.29	0.26	0.01	0.005	0.003

[a]Based on orthogonal contrasts for equally spaced treatments.
[b]A greater titer reflects an improved or greater immune response.
Source: Solaiman et al., 2007.

safe procedures are available to biopsy the liver of cattle, similar safety of biopsy procedures for goats is questionable. A secondary measurement for assessing copper status of goats is plasma or serum copper. Unfortunately, the liver can be markedly depleted before plasma or serum copper concentrations decline.

Copper can be supplemented through mineral mixes that are high in copper. Mineral mixes that are labeled for both sheep and goats should not be used for goats. Because sheep are much more sensitive to high copper levels than goats, mineral mixes appropriate for sheep do not have adequate copper levels for goats, or they may have high levels of molybdenum. Copper also can be supplemented through slow release copper wire needles as copper boluses (0.625–1.35 grams) given early to kids (2–4 weeks of age) or 1 gram of copper oxide in bolus form per 10 kg of body weight every 5–6 months in copper-deficient areas. The needles are deposited in the goat's stomach and release copper slowly. Some feeds (wheat, barley, and oats) are low in copper and some, like alfalfa, are rich in molybdenum. Applying 1.5–3.0 kg of copper per hectare as an organic compound such as copper EDTA, copper lignisulfonates, or copper polyflavonoids has been recommended and can increase soil copper levels for many years.

Selenium or iodine is deficient in certain regions of the U.S. Coastal areas usually have sufficient iodine and are deficient in cobalt. The Dakotas are so rich in selenium that selenium toxicity may occur; however, many other places including California are selenium deficient. Selenium injections often are used for pregnant does toward the end of the pregnancy and for young kids at birth. However, both selenium and copper can be toxic if overdosed. Feeding rather than injecting selenium is recommended unless severe deficiency is prevalent.

Feed Additives

Additives are products of nonfeed origin that may improve feed efficiency, growth, and health of animals. Many herbal and natural remedies are used commonly by goat producers in the U.S. with little if any scientific evidence of their effectiveness. Only two additive classes are available commercially that have proven to be effective for goats.

Ionophores

Ionophores are antibiotics produced by varieties of actinomycetes bacteria that alter the flux of ions across gram-positive bacteria in the rumen and reduce their numbers. This fermentation shift negatively affects methane, acetate, and butyrate production, while increasing the molar proportion of propionate; ammonia production is decreased resulting in a "protein sparing" effect; protein degradation is inhibited; and lactic acid formation associated with high grain diets is reduced (Russell and Strobel, 1989). As a result, feed efficiency and the net energy available from feed increases. Ionophores also may increase milk production and milk protein synthesis and help to prevent ketosis and reduce bloat. Lasolocid and monensin are the two ionophores that are approved for prevention of coccidiosis in meat goats in the U.S., but they are not approved for dairy goats. Ionophores may improve animal health and reduce amino acid catabolism, fat mobilization, nonesterified fatty acids (NEFA), and ketone bodies formation. Readers are directed to the FDA website for more updated information on approved drugs for goats.

Probiotics

Probiotics are live, naturally occurring microorganisms fed directly to animals. They have been shown to relieve stress, increase dry matter intake, and improve growth. They provide a viable culture of microorganisms in the digestive tract that may decrease or prevent the establishment of pathogenic organisms. They also may alter rumen fermentation, optimize rumen pH, increase nutrient flow through the gastrointestinal tract, improve digestibility, and reduce stress by boosting immune function. Benefits from probiotics are not always apparent. A commercial probiotic supplement failed to affect growth performance, diet digestibility, and carcass traits of healthy growing meat goats (Whitley et al., 2009). Commonly used probiotics include fungal cultures (Aspergillus oryzae and Saccharomyces cerevisiae) and lactic acid bacteria (Lactobacillus and Streptococcus).

FEEDING PRACTICES

The process of matching the nutritional requirements of animals with the nutrient content of the feed ingredients is referred to as "feeding practices." The objectives of a sound feeding practice are to (1) optimize animal performance, (2) minimize feed cost, and (3) improve sustainability of the environment. Reproductive performance of bucks and does is crucial for a successful animal production system. Reproductive efficiency of does coupled with improved kid performance will determine the economic profitability of the system. Through enhancing milk or fiber production, matching nutrient requirements with feed ingredients will improve productivity and viability of the system. Feeding practices for goat production are highly variable across the globe ranging from simply tethering animals near households in some part of the globe, extensively grazing or browsing rangelands in some areas, and intensive feeding practices in other areas. In all cases the nutritional goal is to meet fully the nutrient requirements of the animal. In the natural setting and given free choice, goats as intermediate selectors, will manage their own intake, but may or may not meet all of their nutrient and energy requirements. With intensive production systems, diets must be carefully formulated to assure that all nutrient requirements are met. In the following section, feeding management of the entire herd will be discussed starting with raising kids (either as herd replacements or for meat production), the breeding herd, and the herd producing milk or fiber.

