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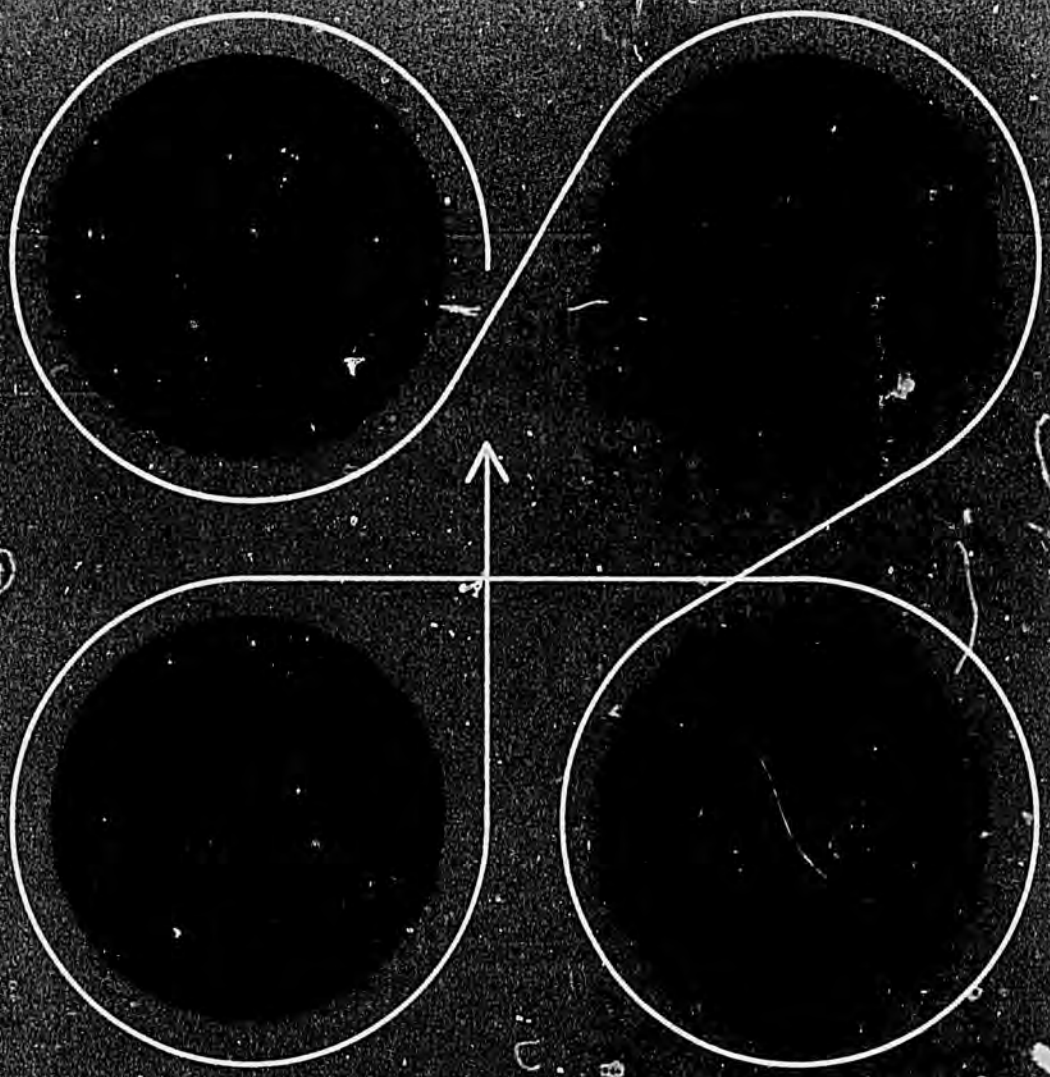

FEEDING STRATEGY [illegible]

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FEEDING STRATEGY OF THE GOAT

by

B. McCammon-Feldman, P.J. Van Soest, P. Horvath and R.E. McDowell

Department of Animal Science
Cornell University
Ithaca, New York 14853

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INTRODUCTION

Many people attribute to the goat a special role in contributing to the food supply in areas of the world with low productive potential and high human needs. Why the goat occupies this role is yet unresolved.

One view is that many small farms are without adequate feed supplies for a cow but the productive needs of several goats could be met. The goat has a smiliar feed conversion efficiency to most other livestock but is simply a smaller unit.

A second explanation for the widespread husbandry of goats in marginal areas is that they are more efficient converters of all feeds than are cattle (Devendra and Burns, 1970; Winrock International, 1977; National Academy of Science, 1981). If this is true, goats would be the best choice where feed, not labor, is the limiting factor.

Some investigators (McCammon-Feldman, 1980; Van Soest, 1980) believe that species differences in feeding behavior among cattle, sheep and goats uniquely fit each species to the utilization of different available feeds. These differences should be considered in determining the best species to utilize a particular ecosystem. Feeding behavior is also important in determining whether single or multi-species will best utilize available plant materials.

This report examines the feeding strategy of the goat compared to other ruminants in an attempt to illuminate ecological conditions which provide it with a nutritional advantage. Results on dry matter intake, cellulose, digestion, and other elements of feeding behavior are used to define the goat's feeding strategy and how it differs from other herbivores.

DRY MATTER INTAKE (DMI)

The quality of DMI is the most important factor determining the feed nutrients ingested. A major component of the nutritional strategy of nonruminants is to ingest high levels of dry matter relative to their body size (Foose and Lloyd, 1974; Uden, 1978). These species move large volumes of material rapidly through the gut, removing soluble nutrients and passing the less digestible fiber. Ruminants retain food for the benefits of pre-gastric-bacterial fermentation and are more limited in their ability to pass large volumes of material through the digestive tract. It has been suggested that goats may be intermediate in this respect with a greater ability to pass fibrous feeds.

Using rumino-reticular retention time as an indicator of rate of passage, the deer is among the fastest; while, among domestic ruminants, goats appear to have a somewhat faster rate than sheep or cattle (Table 1). However, ruminants have slower rates of passage than a number of monogastric herbivores. The horse and zebra, for example, maintain intakes of 10% of body weight through a rapid rate of passage. Rabbits selectively pass indigestible fiber particles while recycling digestible organic matter through the consumption of night feces. Nonruminant herbivores, in general, have fast passage rates, high dry matter intakes and low fiber digestion (Van Soest, 1980).

Ruminants are believed to be limited in their ability to exploit the

Table 1. Rumino-reticular retention time for different ruminant species

Species	Method	Retention time (hr)	Source
Deer	^{51}Cr	21-24	Mautz and Petrides[a]
Goat	stained particles	22	Castle[a]
	mordanted Cr	52	Uden, 1978
Sheep	^{144}Ce	33	Ellis and Huston[a]
	mordanted Cr	70	Uden, 1978
Cow	stained particles	52-63	Shellenberger and Kesler[a]
	inert particles	28-73	Campling and Freer[a]
	mordanted Cr	62-79	Uden, 1978

[a]Summarized by Huston, 1978

strategy of high passage rate because of limits on getting large particles through the omasum. Goats pass larger particles than sheep, which is another indication that goats have a higher rate of passage.

