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REVIEW [REVISIÓN]

RECENT ADVANCEMENTS IN FIBER DIGESTION AND UTILIZATION IN GOATS

[AVANCES RECIENTES EN DIGESTION Y UTILIZACIÓN DE LA FIBRA EN CAPRINOS]

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SUMMARY

Dietary fiber contributes significantly to the balancing of nutrient requirements in goats. Dietary fiber also plays a pivotal role in goat production through its influence in and interaction with the intake and digestion of nutrients. Physiological regulation (feedback from metabolic factors) of intake is dominant in goats fed high-concentrate diets, while physical fill is the predominant factor in the regulation of intake when goats were fed high-forage diets. Mediated through salivation and buffering capacity, dietary fiber intake influences mastication and rumen fermentation. In growing goats, dietary metabolizable energy density above 2.78 Mcal/kg depresses intake and reduces growth rate in goats. Adequate dietary fiber is essential in producing leaner carcasses in growing goats. In high producing lactating dairy goats, dietary fiber intake plays a role in the prevention of milk fat depression. The effect is mediated through the maintenance of favorable acetate to propionate ratio in the rumen liquor, as acetate is the major precursor of milk fat. It appears that 18 to 20 % ADF or 41 % NDF is nutritionally adequate for high producing lactating dairy goats. For growing goats between 4 and 8 month of age, 23% ADF is recommended. Relationship between chewing time and dietary fiber can be defined by the equation: Total Chewing Time (min/d) = 33.11 + 30.13 ADF Intake (%). Milk fat yield can be predicted from dietary fiber intake: Milk fat yield (g/d) = 115.78 – 0.128 x ADF intake (g/d) + 0.00021 x (ADF intake, g/d)^2.

Key words: goat, fiber, digestion, energy, protein.

RESUMEN

La fibra dietética contribuye significativamente en el balance de los requerimientos nutricionales de las cabras. Es importante por su influencia e interacción con el consumo y la digestión de los nutrientes. La regulación fisiológica (factores metabólicos) del consumo es dominante en las cabras alimentadas con dietas altas en concentrados, mientras que el llenado físico es el factor predominante cuando se alimentan con dietas altas en forrajes. El consumo de fibra dietética influye sobre la masticación y la fermentación ruminal a través de la salivación y la capacidad búfer. En cabritos en crecimiento, la densidad de la energía metabolizable en la dieta por arriba de 2.78 Mcal/kg reduce el consumo y la tasa de crecimiento. La cantidad adecuada de fibra en la dieta es esencial en la producción de canales más magras. El consumo de fibra juega un papel importante en la prevención de la reducción de la grasa de la leche. Este efecto esta mediado por el mantenimiento de la relación favorable de acetato a propionato en el líquido ruminal, dado que el acetato es el principal precursor de la grasa de la leche. Un 18-20% de FDA o 41% de FDN parecen ser adecuados para las cabras altas productoras de leche. Para las cabras en crecimiento entre 4 y 8 meses de edad, se recomienda un 23% de FDA. La relación entre el tiempo de masticación y la fibra presente en la dieta se define: Tiempo total de masticación (min/d) = 33.11 + 30.13 consumo de FDA (%). El rendimiento de grasa en la leche se puede predecir a partir del consumo de fibra en la dieta: Redimiento de grasa en leche (g/d) = 115.78 – 0.128 x Consumo de FDA (g/d) + 0.00021 x (Consumo de FDA, g/d)^2.

Palabras clave: cabras, fibra, digestión, energía, proteína

INTRODUCTION

Goats as ruminants require adequate dietary fiber for normal rumen function. Rumen function is associated with rumination to maintain adequate salivation and optimal pH for cellulolytic microorganisms that typically yield higher acetate to propionate ratios in the rumen liquor. Dietary fiber through microbial degradation and synthesis supplies energy to support maintenance, growth, lactation, and reproduction. While there is a comprehensive understanding of the role that dietary fiber plays as a nutrient and its digestion in cattle, fiber digestion and its role in productive performance has not received equal attention in goats. Goats differ in feeding behavior, level of intake, diet selection, taste discrimination, and rate of eating from sheep and cattle (Lu, 1988; Reid *et al*., 1990). Because of these differences the knowledge obtained from other ruminant species may not be able to extrapolate to goats. Fiber requirements for goats have not been defined by the current NRC guidelines (NRC, 1981). Lactating dairy goats, in particular, require fiber to maintain a normal milk fat content. In addition to the quantity of fiber consumed, the particle size (Lu, 1987), type of fiber, fermentation rate, and surface exchange properties influence rumination, milk yield, and milk fat content. To establish optimal dietary fiber concentration for milk production, one must consider factors such as stage of lactation and level of yield. Information pertaining to the effects of chemical composition and physical form of fiber on nutrient utilization could improve the efficiency of goats as producing ruminants for milk, meat, and fiber. The challenge is to understand how much fiber and in what physical form is needed to maintain a normal rumen function without the physical limitation of intake, and how to maximize the availability of fiber to support production.