Feeding Kids

The first 3 days after birth are the most critical days in the life of a newborn kid. Readers are referred to Chapter 8, Digestive Physiology and Nutrient Metabolism, for more detail about digestive function of young kids. The young kid basically is a nonruminant that acquires all of its required nutrients initially from colostrum and later from milk. The kid may be separated from its doe immediately (at some dairy farms), or it may stay with its dam. If separated, the kid should receive colostrum for the first 3 days of its life. Colostrum is the secretion of the mammary glands immediately after parturition. Colostrum contains high levels of protein, milk solids, globulins, fats, and vitamin A. Most importantly, colostrum contains antibodies against the diseases to which the doe has developed immunity. When fed during the first 3 days of life, colostrum provides protection against diseases because these antibodies are absorbed intact. Absorption of large proteins will cease approximately 3 days after birth. (See Chapter 8.) Separated kids should receive milk or milk replacer until they are weaned.

Kids should nurse as long as possible or until weaned. Weaning age for meat goat operation usually is 3 months while for dairy operations it usually is 3 to 4 days but can vary with management practices. If a doe rejects its kid(s), a surrogate doe should be found to adopt the kid(s) as soon as possible. Colostrum from other animals or frozen sources should be fed to the orphan newborn three times a day, a total of 1–1.5 liters (2–3 pints) daily. After 3 days, orphan kid(s) can be fed milk or milk replacer twice daily. When using milk replacer, the manufacturer's directions for feeding should be followed. Supply of milk replacer should be gradually increased. Feeding milk or milk replacer can continue up to 8–12 weeks or until kids are weaned or consuming 0.25–0.5 kg of grain mix (kid starter) daily. Diets for kids typically include a grain mix with high fiber (11%) and protein (16%) content plus good quality hay and should be available starting the first week to encourage development of the rumen and GI tract.

Feeding Herd Replacements

From weaning to 6 months of age, kid starter should be fed at (0.25–0.5 kg/day) together with good quality forage and pasture where available. Silage and nonprotein nitrogen at this age should not be fed because the rumen is not fully functional at this age. Fresh water should be available at all times. Macro and micro minerals should be incorporated into the grain mix or provided in loose form.

As animals grow from 6 months to breeding age, they may require 0.5 to 1 kg of grain mix daily containing at least 14–16% protein, salt-mineral mix, and vitamins A and E. Feeding more than 25% of the protein as nonprotein nitrogen is not recommended for rapidly growing replacement animals at this age. Yearling does and bucks require a proper balance of nutrients for maintenance and growth, but overfeeding so that animals gain a large amount of fat is not recommended. Replacement bucks should be kept in good body condition but not fat. Creep feeding is not recommended for replacement dairy does because fat deposited in mammary glands can negatively impact milk production in the future. The proper time of breeding depends on the age and weight of the doe. Yearlings (12 months of age and older) can be bred. The proper weight for breeding usually is 65% of adult weight for cattle, but no benchmark has been established for goats and may differ with breeds. In order to breed at specific age, doelings should be fed to achieve this weight at the needed time. To improve fertility, flushing is used. Flushing is the practice of feeding supplemental protein or energy to breeding does 30 days prior to and after the introduction of the herd sire (buck). Widely used for dairy goats, flushing may not be necessary for meat-producing animals if the quality and quantity of available forage is ample. When yearlings are bred, they can be placed with pregnant does.

Feeding Pregnant Does

Nutrient needs are not constant for reproducing animals but vary with their reproductive status. Producers must understand these cycles to develop sound feeding practices. Feeding strategies for meat goats and dairy goats for pregnancy will differ markedly. Meat goats generally are dry (not milking) at breeding, whereas dairy goats may be still milking; and continued milk production makes rebreeding efficiency much more challenging.

Feeding Nondairy Does in Early Gestation

During the first 90 days in pregnancy, for meat goats, nutrients are needed for maintenance and growth, especially if the doe is still growing, but additional nutrients needed for fetal growth are miniscule because fetal growth at this stage is minimal. Goats should be kept in positive energy balance and be gaining weight at least at the later part of this period. Feed supply should match body condition of animals. A dry goat in good condition can meet her energy requirements from good quality forage (half legume, half grass) supplemented with salt, minerals, and vitamin A and E. If forage has a low quality, a small amount of protein supplement may be beneficial.

Feeding Nondairy Does in Late Gestation

During the final 60 days of pregnancy, does require more attention, particularly 4–6 weeks prior to kidding. A good pasture, hay, or silage as well as 0.25–0.5 kg of a 12–14% protein grain mixture should be sufficient. Use of alfalfa as a sole source of forage during this period is not recommended because alfalfa has a high calcium-to-phosphorus ratio, which is not desirable for late pregnant does. Does should be kept in good flesh but not fat during this period.

Feeding Early Gestation Dairy Does

Besides growth, dairy does need additional nutrients for milk production during the later part of the lactation. Little additional nutrients are needed for fetuses, but does carrying multiple fetuses may need some additional energy or protein. Starting at the fourth month of lactation, does and doelings should gain at least 1–2 kg per month to restore the tissues lost in early lactation. Providing good quality grass hay or a mixture of grass and legume hay along with fresh water, a salt-mineral mix, vitamins A and E, and a small amount of supplemental grain mix with 12–14% protein is recommended. Pregnant does should be fed grain mix so they are in good body condition but not fat. Fat pregnant does are predisposed to fatty liver (ketosis).