Given limitations on rate of passage characteristic of ruminants, another method of increasing intake would be to expand the physical capacity of the gastrointestinal tract. Hofmann (1973) and Hoppe (1977) found that wild African ruminant grazers, subsisting on high fiber grass diets, had proportionately larger gastrointestinal tracts than ruminant selectors which chose highly digestible diets low in fiber. MacKenzie (1970) claimed that the capacity of the digestive system of goats was proportionately greater than that of steers and sheep, however, Spedding (1975) found that both the length of the digestive tract and the weight of stomach and intestines were about equal in percentage of empty body weight for sheep and goats.

Dry matter intakes for goats, sheep, and cattle fed grasses or legumes are in Table 2. The overall average DM intake as percentage of body weight was 2.69, 2.40, and 1.80% for goats, sheep, and cattle, respectively. However, excluding the abnormally high values for goats (7.3 and 5.2% in Nigeria and Pakistan) the value for goats (2.29%) is in line with the mean for sheep. In the trials with stored forages in Canada (Jones *et al*., 1972), goats averaged 2.77, sheep 3.10, and cattle 2.83%. The high

Table 2. Dry matter intakes (DMI) of grasses and legumes (% body weight) for goats, sheep and cattle

Location	Diet	DMI (% body wt.) Goat	Sheep	Cattle	Source
Zambia	*Hyparrhenia* spp.	1.8	1.6	-	Gihad (1976)
Unknown	*Pennisetum purpureum*	3.3	2.1	-	Devendra (1975)
India	*Trifolium alexandrinum* (hay)	3.0	3.0	-	Sharma & Murdia (1974)
Nigeria	*Cynodon nlemfuensis* + *C. pubescens*	0.8	1.4	0.1	Mba *et al*. (19760
Nigeria	*C. nlemfuensis* + *C. pubescens* + groundnut cake	7.3	11.8	1.0	Mba *et al*. (1976)
India	*Medicago sativa* or *Trifolium alexandrinum* + concentrate	3.7	-	2.5	Mudgal & Kaur (1976)
Pakistan	*Ficus bengalensis* (green leaves)	2.1	-	0.9	Hussain *et al*. (1960b)
Pakistan	*Ficus religiosa* (green leaves)	5.2	-	2.1	Hussain *et al*. (1960a)
Nigeria	*Pennisetum purpureum* (dried and chopped)	1.6	2.0	-	Ademosun (1970)
Guadeloupe	*Digitaria decumbens* (green cut)	1.3	3.1	-	Chenost & Bousquet (1974)
Guadeloupe	*Medicago sativa* (hay)	3.4	3.6	-	Chenost (1972a)
Canada	*M. sativa* (wilted silage)	3.4	3.5	3.1	Jones *et al*. (1972)
Canada	*M. sativa* (hay)	2.9	3.0	3.0	Jones *et al*. (1972)
Canada	Corn (high DM silage)	2.0	2.8	2.4	Jones *et al*. (1972)

Table 2. (cont'd)

Location	Diet	DMI (% body wt.) Goat	Sheet	Cattle	Source
Puerto Rico	*Digitaria decumbens* ADF (goats) = 44.9 ADF (steers) = 45.3	2.0	-	1.7	Gutierrez-Vargas *et al.* (1978)
Puerto Rico	*Cynodon nlemfuensis* ADF (goats) = 44.2 ADF (steers) = 45.4	1.8	-	1.5	Gutierrez-Vargas *et al.* (1978)
Australia	*Acacia pendula* (boree) 16.9% CP, 61% NDF	2.5	2.2	-	Wilson (1977)
Australia	*Casuarina cristata* (belah) 9.4% CP, 62% NDF	2.1	2.0	-	Wilson (1977)
Australia	*Heterodendrum oleifolium* (rosewood) 12.5% CP, 44% NDF	1.6	2.0	-	Wilson (1977)
Australia	*Medicago sativa* 23.1% CP, 49% NDF	2.0	1.9	-	Wilson (1977)

variability among diets indicates species preferences, which can be important in estimations of specie differences in DMI.

Intakes of dry matter by goats on various diets in temperate and tropical areas are in Table 3. The overall average was 3.2 ± 1.7% of body weight. Regional differences were small. Breed effects (improved vs native) were confounded with location (temperate vs tropical areas). Lactating Alpine does averaged over 4% on concentrate diets in temperate areas (MacKenzie, 1970; Brannon, 1975), but as high or higher intakes are reported for tropical breeds. For example, Barmer goats in India consumed 8.2% of body weight when fed *cenchrus ciliaris* hay and Nigerian goats averaged 7.3% on a mixture of *cynodon nlemfuensis* hay and groundnut cake (Table 3). In general, breed differences appear less important than feed composition. Intake levels were highest on diets with a high proportion of concentrates (3.8%) followed by browse (3.4%), hay (3.3%), silage (2.6%) and grass (2.1%). Goats consuming tropical grasses and/or browses without concentrate supplements averaged 2.46 ± 1.01% of body weight. This suggests goats in the tropics need to consume a diet with 60% true digestible organic matter in order to achieve maintenance requirements.

Table 3. Dry matter intake (% body weight) of goats on various diets

Breed	Location	Diet	DMI (%)[a]	Source
		TEMPERATE AREAS		
Alpine (lactating)	New York	Concentrates (72.5% corn, 15% alfalfa, 10% SBM)	5.8	Brown (1979, unpublished)
Alpine (lactating)	New York	High fiber (72.5% alfalfa)	7.5	Brown (1979, unpublished)
Unknown	U.S.A.	Concentrate (<10% fiber)	2.1-2.7	Baile *et al*. (1969)
Cross	Great Britain	Hay + concentrate	3.3[b]	Singleton (1961)
Alpine	Canada	Wilted alfalfa silage	3.4	Jones *et al*. (1972)
Alpine	Canada	Alfalfa hay	2.9	Jones *et al*. (1972)
Alpine	Canada	High DM corn silage	2.0	Jones *et al*. (1972)
		TROPICAL AREAS		
Local		*Pennisetum purpureum*	3.3	Devendra (1975)
Barmer	India	*Cenchrus ciliaris* hay	8.2	Khan *et al*. (1978)
Unknown	India	*Trifolium alexandrium* hay (20.6% CP)	3.0	Sharma & Murdia (1974)
Red Sokoto	Nigeria	*Cynodon nlemfuensis* + *C. pubescens*, (6.48% CP)	0.8	Mba *et al*. (1976)

Table 3. (cont'd)