CHEMICAL, PHYSICAL AND NUTRITIONAL EVALUATION OF FIBER

Nutritionally speaking, chemical composition and physical form of structural carbohydrate or insoluble dietary fiber influenced productive performance in goats. Therefore, measurement of dietary fiber chemically and physically can be useful as nutritional indicators. Chemically dietary fiber can be determined as crude fiber, neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin. By mathematical differences, one can derive cellulose and hemicellulose. For high-concentrate diets amylase can be added to the NDF procedures to improve the accuracy and yield amylase-treated neutral detergent fiber (aNDF). In most of the instances ADF could be a more acceptable assay to analyze dietary insoluble fiber in a total mixed ration. Stage of maturity of forage can also be used to predict fiber content, as fiber content in the forage increases with the stage of maturity. Challenges in measurable insoluble fiber have been reviewed recently (Mertens, 2003). It was concluded that analysis of sugars in insoluble polysaccharides is less reproducible and more expensive, although it provides more information. Measurement of physical form of fiber can be a challenge. Most of the measurements are qualitative, such as coarse vs. fine or long vs. short. Average particle length can be determined with an oscillating screen particle separator and use as a measurement of physical form in dietary fiber (Lu, 1987). A system linking weight with mean particle length of forage may be a better nutritional indicator than the weight alone. Physical form of forage may influence productive performance through the influence in mastication, microbial fermentation in the rumen, and rate of passage and digestion in the gastro-intestinal tract. Furthermore, forage particle length may affect fat content and fat-corrected milk output in lactating diary goats.

MASTICATION

Mastication is important nutritionally because of its relationship with physical limitation of intake and the maintenance of normal fermentation in the rumen. It is generally agreed that a high fiber diet that results in longer rumination time may limit the voluntary feed intake. It is also understood that salivation as a result of mastication can influence the production of acetate, a precursor of milk fat. Particle size reduction via mastication and rumination is an essential part of forage digestion in goats. Chewing during eating and rumination reduces particle size, increases surface area available for digestive rumen microbes and enzymes, and increases digesta passage. Salivation during chewing influences dilution rate and buffering capacity of rumen fluid. When lactating dairy goats fed Bermudagrass hay with a grain mixture, rumination and total chewing time were reduced when mean particle length of Bermudagrass hay was reduces from 3.87 to 2.38 mm (Lu, 1987). Lactating dairy goats spent 188 to 219 min/d eating and 294 to 364 min/d ruminating when Bermudagrass hay with shorter particle length was fed. On the contrary, they spent 207 to 245 min/d eating and 380 to 459 min/d ruminating when longer particle length hay was fed. Time spent ruminating was greater for goats fed the 15% corn brand rations (397 min/day) than for those fed rations with 30% corn bran (338 min/day) (Franz *et al*., 2004). Grinding of corn brand did not significantly change the time goats spent ruminating.

Mastication can be influenced by the forage-to-concentrate ratio in the diet. When Saanen and Marota crossed goats were fed diets with forage to concentrate ratio from 45:55 to75:25; eating time ranged from 188 to 207 min/d and ruminating time ranged from 299 to 363 min/d (Kawas *et al*., 1991).