Feeding Far-Off Dry Does

The dry period for an average milking doe is the break between lactations. A dry period is needed for maximum milk production. Individual cases of high production without a dry period have been reported, but most of the studies show that a dry period will extend the productive life of the doe. The most attention should be given to the pregnant doe during the last 2 months of gestation, so the final 60 days of pregnancy is divided into this "far-off dry period" and "close-up dry period."

The far-off dry period covers the time that does have just turned dry to about 3 weeks before kidding. The dry doe should be maintained in good condition but not fat during this period. This time allows the mammary system to repair, regenerate, and acquire new cells for the next lactation. The greater the production level, the more likely that doe will have depleted her body reserves of nutrients used for milk production. The condition of the animal and the quality of the roughage become the key factors in determining grain intake. Total dry mater intake for a dry doe generally will be about 2–2.5% body weight of which only 0.5–0.6% should be grain. Good pasture, hay, or silage plus 0.5 kg of 12–14% protein grain mix, a salt-mineral mix, and vitamin A and E supplement can provide the required nutrients. The feed trough should be located some distance away to encourage exercise. Fresh water should be available at all times.

Feeding Close-up Dry Does or Transition Does

The last 3 weeks of gestation is referred to as the "close-up dry period" or transition period for pregnant dairy does. This is the period when nutrient requirements for fetal growth and mammary development dramatically increase while at the same time, space in the abdomen becomes limited by the developing concepta so that feed consumption can be limited. Intake often decreases by more than 35% while nutrient requirements increase. At this point, the animal needs high-energy and protein feeds. Dairy rations often use the "halfway rule of thumb" (that is, feed half the amount of feed that will be fed after does kid). Increase intake gradually. No extra buffers should be needed, but if milk fever is expected, an anionic salt program is recommended for goats as it is for dairy cattle.

Feeding anionic salts (Table 10.9) to manipulate the cation-anion balance is recommended especially for high-producing dairy cattle fed forage like alfalfa hay that is rich in calcium, phosphorus, and potassium. Feeding anionic salts lowers blood pH and urine pH, stimulates release of calcium from bones, and increases calcium absorption. The use of anionic salts in dairy goats has not been studied. Nevertheless, it seems prudent to feed low potassium feeds such as beet pulp or corn silage, reduce sodium bicarbonate and limestone in the diet, and add calcium sulfate, or calcium and ammonium chloride to reduce the cation-anion difference (CAD) and urine pH. Along with anionic salts, feeding a palatable total mixed ration properly supplemented with minerals is recommended. Avoid feeding anionic salts to young doelings because it may cause udder edema; instead, young does should be separated and monitored closely. Feeding a high-energy/protein lactation ration along with long hay, yeast, probiotics, and chelated minerals according to the body condition score is recommended (Table 10.10).

Table 10.9 Common anionic compounds fed to dairy cattle late in pregnancy.

Anionic Salts or Mixtures
- Magnesium, Calcium and Ammonium Sulfate
- Calcium, and Ammonium Chloride
- Nutri-Chlor—Canola meal treated with HCl
- Soy-Chlor—Heat treated soybean meal treated with HCl

Feeding Nursing Does

During the first few months of lactation, animals should consume enough to meet their needs for milk production and for nursing kids. High quality legume or grass hay and a grain mix containing a minimum of 16% protein balanced for vitamins and minerals is recommended. Nursing does should be fed both to produce milk and produce heavier weaned kids. Good pasture, browse, and garden products including root crops can be helpful. Grain intake should be increased if needed to optimize kid growth. The grain mix should be supplemented with an adequate salt-mineral mix and vitamins A and E.

Feeding Herd Sires (Bucks)

To have a productive herd and make genetic progress, care must be exercised in selecting and caring for the herd sire. A herd sire should be selected from a high producing doe. Proper early nutrition is necessary to enhance the productive life of a herd sire with good performance and conformation.

Prebreeding Season

A young herd sire should be maintained on a balanced diet year-round for maintenance and growth. Good quality hay provided for free choice intake generally will meet the sire's nutrient requirements. The buck's activities during the off breeding season are limited, but as the breeding season approaches, necessary measurements should be

Table 10.10 Nutrient recommendations for transition rations for lactating dairy goats.

	Far-off	Close-up	Fresh
Net Energy Lactation (Mcal/kg)	1.32	1.5–1.6	1.7
Crude Protein, %	12	15–16	18
Neutral Detergent Fiber, %	45–65	35–40	30
Non-fiber Carbohydrates, %	25	30	35
Fat, %	3	4	5

Source: Adapted from "Feeding the transition dairy cow" by Sandra Stokes, Extension Dairy Specialist, Texas A&M University System, Texas AgriLife Extension Service. http://AgriLifebooksstore.tamu.edu.

taken to prepare the buck for his active season. Some meat breeds are year-round breeders, and must be fed accordingly. Depending on the condition of the animal and his prior plane of nutrition, in addition to good quality hay provided free choice, 0.5–1 kg of 14–16% protein mix may be needed. Supplementation should start as early as 6–7 weeks or could be as late as 2 weeks prior to the breeding season depending on prior nutrition of the buck. Production of fertile sperm begins 40–60 days before it is deposited in the female reproductive tract. Grain supplements should include a sufficient amount of vitamins and minerals. Trace mineralized salt should be provided free choice and preferably in loose form. Avoid overfeeding and overconditioning.