Breed	Location	Diet	DMI (%)[a]	Source
Red Sokoto	Nigeria	*C. nlemfuensis* + *C. pubescens* + groundnut cake	7.3	Mba *et al*. (1976)
Kambing Katjang	Malaysia	*Panicum maximum* (10.8% CP + concentrates)	1.7	Devendra (1967)
Jamunapari	India	Oat straw (*ad lib*.) + groundnut cake, barley grain, paragrass, Berseem and *lobia* (restricted)	1.9-2.7	Singh & Sengar (1970)
Barbari	India	same as preceding	2.0-2.8	Singh & Sengar (1970)
Jamunapari (lactating)	India	Gram *bhusa*, wheat *bhusa*, "green feed", groundnut cake, linseed cake, barley grain	2.7-3.4	Singh & Sengar (1970)
Barbari	India	same as preceding	3.4-4.2	Singh & Sengar (1970)
Sinai	Israel	Barley and wheat hay	2.8-3.0[b]	Shkolnik *et al*. (1972)
Mountain	Israel	Barley and alfalfa hay	3.1[b]	Shkolnik *et al*. (1972)
Alpine x Beetal	India	Concentrate (ADF = 13.85) + *Medicago sativa* (ADF = 22.40) or *Trifolium alexandrinum* (ADF = 25.89)	3.7	Mudgal & Kaur (1976)
Unknown	Pakistan	*Ficus religiosa* (Pipal) leaves (13.99% CP, 22.36% CF)	5.2	Hussain *et al*. (1960b)
Unknown	Pakistan	*Ficus bengalensis* (Bargad) leaves (9.6% CP, 26.8% CF)	2.1	Hussain *et al*. (1960a)

Table 3. (cont'd)

Breed	Location	Diet	DMI (%)[a]	Source
Local	Pakistan	*Ficus religiosa* + rape cake	3.8	Hossain (1960)
Local dwarf	Nigeria	*Pennesetum purpureum* (dried & chopped)	1.6	Ademosun (1970)
Alpine (lactating)	Guadeloupe	*Digitaria decumbens* + concentrates	1.7	Chenost (1972c)
Alpine	Guadeloupe	Alfalfa	3.4	Chenost (1972a)
Alpine	Guadeloupe	*Digitaria decumbens* [over year]	1.0-2.3	Chenost (1972b)
Jamnapari	India	-	2.8-2.9	Majumdar (1960a)
Kambing Katjang	Malaysia	-	2.3-2.7	Devendra (1967)
Anglo-Nubian	Trinidad	*Pennisetum purpureum* + concentrate	4.8-5.0	Devendra & Burns (1970)
Alpine	Trinidad	*Pennisetum purpureum* + concentrate	4.8-5.0	Devendra & Burns (1970)
Jamnapari cross	Malaysia	*Pennisetum purpureum*	2.3-4.1	Devendra (1975)
Alpine	Guadeloupe	*Digitaria decumbens* + concentrate	2.0-3.5	Chenost & Bousquet (1974)
Local	Puerto Rico	*Digitaria decumbens*	2.0	Gutierrez-Vargas *et al.* (1978)
Local	Puerto Rico	*Cynodon nlemfuensis*	1.8	Gutierrez-Vargas *et al.* (1978)
Unknown	Australia	*Geijera parviflora* + *Medicago sativa*	1.9	Wilson (1977)

Table 3. (cont'd)

Breed	Location	Diet	DMI (%)[a]	Source
Small East African	Zambia	*Hyparrhenia* spp. (6.6% CP)	1.8	Gihad (1976)
East African Dwarf	East Africa	Free-range browse	3.4-6.4[c]	Wilson (1977)
Unknown	Australia	*Geijera parviflora* (wilga) (15% CP, 34% NDF)	1.4	Wilson (1977)

[a]All animals not pregnant or lactating unless otherwise noted

[b]As fed, not 100% DM

[c]Estimated from body weight differences before and after browsing (3.4% assumes that feed was 40% DM while 6.4% assumes that feed was 60% DM)

Although this level of intake is comparable to other ruminants consuming coarse forages, it does not approach that of nonruminant herbivores.

The general conclusion is that a relatively high DM intake aids the goat in maintaining itself under conditions of poor feed; however, the intake attributed to goats is insufficient to explain their ability to survive in areas where sheep and cattle experience nutritional stress.

DIGESTION OF CELLULOSE

In our search for more and better sources of animal products, particularly in the developing countries, interest has focused on comparisons of the digestive efficiencies of indigenous animals--goat, buffalo, camel and wild African ruminants--to cattle and sheep. Theoretically, indigenous animals may be better adapted to local environments because they have existed for millenia in comparison to more recently introduced cattle and sheep.

A. Experimental Problems.

Before drawing conclusions concerning the relative digestive efficiences of different species, it is necessary to examine some of the problems and potential errors inherent in testing. In designing experiments to determine digestive efficiency, it is important to begin with an operative hypothesis of the physiological basis for a difference in ability to digest a particular feed. Up to the present time there is a notable lack of such explanations; thus, it is difficult to evaluate the significance of studies proclaiming a greater digestive efficiency by one species.

The first conceptual problem in standardized digestion trials is the standardization itself. Since all inter-animal variation is designated as "error", animals are selected for physiological and genetic uniformity. Following selection, the animals are confined to digestion stalls. Diets may be ground and pelleted to minimize feeding behavior differences, and feed intake is often restricted to have minimal refusals. The resulting values on intake and estimated digestive coefficients are of little use for estimates of possible inherent differences among species because the forced standardization tends to ignore differences in eating habits.

The experimental design of a digestion trial interprets all differences in digestion coefficients as being due to variations in ability to digest. There are, however, several other factors which influence the results. These factors may become more important when comparing animal species. Some of these are:

1) animal specie differences in composition of feed actually consumed, especially when there is opportunity for diet selection;
2) differences in diets of animals prior to the experiment;
3) technical differences with laboratory analyses; and
4) inter-animal variation within species.

B. Physiological Differences.

A superior ability to digest cellulose by the goat can only be proven through demonstration of a physiological basis. Possibilities are differences in:

1) retention time in the rumen;
2) efficiency of rumination;
3) absorption capacity;
4) rumen microbial population;
5) buffering capacity in the rumen; and
6) fecal metabolic organic matter.

Retention time is proportional to body size and is influenced by physical properties of the diet. Ground feeds and those which break down rapidly through mastication are retained for less time than long forages. It has been hypothesized that rumination to a smaller particle size exposes more feed surfaces to microbial attack, increasing the rate of cellulose digestion. More likely rumination increases density (creates space in the rumen) and facilitates passage (Carlos Sequeina, personnal communication; Welch, 1981).

There is some evidence that absorptive capacity differs among species due to differences in size and density of rumen papillae (Hofmann, 1973). Variations in buffering capacity among species are possible, though not adequately documented. While differences in concentration of cellulolytic bacteria in the rumens of various species have not been found, reindeer are known to ferment the carbohydrate lichenen found in lichens. Cattle do not have this capacity (Person, 1975).

It is conceivable that differences in conformation and movement in the rumen of various species could allow formation of different ecological niches in pockets of the rumen of some species, leading to differential abilities to ferment feed substrates. Physiological differences among ruminant species which could cause variation in rumen environments have not been well documented. It is known that the turnover time of the rumen contents has a profound effect on the composition and yield of microbial matter in the rumen due to restriction of generation time (Hespell and Bryant, 1979).