It has been demonstrated in lactating dairy goats that there is a linear relationship between fiber intake and chewing activities. As the intake of fiber increases, eating, ruminating and total chewing time increase (Santini et al., 1991 & 1992). In a study (Santini *et al*., 1991) of 40 multiparous Alpine lactating goats, eating time ranged from 176 to 325 min/d and ruminating time ranged from 267 to 486 min/d when diets of various fiber contents were fed. In a second study (Santini *et al*., 1992) lactating dairy goats spent 180 to 263 min/d eating and 249 to 364 min/d ruminating when they were fed alfalfa hay with corn and soybean meal mixture, with total dietary fiber content ranged from 14 to 26%. Total chewing time can be predicted from dietary fiber intake (in % or g/d) in lactating dairy goats:

Total Chewing Time (min/d) = 33.11 + 30.13 ADF Intake (%) ($P < 0.001$; $r = 0.83$; $n = 40$)

Total Chewing Time (min/d) = 345.33 + 0.32 ADF Intake (g/d) ($P < 0.001$; $r = 0.60$; $n = 40$)

When the total chewing activities is partitioning into eating and ruminating, the ratio varies slightly among reported studies (Lu, 1987; Kawas *et al*., 1991; Santini *et al*., 1991 & 1992). Nevertheless, it provides a general guideline for a normal chewing activity. The reported ratios of eating to ruminating were 37:63 (Lu, 1987), 38:62 (Kawas *et al*., 1991), 43:57 (Santini *et al*., 1991) and 46:54 (Santini *et al*., 1992). In most of the reported studies, both eating and ruminating times were affected concomitantly by treatments that include forage particle length, forage to concentrate ratio and dietary fiber intake. In lactating goats it is reasonable to conclude that ratio for partitioning of total chewing activities into eating and ruminating ranged from 37-46: 54-63 (Table 1).

Table 1. Partitioning of Total Chewing (%) in goats.

	Eating	Ruminating
Lu, 1987	37	63
Kawas *et al*., 1991	38	62
Santini *et al*., 1991	43	57
Santini *et al*., 1992	46	54

It has been reported that body size alone accounts for more than 50% of variability of chewing activities (Bae *et al*., 1983). Welch (1982) reported the rumination efficiency of sheep, goats, and cattle of various ages and suggested that larger animals require less total chewing time per unit of fiber ingested after correction for metabolic size. Therefore, chewing activity adjusted for metabolic body size may be a better parameter to compare results from different studies, especially when animals with different body weight were considered. Total chewing time expressed as per unit NDF and corrected for metabolic body weight (MBW) decreased from 21.2 to 16.3 min/g NDF per kg $BW^{0.75}$ when forage-to-concentrate ratio was decreased from 75:25 to 45:55 (Kawas *et al*., 1990). Total chewing time expressed as per unit of DMI corrected for MBW increased linearly with dietary ADF intake (Santini *et al*., 1991). Total chewing time when expressed as per unit of ADF intake corrected for MBW was not affected by dietary ADF intake. This implies that chewing efficiency per unit of fiber intake can be a constant. However, in subsequent study (Santini *et al*., 1992), chewing efficiency expressed as min/(g of DMI x kg $BW^{0.75}$) decreased from 3.85 to 4.89 when dietary ADF intake was increased from 373 to 738 g/d (Santini *et al*., 1992). Chewing efficiency expressed as min/(g of ADFI x kg $BW^{0.75}$) increased from 26.9 to 19.1 as ADF intake increased. This implied that goats became more efficient chewers as ADF intake increased, chewing only 71% as much per unit of ADF consumed as those in the low fiber intake treatment.

RUMINAL FERMENTATION

Volatile fatty acids are end products of microbial fermentation in the rumen. These products are absorbed across the rumen wall and utilized for biochemical synthesis; further producing products that can be served as energy sources, deposited as body fat, or synthesized into milk fat. Typically a concentrate diet yields higher proportion of propionic acid while a forage diet yields more acetic, butyric and isobutyric acids. Composition of volatile fatty acids in the rumen can be nutritionally significant; it affect host animal not only metabolically and physiologically, but also dictates the efficiency of milk or body fat synthesis. Acetic acid is known to be precursors for milk fat, while propionic acid is mainly utilized for the biosynthesis of glucose or the deposition as body fat. Goats fed high fiber diets had lower peak concentrations of glucose in the plasma (Schmidely *et al*., 1999a) implying less glucose for energy use than milk fat deposit. We also know that pH in the rumen liquor plays a role in the composition of fatty acids. A higher pH typically favors the cellulolytic microorganisms (*Fibrobacter succinogenes*, *Ruminococcus flavefaciens*, and *Ruminococcus albus)* that yield a higher proportion of acetic and butyric acids. On the other hand, a lower pH tends to favor the amylolytic microorganisms that yield a higher proportion of propionic acid. Kinetics of cellulose digestion is first order and cellulose digestion is limited by the availability of substrate; not by cellulolytic capabilities of the resident microflora (Weimer, 1998). Therefore, availability of fiber, the total amount and surface accessible for digestion, plays an important role in production performance in goats.