Breeding Season

In the breeding season (that usually starts in August and lasts through December for seasonal breeders in the northern hemisphere), the herd sire is quite active. Males will fight with other bucks, and with their breeding activities, they may devote little time to grazing or eating. Therefore, body reserves will be depleted. Sometimes bucks completely stop eating during the mating season and lose 15–20% of their body weight. Breeding males may serve does up to 20 times a day with 350 services being possible during a limited breeding season. Therefore, bucks should be provided with good quality hay and 1–1.5 kg of concentrate mix containing 14–16% protein, adequate amounts of minerals, and vitamins. The buck should receive 2,000–6,000 retinol equivalent (RE) of vitamin A and 300–800 IU of vitamin E daily. Plenty of clean water and salt mineral in loose form should be provided at all times.

Post-Breeding Season

Unless year-round breeding is practiced, the herd sire should be removed from the herd at the end of the breeding season. Feed allowance should be reduced to 0.5–1 kg of grain mix (16% crude protein) per day at the end of the breeding season depending on the animal's condition. If good quality hay is provided, the animal will not need additional supplement. However, if the hay is poor in quality, additional supplement may be needed to meet maintenance energy requirements. Salt and a mineral mix preferably in loose form should be provided at all times.

Feeding Kids to Produce Meat

After weaning at about 3 months of age, doelings may be placed in the replacement herd while bucklings (young bucks) usually are raised for meat. Creep feeding is defined as providing additional supplemental feeds to kids to increase their growth rate so that they reach their market weight (often 30–35 kg) at an early age (less than 6 months). Although it has not been a common practice in meat goat production, creep feeding should be more profitable with changes in goat marketing strategies that promote premium prices for larger, more highly finished kids. Feed is provided in a creep feeder that will allow access to feed by the kids but not by other animals. Creep feed can be simple like corn and oats, barley and oats, or a more complex commercial kid grower mix containing 14–16% protein and about 10% fiber. Adding more fibrous feeds such as beet pulp, oats, or dehydrated alfalfa to creep feed will promote rumen development. Loose mineral mix and salt should be provided at all times. The creep feeder should be conveniently located where animals spend most of their time.

Generally, most male kids and female kids that are not herd replacements are either sold as weaned kids or are fed for meat production. Weaned goats should be fed according to their nutrient requirement to reach the desired slaughter weight of 30–35 kg (in the U.S.). Some ethnic groups may desire older animals with heavier carcasses or want kids before specific holidays. Following the typical growth curve, male kids grow faster than female kids (Figure 10.3), and growth rates are most rapid between birth and 6 months of age.

For ease of handling and to improve docility, all male kids in the U.S. except those kept for breeding are castrated very early in life. However, as shown in Figure 10.4, buck kids grow faster than wethers, and castration will stunt

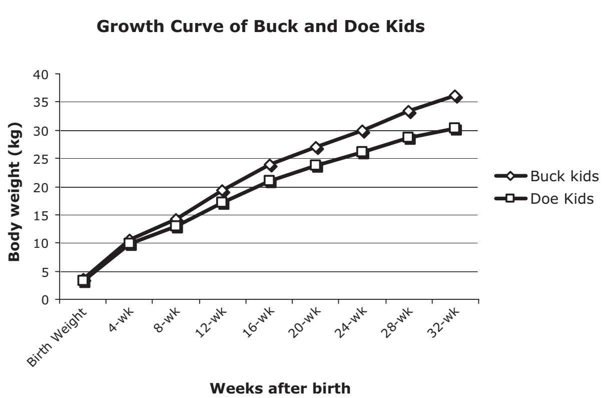

Figure 10.3 Growth curves for bucks and does from birth to 35 weeks of age.

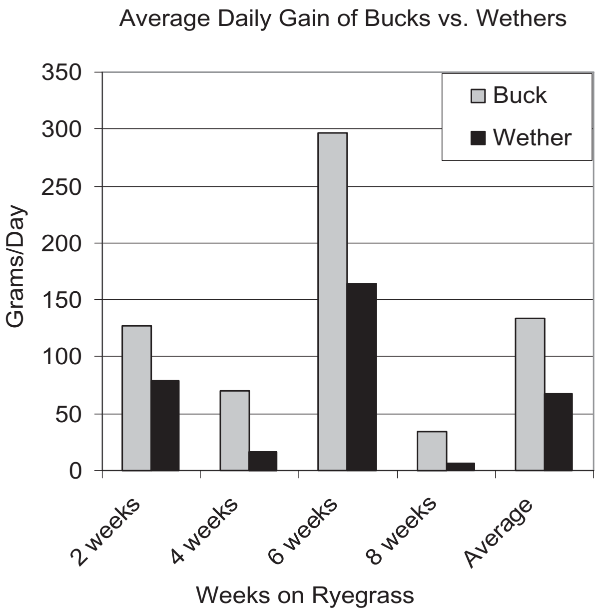

Figure 10.4 Period and total daily gain of bucks versus wethers grazing ryegrass pastures over an 8-week period. Source: Solaiman et al., 2006.