The quantity of metabolic organic matter in the feces effects the apparent digestibility of a feed. The quantity of metabolic organic matter (Mi) is proportional to the quantity of feed ingested and is higher for cattle than sheep. McCammon-Feldman et al. (1980) reported a lower Mi for goats than for sheep and cattle. It has been postulated that metabolic fecal organic matter values are highest for grazing animals and progressively lower for animals which ferment less cellulose (Van Soest, 1981). Goats feeding on grass (high cellulose) diets had higher Mi values than those on browse (low cellulose) diets. Wilson (1977) found similar Mi values for sheep and goats on the same diet.

C. Intake Level.

Level of intake is known to profoundly effect the digestibility of a feed, since the longer a feed remains in the rumen the greater the time for cellulo-

lytic bacteria to breakdown the material. When a feed is more palatable to one species than another, intakes may vary resulting in differences in digestibility. Since gastro-intestinal tract size is proportional to body size (Parra, 1979), equivalent intake should be calculated on the basis of body weight not metabolic body size.

In feeding experiments, the composition of feed offered cannot be assumed as that consumed. When comparing a species like goats with species that are less selective, such as cattle, it is important to measure the refused feed, not only in total quantity but also for possible disparities between feeds, such as portions of leaves and stems of forages.

D. Previous Diet.

The microbial population of the rumen is affected by the diet the animal consumed prior to the feeding trials. An adaptation period of seven to fourteen days is usually considered sufficient for development of microbes able to utilize a particular diet. The period required may be longer for adaptation to inhibitory compounds or atypical substrates.

E. Technical Difficulties.

The use of crude fiber as a measure of forage cellulose, as in the proximate analysis method, has several technical difficulties, particularly for tropical forages. Loss of lignin and hemicellulose from the crude fiber fraction can result in a crude fiber with equal or greater digestibility than the nitrogen free extract. Tropical grasses, which are higher in lignin and hemicellulose than temperate grasses, are especially liable to this error (Van Soest, 1975).

The chemical analysis for crude fiber does not adequately describe materials high in either lignin or hemicellulose. About 80% of the hemicellulose or pentosan in forages is soluble in weak acid alkali, while 50 to 90% of the lignin is soluble in alkali, and cellulose is dissolved from 19 to 50%. Losses of lignin and cellulose vary with type and species of plant material (Van Soest and Robertson, 1980). With this magnitude of variable losses of the fiber fraction, differences in digestibility of four or five percent between species lose their significance.

F. Inter-Animal Variation.

An additional problem in defining important differences in digestive capacity among ruminants is the high inter-animal variation found in intake and the effect this has on measurements of digestibility. Most studies comparing species have involved few animals (2 to 5) per treatment, yet it has been determined that sixteen sheep are necessary to distinguish intake differences at the 5% level of alpha error (Van Dyne, 1964).

G. Digestive Efficiency.

The possibility of real differences in digestive efficiency among ruminants exists through differences in retention time, metabolic organic matter

excretion, rumen absorption capacity and/or the maintenance of unique rumen environments.

The digestibility coefficients for goats, sheep and cattle for various dietary constituents are in Table 4. When fed the legume Trifolium alexandrinum goats and sheep were significantly superior to cattle in digestion of DM, CF and CP, but on timothy hay the rank order for digestibility coefficients was significantly higher for cattle. These tests indicate a strong interaction between diet and animal species.

Particularly relevant to estimates of speciesdifferences are those experiments for which digestible energy was measured (Baumgardt et al., 1972; Gihad, 1976). These tests showed no significant differences among the three species, but where cellulose was measured, using either the modified techniques of Crampton and Maynard (Baumgardt et al., 1964), or the method of Van Soest (Jones et al., 1972; Gutierrez-Vargas et al., 1978; Uden, 1978), cattle digested cellulose better than sheep or goats. This is as expected because of the lower body size and slower passage rate of cattle (Huston, 1978). Although the possibility of greater organic matter and cell wall digestibilities of low quality trees by goats is suggested by Wilson's data (1977), large within-species variation and differences in the level of intake make differential digestibilities difficult to substantiate.

Those measuring crude fiber, e.g. Hussain (1960a, 1960b); Jang and Majumdar (1962), found that goats digested crude fiber better than sheep, while Ademosun (1970), Chenost (1972a), Sharma and Murdia (1974) and Adeyanju et al. (1975) did not find this the case.

Differences in feeding habits between goats and cattle and, to a lesser extent, between goats and sheep are documented (Staples et al., 1942; Hafez and Scott, 1962; Knight, 1965; Devendra and Burns, 1970). Due to differences in feeding behavior, it does not seem valid to assume that the diet selected by each species is the same. Of the papers reviewed, only three (Hossain, 1960; Hossain, 1961; Gutierrez-Vargas et al., 1978) reported analyses of refusals or of the diets eaten by each species. These showed only small differences between offered and refused feed for goats, sheep and cattle. In interpreting these comparisons, it should be pointed out that the animals were stall fed, hence their diet selection was severely restricted. Restriction of feed offered to less than free choice, in order to avoid refusals, results in higher digestibility coefficients due to increased retention time. Such a system may prove satisfactory for high concentrate diets or forages of temperate areas, but is unreliable for tropical forages where leaf and stem portions may be highly differentiated in nutritive quality. A normal proportion of refusals for tropical forages may be up to 60% of feed offered (Olubajo et al., 1974).

In general, efficiency of cell wall digestion has a negative relation to body size in ruminants. Sheep do not digest poor quality forages as well as cattle. Since goats are generally smaller than sheep and more selective in their feeding, their efficiency for fiber digestion should be similar to sheep, or perhaps poorer (Hofmann, 1973; Huston, 1978; Demment and Van Soest, submitted). In terms of efficiency of forage utilization, there is an animal

Table 4. Some digestibility coefficients (%) for goats, sheep and cattle of organic matter (OM), crude fiber (CF), crude protein (CP), dry matter (DM), cellulose, energy, acid detergent fiber (ADF) or neutral detergent fiber (NDF)

Diet	Substance	Goats	Sheep	Cattle	Source
Bargad leaves	OM	54.5	-	46.8	Hussain *et al.*
	CF	41.8	-	26.4	(1960a)
	CP	42.5	-	20.0	
Pipal leaves	OM	51.9	-	46.1	Hussain *et al.*
	CF	29.4	-	39.2	(1960b)
	CP	54.3	-	56.6	
Pipal leaves + rape cake + bhoosa suppl.	OM	43.8	-	34.4	Hussain *et al.*
	CF	18.6	-	23.3	(1960b)
	CP	54.3	-	54.9	
Good quality hay + conc.	DM	53.9	-	58.2	Singleton (1961)
Andropogon contortus	DM	59.7	59.9	53.5	Jang & Majumdar
	CF	66.9	64.3	61.6	(1962)
Alfalfa-brome hay	DM	62.1	-	62.3	Baumgardt
	cellulose	64.9	-	65.4	*et al.* (1964)
	energy	60.1	-	61.8	
Pennisetum purpureum	DM	55.2[a]	59.2[b]	-	Ademosun (1970)
	energy	56.3	59.4	-	
Alfalfa hay	OM	59.7	59.3	-	Chenost (1972a)
	CF	53.9	51.4	-	
	CP	57.7	59.8	-	
Digitaria decumbens	OM	66.3	68.9	-	Chenost (1974)
	CF	72.8	70.4	-	
	CP	68.5	71.0	-	
Wilted alfalfa	DM	62.3	59.3	-	Jones *et al.*
	cellulose	66.6	66.4	-	(1972)
	CP	66.6	44.5	-	
	energy	63.6	56.7	-	
Alfalfa hay	DM	54.2	51.1	-	Jones *et al.*
	cellulose	53.3	56.4	-	(1972)
	CP	61.0	63.8	-	
	energy	64.3	57.2	-	