A high fiber diet provides not only the substrates that favor the growth of cellulolytic microbes, but also increase salivation through eating and ruminating. Salivation through its buffering capacity further increases ruminal pH that favors the growth of cellulolytic microbes and produces more acetic and butyric acids. Feeding of forage with longer particle length slightly increased ruminal pH and acetate to propionate ratio in primiparous lactating dairy goats (Lu, 1987), although the differences were not statistically significant. However, in multiparous lactating goats there is a clear relationship among ruminal pH, acetate to propionate ratio and dietary fiber intake (Santini *et al*., 1992; Figure 1). Ruminal pH increased linearly from 6.28 to 6.55 as ADF intake increased. Ruminal acetate concentration increased as dietary fiber intake increased. Acetate to propionate ratio increased from 3.3 to 3.6 as dietary ADF increased from 14 to 26%. In these studies ruminal pH and acetate to propionate ratio were associated with total chewing activity. In another study ruminal pH was clearly related to ruminal acetate concentrations (Bava *et al*., 2001).

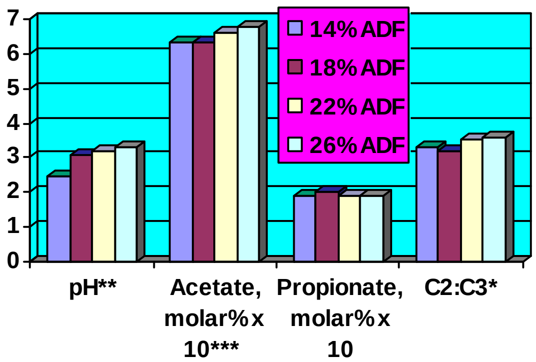

Figure 1. Level of fiber intake (%) and ruminal fermentation (Santini *et al*., 1992).

Several secondary plant compounds can affect ruminal fermentation (Lu, 1990). They are often considered toxic because of the inhibition in microbial growth and/or reduced performance in host ruminants. Alfalfa saponins reduced microbial protein synthesis in the rumen (Lu and Jorgensen, 1987). Leucaena mimosine is known to be converted to toxic goiterogen 3-hydroxy-4(1H)- pyridone and develop toxicosis in goats. Milkvetch leaves contain arabinogalactan protein that prevents cellullolytic bacteria from adhering to cellulose (Weimer *et al*., 1993). It is apparent that understanding of these compounds and their detoxification through ruminal fermentation is beneficial for the fiber digestion and utilization.

GROWTH AND CARCASS COMPOSITION

Feeding of high-fiber diets often results in slower growing rates as compared to the feeding of high concentrate diets (Mahgoub *et al*., 2003). Batina and Dhofari goats fed 12.3, 18.3 and 24.7% ADF (23.6, 33.0 and 43.4% NDF) grew at 45 and 45, 83 and 51, and 98 and 55 g/d, respectively.

Increasing levels of dietary fiber decreased fat content of carcass and non-carcass portions in goats (Mahgoub and Lu, 2004). Carcass fat was 5.3, 4.6, 4.3%; and noncarcass fat was 4.6, 4.5, and 3.8%; in goats fed 12, 19, 26% ADF diet, respectively. The corresponding NDF was 24, 34 and 44%.

Increasing dietary fiber levels also decreased chemical fat (Mahgoub *et al*., 2003). In goats fed 12.3, 18.3 and 24.7% ADF (23.6, 33.0 and 43.4% NDF), carcass chemical fat (ether extracted fat) was 36.7 and 38.9, 45.1 and 43.7, and 47.4 and 46.7% for Batina and Dhofari goats, respectively. Corresponding noncarcass fat in the same animals were 45.5 and 46, 56.4 and 43.5, and 59.5% and 47.1%, respectively.