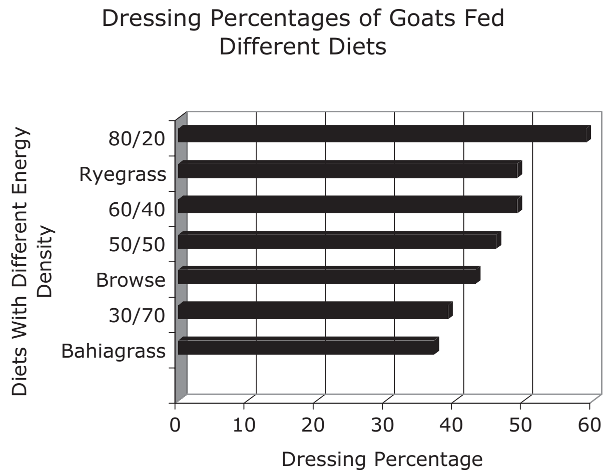

Figure 10.5 Dressing percentages of growing goats (BW = 35–40 kg) fed different diets or various levels of concentrate : hay ratio.

growth, reduce average daily gain, and increase the time needed for goats to reach market weight. Premature castration also increases the incidence of urinary calculi by reducing the development of the urinary tract. Intact buck kids gain 20–30% more weight than castrated wether kids. If kids are slaughtered at 6 months of age or less for meat, and provided bucks are separated from does, castration can be skipped so that bucks will gain weight more rapidly. However, success in raising intact bucks for meat will depend on the management skills and practices on an individual farm.

Lightweight goats that are in poor condition or that have been transported a long distance can be reconditioned through a controlled grazing scheme without or with a limited amount of grain. Goats fed concentrate diets will have higher dressing percentages at slaughter largely because their carcasses tend to contain a higher percentage of body fat and more muscle but a smaller digestive tract with less digesta (Figure 10.5).

Feeding for Milk Production

Management is challenged to maintain health and maximize milk production of lactating does, particularly early in lactation when the animal is in negative energy balance. Milk production by dairy goats generally peaks at 6–8 weeks of lactation (Figure 10.6) while intake of feed and energy peaks at 3–4 months into lactation. During this period, the lactating doe relies on body reserves to produce milk, and generally is in a ketotic condition. Animals often lose 0.5–1 kg of body weight per week for the first 2 months in lactation, but starting at 4 months in lactation, they should gain weight (1–2 kg per month) to restore the tissues lost during early lactation. Lactating does should be fed according to their requirements for milk production (Appendix A). Nutrient composition of a complete mixed dairy ration is presented in Table 10.11. Adding fat at 3–4% of diet DM can increase energy density of the diet to help meet the needs for early lactation and allow feeding forage to promote optimum milk fat synthesis. However, higher levels of fat will reduce fiber digestion and calcium absorption. A higher protein level also is required in early lactation for microbial protein synthesis, and additional rumen by-pass protein will help provide the amino acids necessary for milk synthesis as well as glucogenic amino acids for lactose production. Some suggested maximum limits for ingredients in diets for dairy goats are presented in Table 10.12.

The ideal environmental temperature for milk production is between 5 and 25°C. A temperature-heat index (THI) higher than 72 reduces DM intake by 10–12% and

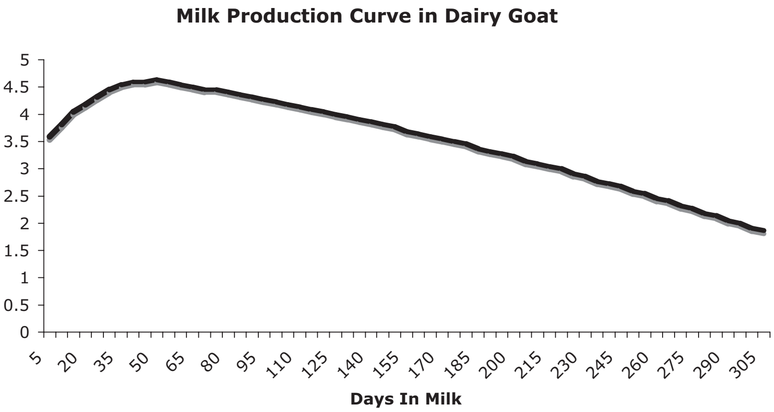

Figure 10.6 Typical lactation curve for dairy goats.

Table 10.11 Recommended nutrient contents for complete mixed rations for dairy goats.

Item	Amounts
Total Digestible Nutrients	75% for early lactation and reduced to 60% during late lactation
Crude Protein	18% for early lactation and reduced to 14% during late lactation
Acid Detergent Fiber	18% for early lactation and increased to 20–22% during late lactation
Fat	3–4% added fat particularly for early lactation
Concentrate:Forage Ratio	60 : 40 for early lactation and changing to 40 : 60 during late lactation
Calcium:Phosphorus Ratio	At least 1.5 : 1
Phosphorus	0.4%
Added Salt	0.5%
Sulfur	0.25–0.35%
Nitrogen:Sulfur Ratio	10–12 : 1, with added sulfur usually needed when diets contain nonprotein nitrogen
Magnesium	Higher magnesium may be needed with N and K fertilized pastures to prevent hypomagnesemia
Copper	15 ppm
Selenium	3 ppm

Table 10.12 Recommended maximum limits for select feeds in diets for dairy goats.