Table 4. (cont'd)

Diet	Substance	Goats	Sheep	Cattle	Source
High DM corn silage	DM	67.3	70.0	-	Jones *et al.*
	cellulose	56.0	62.0	-	(1972)
	CP	52.8	53.8	-	
	energy	67.0	69.7	-	
Low DM corn silage	DM	58.4	58.1	-	Jones *et al.*
	cellulose	62.8	63.7	-	(1972)
	CP	54.0	49.2	-	
	energy	58.8	58.2	-	
Trifolium alexandrinum	DM	57.2[a]	55.8[a]	52.3[b]	Sharma & Murdia
	CF	54.5[a]	49.2[ab]	43.5[b]	(1974)
	CP	60.1[a]	60.3	52.8[b]	
Concentrate diet					
4.2% CF	DM	78.0	77.0	-	Adeyanju *et al.*
	CF	27.3	28.2	-	(1975)
	CP	89.2	91.7	-	
5.6% CF	DM	76.0	77.3	-	Adeyanju *et al.*
	CF	38.5	37.2	-	(1975)
	CP	87.5	89.9	-	
6.6% CF	DM	72.5	76.2	-	Adeyanju *et al.*
	CF	36.0	43.8	-	(1975)
	CP	86.3	88.8	-	
10.7% CF	DM	67.5	69.2	-	Adeyanju *et al.*
	CF	40.3	39.0	-	(1975)
	CP	84.0	86.2	-	
Alfalfa hay (22.4% ADF) or Berseem hay (25.9% ADF) + concentrate (13.9% ADF)	DM	71.3[a]	-	65.3[b]	Mudgal & Kaur
	ADF	80.2[a]	-	53.1[b]	(1976)
	CP	80.5	-	73.5	
Digitaria decumbens	DM	48.4[a]	-	65.3[b]	Gutierrez-
	cellulose	58.2[a]	-	65.9[b]	Vargas *et al.*
	NDF	52.1[a]	-	56.7[b]	(1978)
	CP	37.6	-	40.6	
Cynodon nlemfuensis	DM	44.3[a]	-	50.2[b]	Gutierrez-
	cellulose	52.1[a]	-	56.7[b]	Vargas *et al.*
	CP	38.0	-	43.5	(1978)

Table 4. (cont'd)

Diet	Substance	Goats	Sheep	Cattle	Source
Phyleum pratense (Timothy hay) 67%	DM	49.3[a]	47.8[a]	55.3[b]	Uden (1978)
	cellulose	47.2[a]	47.5[a]	56.8[b]	
	NDF	45.1[a]	44.5[a]	52.3[b]	
Acacia pendula (boree)	OM	46.7	43.4	-	Wilson (1977)
	NDF	31.8	27.9	-	
	CP	68.8	63.2	-	
Casuarina cristata (belah)	OM	35.0	29.3	-	Wilson (1977)
	NDF	23.1	14.0	-	
	CP	32.3	22.1	-	
Heterodendrum oleifolium	OM	43.1	40.2	-	Wilson (1977)
	NDF	6.9	1.3	-	
	CP	32.6	14.0	-	
Medicago sativa	OM	63.2	63.1	-	Wilson (1977)
	NDF	46.9	47.2	-	
	CP	80.9	82.0	-	
Lucerne, sorghum grain + cottonseed husks	DM	56.1	63.2	-	Gallaghar & Shelton (1972)
Hyparrhenia spp.	OM	58.5	58.7	-	Gihad (1976)
	CF	60.3	56.5	-	
	CP	43.5	44.3	-	
	energy	56.6	56.6	-	
Berseem hay (16% CP)	DM	61.0	62.2	-	El Hag (1976)
	CF	64.3	65.8	-	
	CP	72.7	73.4	-	
Dianthium annulatum (5.9% CP)	DM	58.9	57.3	-	El Hag (1976)
	CF	74.4	71.6	-	
	CP	67.2	65.8	-	
Dactyloctenium Aegyptium (Hummra), Shoenefeldia gracilis,	DM	54.5	51.7	-	El Hag (1976)
	CF	59.6[a]	54.2[b]	-	
	CP	75.1[a]	70.4[b]	-	
60% alfalfa hay + cottonseed hulls (ground & pelleted)	DM	58.8	60.6	64.3	Huston (1976)

Different superscripts denote values which are significantly different across animal species ($P<.05$)

species by available forage interaction both for selection and intake capability which must be recognized.

FEEDING BEHAVIOR

A. Plant Preference.

There are numerous reports of goats consuming plants which other livestock avoid (Maher, 1945). Should eating these plants improve either the quantity or the quality of nutrients available, goats would have an advantage (Table 5). Even when goats eat grass, forbs and browse are still important components of the diet (Cory, 1927; Fraps and Cory, 1940; McMahon, 1964; Davis *et al.*, 1973). Others have reported that goats browse when grass is mature or unavailable but once the grasses begin to grow, browsing largely ceases (Irvine, 1941). These observed changes are supported by the seasonal changes in the ratio of browse, grass and forbs in Table 5. Still there are others, e.g. Askins and Turner (1972) and Knight (1965), who concluded that grass was more important than browse or forbs in the diet of goats. In Nicaragua, Pineda (1975) found that of 60 plant species, 47 (78%) were utilized by goats. McMahon (1964) observed that the food habits of deer and goats were similar, but differed from sheep and cattle.

Van Soest (1981) adapted data from Hofmann (1973), Peterson and Casebeer (1971) and Hansel *et al.* (1977) to classify herbivores according to three classifications of feeding habits (Table 6). Goats were classified as intermediate selector feeders, lying between sheep, which prefer grass but will browse, and deer, which primarily browse but consume grass.

The ability of goats to consume a large variety of plant materials is likely due to their agility and dexterity, narrow mouth, mobile upper lips, prehensil tongue, and propensity to stretch upward on its hind legs to reach browse (Staples *et al.*, 1942). French (1970) observed that goats were not persistent grazers but tended to nibble for a short period, then move to a new area.