MILK FAT COMPOSITION

Milk fat depression has been linked to inadequate dietary fiber intake in lactating cows. Milk fat depression perhaps can be observed in high producing diary goats during early lactation. The mechanism that explains milk fat depression syndrome in high producing lactating ruminants involves dietary fiber intake, chewing activity, salivation, and ruminal fermentation. A high fiber diet results in higher chewing activity, which in turn increases salivation and favors the growth of cellulolytic microbes and production of acetic acid. Higher acetate to propionate ratio in the rumen liquor favors the synthesis of milk fat, since acetate is the major precursor of milk fat. Feeding of corn silage from brown midrib mutants depressed milk fat concentration in cows when fed in a low NDF diet (Oba and Allen, 2000). Lower lignin content compounded with low dietary NDF contributed to the milk fat depression. One must recognize that diets with lower fiber do not always result in low milk fat even though the chewing activities were depressed (Colenbrander *et al*., 1991). In that study sufficient amount of effective fiber was presented in the low fiber diet. Requirement of fiber to maintain milk fat content was demonstrated by feeding diets rich in starch (15 vs. 43 % NDF or 6 vs. 25% ADF) that resulted in milk fat depression in multiparous Alpine and Sannen goats (Schmidely *et al*., 1999b).

It may not be able to always link dietary fiber intake with milk fat depression in goats at least for a couple of reasons. One is that most of the goats studied are not high producers (more than 2.5 kg milk/day) and not in early lactation (during the first 12 weeks postpartum). Another reason is that high concentrate diets are not frequently fed to goats. In a study utilized lactating Granadina goats (Sanz Sampelayo *et al*., 1998), physical form (long hay vs. pelleted alfalfa) did not affect milk production (1.35 vs. 1.31 kg/day) and milk fat content (6.3 vs. 6.7%). In primiparous lactating goats milk fat was 0.4% higher when longer forage particle length was fed (Lu, 1987). This was associated in an increase in chewing activities, a slightly higher acetate to propionate ratio, and only 0.1 unit increase in pH value in the rumen liquor. In another study when primiparous goats were studied, milk fat decreased from 3.62% to 2.92% when the concentrate was increased from 25 to 55% of the diet (Kawas *et al*., 1991; Figure 2).

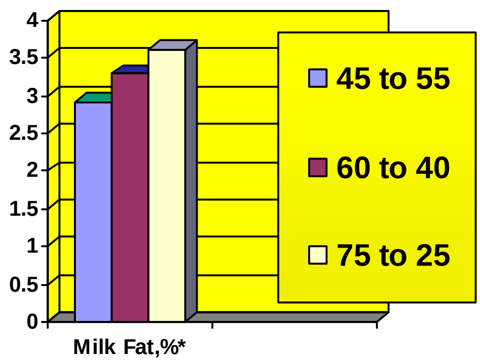

Figure 2. Forage to concentrate ratio and milk composition (Kawas *et al*., 1991)

There was a clear association among dietary fiber intake, chewing activities and milk fat content. In a study utilized large number of multiparous goats, there was an apparent effect of dietary fiber intake on milk fat content, with a linear increase from 4.85 to 5.40% as dietary ADF intake increased from 396 to 839 g/d (Santini *et al*., 1991). In that study the milk fat increase was also associated with an increase in chewing activities. In subsequent study milk fat was 2.48, 3.09, 3.19 and 3.32 % in multiparous goats fed 14, 18, 22 and 26% ADF diet, respectively (Santini *et al*., 1992). In that study the depression in milk fat content was associated with decreased chewing activities, lowered pH, and lowered acetate to propionate ratio in the rumen liquor. Milk fat yield can be predicted from the following equation:

Milk fat yield (g/d) = 115.78 – 0.128 x ADF intake (g/d) + 0.00021 x (ADF intake, g/d)^2
($P < 0.01$, r = 0.55, n = 40)

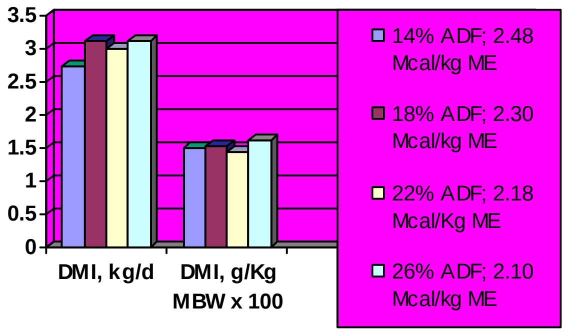

Figure 3. Fiber and DMI in lactating goats (Santini *et al*., 1990)