	% of Concentrate Mix	% of Body Weight
Nitrogen Sources		
Urea	1.5	0.03
Fish meal	3	0.08
Whole soybeans	25	0.5
Corn gluten feeds, dry	30	0.8
Energy Sources		
Tallow	4	0.12
Molasses	6	0.15
Bakery products	—	0.3
Soy hulls	20	0.4
Wheat middlings	20	0.4
Cottonseed hulls	20	0.4
Whole cottonseeds	20	0.4
Brewers grain, dry	25	0.5
Brewers grain, wet	—	2.3
Distillers grain	25	0.5
Citrus pulps, dry	—	0.6

milk production by 20–30% for lactating dairy cows. Corresponding responses by goats to THI have not been determined, but heat stress definitely can reduce milk production. To reduce heat stress of dairy does, a number of management changes can prove to be useful, including (1) feeding smaller portions of the ration more frequently, (2) feeding during cooler times of the day or under shade with adequate air flow, (3) feeding only high quality forage, (4) reducing the forage : concentrate ratio (to reduce the heat increment), (5) adding dietary buffers to help maintain rumen pH if diets are high in concentrates, (6) feeding yeast to increase fiber digestion, (7) feeding fungal products and niacin to improve energy utilization, (8) supplementing fat to increase energy density for higher milk production, (9) providing cool water, and (10) providing fans, water sprinklers, or sprayers for additional cooling aid.

Feeding for Fiber Production

Management of goats for fiber production in many ways is similar to that of meat-producing goats. But fiber-producing goats usually are smaller in adult size than meat goats and have a slower growth rate. Diets of fiber-producing animals generally will be only forage with little or no supplemental grain. Fiber proteins contain higher levels of sulfur, so when nonprotein nitrogen is fed to fiber-producing goats, supplemental sulfur should be provided to maintain a nitrogen : sulfur ratio between 10 : 1 and 12 : 1. Feeding a high quality protein diet will increase fiber diameter and result in a coarser, lower quality fiber, but it will result in greater fiber yield. Therefore, the management choices (quality versus quantity of fiber) must be considered carefully when designing the feeding regime. Fiber quality (fineness) will be at a maximum under adverse nutritional conditions. The higher the feed quality, the coarser the fiber, but the greater is the yield of fiber. Basic nutritional requirements (see Appendix A) still should be met to ensure that the herd will be healthy and profitable.

GOAT FEEDING SYSTEMS IN THE U.S.

Meat goats in the U.S. are raised under a wide variety of environments that include the West (California), under a Mediterranean climate; the Southwest, a semiarid climate; Southeast, a temperate and subtropical climate; and the Midwest, a temperate climate. Dairy goats are raised mainly in California, Texas, and Wisconsin, and fiber goats are mainly concentrated in Texas, New Mexico, and Arizona. Feeding practices specific for goat production in these regions will be covered briefly in this section.

Feeding Systems for the Southeastern U.S.

The Southeastern states have a mild, temperate environment with hot and humid summers, mild winters with not more than 20 freezing days, and high rainfall throughout the year. Goat production systems in this region can range from pasture and browsing woodlands to total confinement. Feeds available include grasses; legume trees (mimosa, kudzu); forbs; understory brush as forage; sweet potatoes, peanuts, and cotton by-products; and conventional supplements. The quality of forage, especially of pastures, drops drastically in the summer, therefore supplemental energy and protein are needed for optimum gain. Legume trees or small grain pastures can reduce the need for supplemental feeds. Ideal animal production systems may be localized to maximize use of available feed and land resources, and producers must develop sound feeding programs. Pasture and browse provide needed nutrients and energy for feeding goats year-round, particularly in the Southeast. A year-round foraging system for this region may include annual Marshall ryegrass (a cool season grass) for winter grazing (December–April), peas or soybean greens (legume) for late spring and early summer (May–June) grazing, mimosa browse, sorghum, or bermudagrass (warm season grasses) for summer (July–October), with hay or concentrates being used sparingly when needed (Solaiman et al., 2006). Unfortunately, this system is very management intensive and requires outside input (fertilizer, anthelmintics). Compared to goats on bahiagrass pasture and mimosa browse (gaining 46 and 80 g/d, respectively), animals in a feedlot or grazing Marshall ryegrass (winter pasture) grew faster (141 and 139 g/d, respectively) and reached their expected slaughter weight in less time. Animals on feedlot and Marshall ryegrass had superior carcass quality, but this difference was not significant. In contrast with the performance advantages for feedlot, economic returns from the Marshall ryegrass system were superior followed by the mimosa browse system.

Parasite infestation is one of the major problems in raising goats in many areas of the country, especially in the Southeast. Most common and effective anthelmintics lose their effectiveness with frequent use as parasites develop resistance after a short period of time. Bioactive forage plants containing condensed tannins may help in control of parasites. Browse plants containing tannins like mimosa can be safely incorporated in the diet of goats in this region to reduce parasite load (Solaiman et al., 2006).