Although goats will eat a wide variety of plant materials, they have definite preferences. In Kenya, where goats were used for restricting regrowth of leleshwa-shrub (*Tarchooanthus comaboratus*), consumption was low as this shrub was relatively unpalatable (Knight, 1965). Staples *et al.* (1942) also found the shrub *Combretum purpeureiflorum* not well liked. In Mexico, the preference of goats coincided with the dominant plant species in the plant communities in semiarid and arid areas (Xolocotzi, 1970). Malachek and Leinweber (1972) reported that junipers (*Juniperous pinchot* and *Juniperous asheri*) were eaten only by goats in the late dormant season when no other forage was available. Prickly pear (*Oauntia lindheimeri*) is preferred to junipers, while Shin oak is browsed more heavily than either prickly pear or junipers. Clearly, goats feed on a wide range of forages and show high variability in feeding habits in different ecological zones as well as a certain season variation in habits within the same region.

Table 5. Estimates of proportions of diet(%) of browse, grass or forbs consumed by goats under range conditions

Region	Prior Treatment of range	Yearly rainfall (inches)	growing season & temp.(°F)	Management system	Range type	Forage type consumed as percent of diet			Reference
						browse	grass	forbs	
Uganda	N.R.	53.6	85.6	N.R.	"short-grass"	59.1	33.5	7.1	Wilson, 1957
Tanganyika	cut, burned, reseeded (*Cynodon plectostachyum*) 5 years previously	12-25		continuous grazing	"deciduous bushland"		N.R.		Hornby & van Rensburg, 1948.
Kenya	"disclimax community"	12-20	April-Nov.	continuous grazing	"deciduous thicket"	100.0	0.0	0.0	Edwards, 1948
Kenya	cut to knee height & burned 12 months prior to experiment	34	April-Nov.	continuous grazing	dense "mixed Acacia-Tarchonanthus woodland"	27.2[3] 11.9[4]	65.4 82.5	7.4 3.6	Knight, 1965
Kenya	none, virgen bush	34	April-Nov.	continuous grazing	"	28.0	38.4	33.6	Knight, 1965
Texas	N.R.	N.R.	April-Nov.	continuous grazing	*Hiberia belangeri* & *Opuntia lindheimer* range. "good" condition	35.0[1] 39.0[2] 52.0[3] 30.0[4]	62.0 60.0 45.0 70.0	3.0 1.0 1.0 0.0	Malechek & Leinweber, 1972
Texas	N.R.	N.R.	April-Nov.	continuous grazing	" "fair" condition	15.0[1] 37.0[2] 43.0[3] 26.0[4]	83.0 62.0 56.0 74.0	2.0 1.0 1.0 0.0	Malechek & Leinweber, 1972
Texas	N.R.	N.R.	April-Nov.	N.R.	N.R.	53.0	38.0		Cory, 1927

Table 5. (cont'd)

Region	Prior Treatment of Range	Yearly rainfall (inches)	growing season & (temp.(°F)	Management system	Range type	Forage type consumed as percent of diet			Reference
						browse	grass	forbs	
Texas	N.R.	N.R.	April-Nov.	N.R.	N.R.	15.0[1] 50+ [2] 50+ [3] 50+ [4]	32.0 32 43 32	53.0 15- 7- 15-	Fraps & Cory, 1940
Texas	ungrazed range stocking rates of 8, 16, 24 A/animal Unit	N.R.	April-Nov.	N.R.	N.R.	50+	50-		McMahan, 1964
Texas	N.R.	N.R.	N.R.	continuous grazing	Rocky hill-sides and valleys	42.0[1] 94.5[2] 100.0[3] 51.7[4]		58.0 5.5 0.0 48.3	Askins & Turner, 1972
Colorado (southwest)	roller chopped, seeded intermediate wheat-grass one year previously	N.R.	N.R.	not grazed in winter or late fall	Gambel oak range	90-95		5-10	Davis *et al.*, 1973

N.R. = not reported [1]spring [2]summer [3]fall [4]winter

Table 6. Classification of herbivores according to feeding habit[a]

Classification	Ruminants	Non-ruminants
Concentrate selectors		
Fruit + foliage selectors	Duikers, suni	Rabbit
Tree + shrub browsers	Deer, giraffe, kidu	Rhinoceros
Intermediate feeders		
Forb preferring	Moose, goats, eland	
Grass preferring	Sheep, impala	
Bulk and roughage eaters		
Fresh grass grazers	Buffalo, cattle	Hippopotamus
(tropical)	Gnu, kib, oribi	
Roughage grazers	Hartebeest, topi	Horse, zebra and elephant
Dry region grazers	Oryz, camel, roan and sable antelope	

[a]Adapted and extended from Hofmann (1973), Hansen *et al*. (1977), Petersen and Casebeer (1971) by Van Soest (1981a)

B. Diet Selection

Available forage is not automatically the diet of herbivorous animals. They make selections (Cable and Shumway, 1966; Arnold, 1970; Klein, 1970; Kreulen, 1975; and others). A point of interest is whether feed selection is based on nutritive value or other factors. At low grazing pressure, cattle can compensate to some extent for poor quality feed by selectively grazing the more nutritious parts of the available forage (Stobbs, 1975). Coleman and Barth (1973), however, decided that although the nutritional value of selected forages was generally higher than the average nutritional value of the available plant material, secondary factors were of importance in selection. Many investigators found that forage selection by goats was not correlated with availability, (e.g. Malechek and Leinweber, 1972; Pineda, 1975; McCammon-Feldman, 1980).

Significant seasonal fluctuations occurred in the chemical composition and *in vitro* digestibility of forage selected by goats on lightly and heavily stocked ranges (Malechek and Leinweber, 1972). Goats on heavily stocked range were able to select a diet as high in nutritive value as those on a lightly-stocked range. Differences in total intake accounted for the higher body weight gains (5.1 kg/goat) on the lightly-stocked range. These results contrasted with those for sheep (Cook *et al.*, 1965). Sheep on heavily-stocked ranges consumed a more fibrous, less digestible diet than those on lightly-stocked ranges. The fact that goats lowered their dry matter intake more than sheep, instead of consuming forage of higher fiber content, supports the hypothesis that selection on the basis of nutritive quality is an important part of the goat's feeding strategy.

In Nicaragua, goats showed distinct changes in forage preference between wet and dry season. During the wet season, grass was eaten more readily than forbs, shrubs or trees but in the dry season goats consumed mainly legumenous trees (McCammon-Feldman, 1980).

Although the number of observations is relatively low, there is evidence that goats are selective in their food gathering based on nutritive quality. Seasonal shifts in consumption favoring the more nutritious plants are clearly evident. The factors which signal the nutritional value of a forage to the goat are unknown.

C. Use of Browse Plants.

A factor in understanding the nutritional strategy of the goat is the limited knowledge of the nutritive value of browse plants. Part of the complication arises over definition of browse. Another problem rests in applying the proximate analysis method to highly lignified materials.