DIGESTION KINETICS

In lactating diary ruminants, dry matter intake (DMI) is limited by physiological regulation during high concentrate feeding and by physical factors during high forage feeding. As observed in other ruminant species, increase in dietary fiber content reduces DMI in goats. As forage-to-concentrate ratio increased from 45:55 to 45:55, total daily DMI decreased from 84.3 to 59.8 g/kg BW$^{0.75}$ (Kawas *et al*., 1991). Presumably DMI was regulated by the physical fill in that study. A typical example can be used to demonstrate both physical fill (rumen distention) and metabolical/physiological (dietary energy density) regulations of DMI in multiparous lactating diary goats (Santini *et al*., 1991). Dry matter intake peaked when goats were fed a diet containing 18% ADF with 2.30 Mcal/kg ME. When dietary ADF was higher than 18%, there was a slight reduction in DMI. When dietary ADF was lower than 18%, there was also a reduction in DMI. It appears that diet with 14% ADF and 2.48 Mcal/kg ME reduced DMI through physiological regulation. This was confirmed by a subsequent study that diet with 14% ADF and 2.39 Mcal/kg ME did not reduced DMI as compared with diets with 18% ADF and 2.19 Mcal/kg ME (Santini *et al*., 1992; Figure 3). DMI decreased linearly with increasing dietary NDF (52.4 to 62.1 %) in Boer goats and crosses (Luginbuhl *et al*., 2000). The dietary NDF in that study was likely above the critical range of physical control. Because of fibrous components ferments and passes from the reticulorumen more slowly than other dietary components, they have greater filling effect over time (Allen, 1996). Particle size, chewing frequency and effectiveness, particle fragility, indigestible NDF, and characteristics of reticular contractions affect physical fill (Allen, 1996).

In lactating dairy goats physiological regulation occurred in dietary energy density somewhere between 2.39 and 2.48 Mcal/kg ME. Metabolic constrains on voluntary intake in ruminants have been reviewed (Illius and Jessop, 1996). It was concluded from the model of the effects of asynchrony of nutrient supply to ruminal microbes that ammonia and microbial recycling and the contribution of hind-gut fermentation reduces the asynchrony in the balance of nutrients absorbed into the bloodstream. Using stepwise regression analysis, dietary energy density, milk yield and body weight were the top three variables which best estimate DMI (Lu *et al*., 1991). The predict equation is:

Dry Matter Intake (kg/day) = 3.61 + 0.35 x Milk Yield (kg/day) + 0.02 x Body Weight (kg) – 0.05 x TDN (%) ($P < 0.001$; $r = 0.92$; $n = 60$)

In growing Alpine and Nubian goats fed complete mixed diets containing 2.46, 2.77, or 3.05 Mcal/kg ME, DMI decreased curvilinearly as dietary energy density increased (Lu and Potchoiba, 1990; Figure 4). This relative large study with 90 animals suggested that physical fill in growing goats was higher than 26% ADF and critical point for physiological control of intake was near or lower than 2.46 Mcal/kg ME.

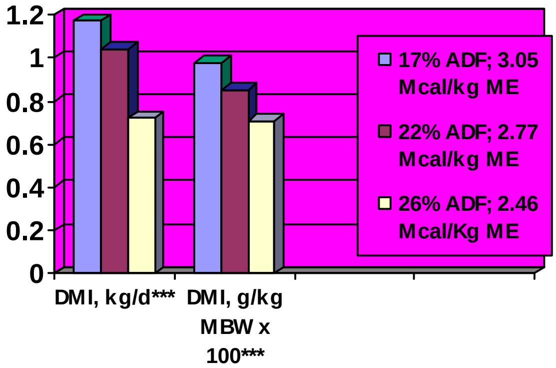

Figure 4. Fiber and DMI in growing goats (Lu and Potchoiba, 1990)

It is generally recognized that increasing fiber intake depresses digestibility of other dietary components except fiber, which usually increases in digestibility. Lower fiber intake shifts the microbial population toward an increase in lactate production in the rumen, depresses ruminal pH, and reduces cellulolytic activity. In lactating dairy goats fed diets with forage to concentrate ratio ranged from 45:55 to 75:25, apparent digestibility of DM was reduced from 74.5 to 61.0 % (Kawas *et al*., 1991). On the contrary, apparent digestibility of NDF was increased from 43.4 to 55.0%. In lactating dairy goats fed diets with ADF content from 14 to 26 %, apparent digestibilities of DM and energy were only slightly reduced, while that of ADF was essentially the same across the treatments (Santini *et al*., 1992).