Goat Feeding Systems for the Midwest

In the Midwest region of the U.S., interest in raising dairy and meat goats has had a resurgence. Known as the agriculture heartland of the country, the Midwest has locations that provide ideal conditions for raising goats. Daily temperatures range from −10 to 8°C in the winter and 18 to 27°C in the summer. Rainfall usually is plentiful, averaging 250 to 500 cm annually. The lower Midwest region has higher temperatures and more precipitation than the colder and dryer upper Midwest. Because of the low precipitation and humidity, farmers have fewer problems with goat internal parasites than in the Southeast. The Midwest region also produces pastures and forage with excellent quality. These forage products reduce the requirement for supplemental grain. Although the lower part of this region has cool season grasses and legumes for winter grazing, the middle and upper portions of the Midwest are not as fortunate with very cold winters and grazing of cool season grasses for only a few months out of the year, usually May and June. In July and August, sudangrass or corn can be fed to goats. Harvested hay or silage can be used when the pasture is not available. Silage and haylage are produced in this region, but caution should be used when feeding silage or haylage to goats. Corn silage is an underutilized feed because of the labor involved in production and feeding. If poorly harvested and preserved (with soil contamination and presence of oxygen), it can harbor *listeria*, the bacteria that causes listeriosis (circling disease). Corn silage also is deficient in protein, calcium, and phosphorus, so, for best results, it should be supplemented with a protein source like alfalfa. Because corn silage produces more energy per acre than other crops, more goats can be maintained using corn silage than with any other harvested feed. Haylage usually is produced from alfalfa and brome forage. Though more variable than corn silage in quality, it is higher in protein and minerals. Hay or other roughage usually is fed with silage and haylage to reduce the incidence of metabolic disturbances in goats. Ryegrass, orchardgrass, bluegrass, festuloliums (cross between fescue and ryegrass), and other grasses as well as alfalfa, clover, and other legumes are common forage produced in this region. Winterkill of legumes can be a problem, so a diverse mixture of species usually is sown for pasture and hay for goats. Protein supplements such as soybean meal, linseed meal, sunflower meal and by-products such as corn stover and soy hulls are readily available. Distillers' grain and other grain by-products are plentiful in the Midwest and are excellent sources of feed energy and protein for goats. By-products of the ethanol industry of interest include wet and dried distillers' grain, wet and dry distillers' grain with solubles, modified wet cake, and condensed distillers' solubles. Although distillers' grains are good sources of energy and protein, protein availability can be reduced by high temperature drying.

Semiarid Goat Production System

This goat production region includes rangeland, chaparral, grasslands, and woodlands where dry, sandy, rocky, and saline soils predominate and the environment (typically rainfall) will dictate both the quality and quantity of vegetation available. Parts of Texas (west), Arizona, New Mexico, California, and some other states fit under this production system. In contrast to intensive systems where many goats are produced in a confined space, most goats in this region are raised under very extensive conditions with minimal inputs of feed and labor. Low rainfall, a diversified native forage material, extensive rangeland goat production, goat herds with a very large number of head, and hundreds of acres of rangeland per ranch are characteristics unique to this system.

Rangeland vegetation, brush, browse, and other bushes and forbs are widely available. Natural grassland will provide sufficient forage for growth and meat production during the rainy seasons (spring and summer) while forbs, bushes, shrubs, and trees provide feed for maintaining these free-ranging goats during the rest of the year. The nutritive quality of vegetation diminishes drastically during the winter and dry seasons, so productivity can only be sustained with supplemental feeds. Nevertheless, feeding of supplement is seldom practiced. Due to dry environmental conditions and extensive goat production, unlike other systems, internal and external parasites pose little problem so parasite control is rarely practiced in this region. Highly variable climates and unpredictable environmental conditions from season to season and from year to year make this system quite challenging for goats and goat producers. Due to the nature, quality, and variability of vegetation, and these variable environmental conditions, it is difficult to design proper supplementation programs for optimum production. Experienced managers can assess range conditions as well as animal conditions to determine quality and quantity of supplemental feeds that are needed. Goats are usually used for range improvement and vegetation clearance in this region. Readers are directed to Chapter 16, Environmental Enhancement, for further information.

Goat Production Practices Focused on California

California historically has led the nation in agricultural production for more than 50 years. Its moderate Mediterranean climate, fertile soils, and progressive farmers have contributed to this success. More than 250 commodities are produced in California, with this state being the national leader in production of 75 of them. Regions are ideally suited to produce fruits, vegetables, nuts, and animal products such as milk and meat. Most importantly, more than 97% of farms in California are family owned, another key factor conducive to excellent goat production. California's abundance of rangeland caters to the browsing ability of goats and mixed grazing. The mostly dry, mild Mediterranean climate in California helps reduce gastrointestinal parasitism of goats.