"Browse" may be defined as the twigs and leaves of woody plant species. A characteristic of woody plant species is the large difference in crude protein, digestible organic matter and cell wall content between the stems and leaves (Table 7). In temperate areas, leaves and terminal stems have similar nutritive values in early spring but the value of the stems soon declines as metabolic

Table 7. Estimates of composition of leaf and stems of some browse plants from tropical and temperate areas

Location	No. Species	Percentage CP leaf	CP stem	DOM leaf	DOM stem	CWC leaf	CWC stem	Source
				TROPICAL AREAS				
Kenya	Rumen contents	15.1	9.0	-	-	-	-	Hoppe *et al.*, 1977
Uganda								
wet season	5	23.7	4.8	-	-	-	-	Bax & Sheldrick, 1963
dry season	5	12.8	3.4	-	-	-	-	"
Uganda		16.5	13.5	-	-	-	-	Field, 1971
Uganda	9	13.4	8.4	-	-	-	-	Field, 1975
Uganda		17.7	7.6	-	-	-	-	Field & Ross, 1976
				TEMPERATE AREAS				
Louisiana								
spring		-	-	79	75	26.1	35.8	Short *et al.*, 1973
summer		-	-	67	36	35.0	67.4	"
Colorado	4	16.2	7.9	-	-	-	-	Dietz *et al.*, 1962
Texas		12.1	6.3	60	31	36.2	68.8	Blair *et al.*, 1977

materials pass into the developing leaves (Short et al., 1973). In the tropics, stems of grasses, browse, forbs or trees are always lower in nutritive value than leaves due to temperature induced differentiation (Van Soest et al., 1978). Authors frequently refer to chemical analysis or nutritive value of a plant without identification of the plant parts evaluated. This approach is particularly prevalent in reports on temperate deer browse where deer consumed terminal stems during the winter months (Robbins et al., 1975). In the tropics, percentage crude protein in browse leaves averaged 16.5% (13.4-23.7%) while that in browse stems averaged 7.8% with a range of 3.4-13.5% (Ghadaki et al., 1974). Similar differentiation was found in temperate woodland vegetation (crude protein 14.1% for leaves vs 7.1% for stems). Digestible organic matter averaged about 24 units higher in leaves than in stems of temperate browses (Short et al., 1973; Blair et al., 1977).

In vivo digestibility studies are difficult to perform on browse species due to the logistics of collecting and feeding. The in vitro digestibility technique (Van Soest et al., 1965), is considered suitable for the prediction of the in vivo digestibility in browse species (Newman and McLeod, 1973), but the effect of inoculum source on the results is disputed. Some workers found no difference in the in vitro digestibility of browses using inocula from several animal species (Grant, 1973; McCammon-Feldman, 1980) while others have found differences (Hungate et al., 1960; Ichponani et al., 1962; Short, 1963; Robbins, et al., 1975). It has been theorized that cow inoculum has greater cellulolytic activity than deer inoculum. For fermentation periods of less than 48 hours, faster rates of fermentation were observed using buffalo rumen fluid than using cow rumen fluid (Grant, 1973). Forty-eight hour in vitro dry matter digestibility of lichens was 16.2% using inoculum from reindeer fed mixed lichens compared to 6.4% using rumen liquor from reindeer on commercial pellets (Person, 1975).

The inoculum source x feed interaction probably depends on the presence of refractory and inhibitory materials in the feed and on the presence of a functioning population of microorganisms in the inoculum capable of dealing with them. Cellulolytic bateria would be expected to be present in inoculum from animals on a high cellulose diet. Microorganisms tolerant of specific secondary plant compounds could be present in the rumen liquor of an animal on a diet containing these compounds. This could influence the estimate of digestibility. Extreme discrepancies are found between in vivo and in vitro digestibilities of some browse species even when inoculum from adapted animals is used. The in vivo digestibility of mixed lichens by reindeer was 55.4% compared to 16.2% in vitro (Person, 1975). In vivo retention time for the lichens was about five days, indicating that perhaps a 48-hour in vitro fermentation was too short. In vivo dry matter digestibility by goats for Cordia dentata, a tropical tree, was 48.2% compared to in vitro digestibilities of 22.8% after 48 hours and 34.8% after 96 hours (McCammon-Feldman, 1980). Grant (1973) recommended 72 hours as giving the most accurate replication of in vivo digestibilities for tropical grasses. Short et al. (1974) reported that maximum dry matter digestibility was attained after 4 hours in woody plant leaves from temperate areas, while 72 hours was necessary for forbs and 168 hours for grasses. The most suitable in vitro fermentation time apparently

depends on the presence or absence of slowly digesting cellulose and inhibitory compounds.

The digestibility (DDM or DOM) of browse plants is moderate to low both in tropical and temperate regions (Table 8). Their importance as a feed source arises from their stable protein and soluble carbohydrate content throughout the year (Wilson, 1969; McLeod, 1973). The particular importance of browse to the tropics is due to striking differences in the composition of grasses in tropical versus temperate areas. While grasses in the northern latitudes maintain high levels of protein and low cell wall lignification, tropical grasses form highly lignified cell walls and protein levels decline with maturity. Protein content may in fact be adequate for goats less than one month per year, hence a high dependence on browse. Fistula samples during the dry season in western Nicaragua had an apparent organic matter digestibility of 57.7% and 15.7% CP. Hand-plucked samples of the dominant grasses averaged 64.0% in digestibility but only 4.8% CP. Similar samples of shrubs had digestibilities of 63.5% with 23.0% CP. With heavy use of shrubs, does kidded year-round (Feldman, 1980).

Browse plants in the semiarid areas of the tropics may be generally characterized as moderate to high in protein, low in fiber and moderate in digestibility. Although lignin content is substantial, its effect is offset by the low plant cell wall content and a reduced association with cellulose. There is evidence, however, that some desert shrubs are low in both protein and digestible organic matter, which results in rumen impaction when they comprise the sole food of goats. The extreme differentiation in nutritional value between leaves and stems of tropical plants and temperate browses provides a basis for selective feeding by animals which have this ability. The high protein levels of browse in the dry season compared to tropical grasses and the maintenance of moderate digestibility throughout the year make it an invaluable nutrient source. The low occurrence of leguminous browse plants in the lowland humid tropics is no doubt a factor in the low density of goats.

D. Plant Defense Mechanisms.

In the tropics, plants have evolved elaborate means of protecting themselves from grazing herbivores. Some hide in space and/or time. Others reduce their palatability or nutritive value. Some use toxins or physical structures. In domestic plants, breeders have removed many of the defense mechanisms, but in wild plants these mechanisms can profoundly influence the value of the plant as feed. Physical defense can take the forms of thorns, spines, tough epidermis, etc. A possible example of coevolution to circumvent the plant's defense is the development of tapered muzzles and prehensile lips by certain species of animals.