Measurement of digestion kinetics can be useful for the explanation of the effect of dietary fiber on intake and digestibility of nutrients. While data in goats are still somewhat limited, our laboratory conducted a study to measure the ruminal turnover rate, turnover rate in the hindgut, and transit time through the hindgut (Santini *et al*., 1992; Figure 5). Total mean retention time is calculated as the summation of ruminal turnover time, turnover time in the hindgut and transit time using rare earth markers. The turnover rate in the hindgut has an uncertain biological meaning. It is thought to represent turnover rate of contents in the cecum and proximal colon. Rate of passage is affected by the level of intake, forage to concentrate ratios, physiological stage, and ruminant species. Rate of passage of liquid, concentrate, and forage can be measured separately using different markers. These rates can be different among different species. In general liquid fraction moves faster than the particular matter, but the difference is smaller in cows than in sheep and goats. The species difference may be attributed to gut architecture (longer caudoventral blind sac) and feces structure (pellets).

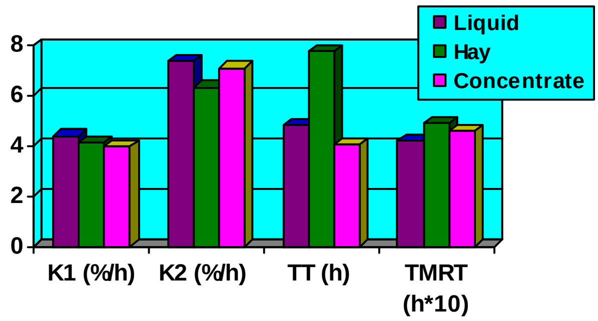

Figure 5. Rate of passage of liquid, hay and concentrate in dairy goats (Santini *et al*., 1992)

The effect of fiber intake on rumial turnover rate can be mediated through saliva production as a result of increased in chewing activities. The ruminal turnover rates were: 3.96 to 4.60 % per hour for liquid; 4.01-4.28 % per hour for hay; and 3.66-4.12 % per hour for concentrate in lactating dairy goats fed diets with ADF from 14 to 26 %. The corresponding total mean retention times are 40-45 hours for liquid; 47-53 hours for hay; and 42-55 hours for concentrate. It appeared that the longest total mean retention time for the concentrate and liquid were in goats fed 18 % ADF.

The longest total mean retention time of hay was observed in goats fed 14 % ADF. A recent study (Walz *et al*., 2004) demonstrated a gradient potentially digestible NDF to indigestible NDF ratio at various locations of reticulorumen, omasum and abomasum in Spanish goats and concluded that rare earth compartment method was more reliable than the indigestible NAF pool dilution method. They also pointed out that estimates of mean escape rates over days must consider the complex interactions among plant tissues and the dynamics of their ruminal digestion of potentially digestible NDF.

FUTURE UNDERSTANDING

Based on the existing literature, we know that dietary fiber content is pivotal to the regulation of intake in goats. Dietary fiber is also vital in the digestion of nutrients mediated through mastication, microbial fermentation in the rumen, and rate of passage in the gastro-intestinal tract. We have an idea about the minimum amount of fiber required to maintain a normal rumen function of goats in all physiological stages, and the prevention of milk fat depression in high producing lactating goats in particular. The bulk of information is still far too small to draw reliable and precise conclusion. In order to quantitatively define relationships among dietary fiber intake, mastication, microbial degradation and synthesis, rate of passage, and biosynthesis of body and milk fat, much more studies are still needed. Synchronization of structural carbohydrate digestion and protein degradation and synthesis in the rumen, the effect of fiber intake on fatty acid composition of adipose tissue and milk fat, and fiber digestion kinetics are a few areas that merit further exploitation. For goats continue to be economically important, research should focus on the improvement of production efficiency. Continuation of the improvement of the efficiency of utilization in important feed resource such as fiber will certainly contribute to goats as productive ruminants. Manipulations of fiber utilization to increase milk, meat and fiber production, and to produced products of quality that are desirable by the consumers remain a challenge in the goat sector worldwide.

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