California has the highest product value per acre in the U.S., and a wide variety of agricultural products are grown on its fertile land. Energy-rich cereal grains such as wheat, barley, and sorghum are grown locally, and protein feeds such as cottonseed, sunflower meal, and other by-products are readily available. Roughage such as good quality hays and silages, and by-products such as rice bran, wheat bran, and sugar beet pulp are common. Garden produce, often sold in farmers' markets, provides residues that can be used as compost or as feed for goats. California's diverse topography—valleys, foothills, coastal areas, and deserts—make this diverse Western state suitable for production of a variety of agricultural products including goats.

North Coast and Mountains of California

This area has fewer farms of middle and large size than other areas of the U.S. and is well suited for timber and production of cattle, sheep, and some goats that can graze hills and rough terrain over wide expanses. Goats raised in this region often form part of herds used in a mixed grazing system with other livestock. Hay produced on irrigated pastures and rangeland covering private and leased public lands provides high quality forage for goat production in this region. With more than 32% of California's terrain covered by forestland, and with proper management, goats as browsers can be successfully raised for meat production in silvopasture systems using undercover brush and browse.

Central Valley of California

The Sacramento Valley, with its cooler winters and high rainfall, produces small grain crops and seasonal grazing on nonirrigated land. Rice is produced on irrigated lands. Row crops including tomatoes, beans, corn, milo, and sunflowers also are produced in this region.

The foothills of the Sacramento Valley support seasonal grazing. The southern portion of the great Central Valley, the San Joaquin Valley, is the most extensive and productive agricultural region in California and the nation. In this region, several favorite feeds for goats are grown including alfalfa, cotton by-products, vegetables, and field crops. Sheep, cattle, and sometimes goats, can graze on the irrigated pastures in the foothills of this region.

Central Coast of California

With the highest value farmland in the nation, the Central Coast is home to the country's premium agricultural products including grapes, strawberries, orchard crops, and vegetables. By-products of the fruit and vegetable industries can be used for goat feed. The Salinas Valley is the salad bowl of the nation, creating an abundance of leftover greens for goats.

Southern California

The South Coast region tends to have farms of smaller size and is a major producer of avocados, citrus, vegetables, and hays. Alfalfa, cotton, citrus, dates, small grains, and winter vegetables are produced in abundance in the hotter interior valley where farms are generally larger.

GLOBAL LIVESTOCK PRODUCTION SYSTEMS

According to the FAO, livestock production systems are classified as (1) livestock production systems, where less than 10% of the total value of production comes from non-livestock farming practices, and (2) mixed farming systems, where more than 10% of the total value of production is from non-livestock farming activities (Seré and Steinfeld, 1995). A landless livestock production system is where less than 10% of animal feed is produced on-farm, and animal density is more than 10 livestock units per hectare. This system is mainly concentrated in the developed countries and is capital and feed intensive, and labor extensive. A grassland-based livestock production system is where more than 10% of the animal feed is produced on-farm, and animal density is less than 10 livestock units per hectare. This system is used in Central and South America and in developed countries. Rain-fed, mixed farming systems in developed countries and Asia produce more than 70% of the meat produced in the mixed farming system, and the remaining 30% is produced by irrigated mixed farming systems. Grazing and mixed farming systems are represented in temperate and tropical highland zones; the humid and subhumid tropical and subtropical zones; and arid, semiarid tropical and subtropical zones of the world.

Globally, mixed farming systems provide more than 54% of total meat and 92% of total milk production followed by landless systems; grazing systems contribute less than 10% of total production for meat and milk. It is expected that mixed system farming will continue to grow (Table 10.13).

Table 10.13 Total meat production and share of meat or milk production from different livestock production systems in the world.

Regions	Landless[1]	Grassland[2] %	Mixed Farming[3]
Developed countries	54.6	37.5	35.8
Eastern Europe	14.9	—	16.1
Asia	19.3	8.5	34.9
Central and South America	8.8	39.0	7.6
West Asia and North Africa	1.9	2.4	3.4
Sub-Saharan Africa	0.5	12.5	2.1
Share of meat production	36.8	9.3	53.9
Share of milk production	—	7.9	92.1

[1]Landless Livestock System represents an intensive system.
[2]Grassland Based Livestock system represents extensive system.
[3]Mixed Farming System represents livestock and crop production system.
Source: www.fao.org.

SUMMARY

Feeds for goats fall into two groups: forage/roughage and concentrates. The optimum proportions of forage and concentrate in the diet will vary depending on an animal's physiological stage and its level of performance. Specific nutrients (protein, energy, minerals, vitamins, and water) are required by goats and must be provided in the diet through feed. Diets must contain a protein source that for goats, like other ruminants, may be derived partially from nonprotein nitrogen sources like urea. Energy is derived primarily from dietary carbohydrates (sugars, starches, and fiber) though fats and excess protein also provide energy. The process of matching the animal's requirements with the nutrient contents of feed ingredients is referred to as "feeding practices." Sound feeding practice will (1) optimize animal performance, (2) minimize feed cost, and (3) sustain the environment. Each animal should be matched to its specific energy and nutrient needs for maintenance, growth, reproduction, and production of meat, milk, and fiber. Improper feeding practices or imbalances of nutrients will reduce production and may cause metabolic disorders. Feeding management practices specific for goat production in different regions of the United States and throughout the world will vary widely depending on the availability of feeds and natural resources.

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