Chemical defense is much more widespread than physical. Plant secondary compounds include tannins, alkaloids, oils, terpenes, cyanogins, glucosinolates (mustard oils), protease inhibitors, sesquiterpens lactones, saponins, cardiac glycosides, non-protein amino acids, toxic peptides and organic acids. All have been implicated in plant defense and been shown to

Table 8. Estimates (%) of crude protein (CP), digestible dry matter (DDM, or cell wall content (CWC) of leaves of browse plants fror tropical and temperate areas

Geographic Location	No. Species	CP Mean	CP Range	DDM[a] or DOM Mean	DDM[a] or DOM Range	CWC Mean	CWC Range	Source
				TROPICAL				
Australia		-	-	49	31-74	-	-	McLeod, 1973
(high dig)	3	-	-	62	-	-	-	Wilson, 1977
(low dig)	4	-	-	50	-	-	-	"
Australia		12.3	9.6-14.2	45	37-52	-	-	Harvey, 1952
India	2	11.8	9.6-14.0	54	52-55	-	-	Hussain *et al.*, 1960a,b
Iran								
(immature)		14.5	10.2-22.4	57	30-77	43.2	31.5-57.3	Ghadaki *et al.*, 1974
(mature)		7.5	4.1- 9.3	37	32-57	58.9	46.2-74.9	"
Kenya	17	15.1	8.0-26.0	-	-	-	-	Dougall & Bogdan, 1958
rumen contents		15.1	-	-	-	-	-	Hoppe *et al.*, 1977
(leguminous)	64	14.8	13.0-18.5	-	-	-	-	Dougall *et al.*, 1964
(nonlegume)	170	12.7	-	-	-	-	-	"
So. Baringo Dist.	32	18.2	5.0-43.0	-	-	-	-	"
Nicaragua								
(legumes)	5	19.4	14.3-25.3	43	46-74	46.0	21.7-60.8	McCammon-Feldman, 1980
(nonlegumes)	26	14.9	5.1-28.8	49	44-79	39.9	20.2-57.0	"
Panama		10.9	6.4-20.7	-	-	-	-	Milton, 1979
Rhodesia		14.8	10.0-20.0	-	-	-	-	cited by Owen-Smith, 1980
Transvaal		11.8	9.0-14.0	-	-	-	-	Groenewald *et al.*, 1967

Table 8. (cont'd)

Geographic Location	No. Species	CP Mean	CP Range	DDM[a] or DOM Mean	DDM[a] or DOM Range	CWC Mean	CWC Range	Source
Uganda		16.5	7.6-21.9	-	-	-	-	Field, 1971
	9	13.4	11.6-15.8	-	-	-	-	"
		17.7	11.5-22.4	-	-	-	-	Field & Ross, 1976
(wet season)	5	23.7	16.8-30.5	-	-	-	-	Bax & Sheldrick, 1963
(dry season)	5	12.8	6.6-13.5	-	-	-	-	"
				TEMPERATE				
Arizona	3	13.5	11.4-15.4	37	29-47	-	-	Short, 1977
		-	-	67	30-93	34.3	12.2-56.0	Short *et al.*, 1974
	9	10.4	6.3-16.3	46	32-61	-	-	Newman & McLeod, 1973
California	3	12.4	9.4-15.9	56	55-56	-	-	Bissell *et al.*, 1955
Colorado	4	16.2	11.1-25.0	55	53-59	-	-	Dietz *et al.*, 1962
Greece		14.6	12.7-16.2	-	-	-	-	Papageorgion, 1978
New Hampshire (autumn leaves)	4	-	-	-	-	41.1	27.1-63.0	Nodvin, 1981 (personal communication)
Louisiana	20	-	-	60	54-66	30.6	26.1-35.0	Short *et al.*, 1973
Texas		12.1	9.8-16.4	60	56-67	36.2	34.0-39.0	Blair *et al.*, 1977
Utah	4	11.1	7.2-18.7	63	45-78	-	-	cited by Dietz, *et al.*, 1962
	6	12.5	9.0-22.0	53	42-68	-	-	Urness *et al.*, 1977
	3	8.0	-	37	-	-	-	"

[a] *In vivo* apparent digestibility

have an effect on palatability with herbivores.

Tannins are found in 15% of all annuals and herbaceous perennials, 79% of woody dicots and 87% of tree species (Rhoades and Cates, 1976). Typically tanniniferous species are tropical and semitropical (Bate-Smith, 1972). Alkaloids are found in about 33% of annual herbs, 20% of perennial herbs, shrubs and shrubbery trees and 17% of tree species (Levin, 1976). There is an increase in the prevalence of alkaloid species at the low latitudes. For a plant to reduce its acceptance to herbivore, it must warn of toxicity in some way. Bitterness is a universal feeding deterent. Alkaloids, cyanogens, saponins and terpenes are in general bitter. Tannins are astringent. The glucosinolates cause irritation of the mouth and can reduce intake (Harborne, 1977).

Polyphenols (tannins) have been intensively studied because of their widespread occurrance. Of the secondary compounds, they are most closely associated with digestibility interference (Feeny, 1976). They decrease protein digestibility and inhibit microbial protein fermentation (Zelter and Leroy, 1966; Donelly and Anthony, 1969; Driedger and Hatfield, 1972). They decrease _in vitro_ cell wall (Horvath, unpublished), cellulose (Tagari _et al_., 1965; Lyford _et al_., 1967) and organic matter (Mika, 1978) digestibility (Lyford _et al_., 1967; Donelly and Anthony, 1969; Harris _et al_., 1970; Burns and Cope, 1974; Schaffert _et al_., 1974). They are bacteriostatic and bacterocidic (Henis _et al_., 1964). No effect of tannis may be noticed when the level of protein in the diet is high (Lyford _et al_., 1967; Glick and Joslyn, 1970) emphasizing the importance of the high levels of most browse leaves.

Glucosinolates are powerful antibiotics and can cause diarrhea (Mitcher, 1975). Mustard oils depress organic matter digestibility at concentrations as low as 0.2% of DM (Mika, 1978). Oils of sage brush have been shown to slow down the digestion of cellulose and volatile fatty acid (VFA) production (Nagy _et al_., 1964). Rumen contractions of deer stopped after four days on a diet of 15% sagebrush. Rumen microorganisms are able to adapt to the presence of many of these compounds. Deer that were accustomed to eating Douglas Fir was less affected by it than those who were not. Microorganisms receiving low levels of oxalic acid for a few days were able to tolerate large amounts (Cronin _et al_., 1978). Some tannins can be degraded by rumen microbes (Grant, 1976) and enzymes of the digestive tract. Cyanogens may be used in the rumen as a nitrogen source, thus detoxifying them (Harborne, 1977). There are animal species differences in susceptability. Goats and sheep are not affected by _Senecio_ alkaloids, while cattle are.

Since our current schemes of forage analysis ignore the presence of plant secondary compounds, estimates of forage intake and digestibility from laboratory analyses can be very misleading when these compounds are present. Alkaloids can constitute up to 8% of the dry matter of certain plants (Hylin, 1969). Some plants may contain toxic amino acids in high concentrations (6-10% of DM) (Bell, 1959). Kjeldahl nitrogen x 6.25 would not give good evidence of available plant protein in these cases.

Essential oils may radically inflate the caloric density of some plants and appear as digestible energy because of their absence in the feces (Eberhard,

et al., 1975). Tannins may be measured as cell contents by the detergent method and thus be considered as almost totally digestible, or they may be precipitated by acid detergent solution (Osbourne et al., 1971; Ward et al., 1977; Marquardt et al., 1977) resulting in their appearance in the lignin fraction of the detergent analysis system.

The effect of plant defense mechanisms on the nutritive value of forage is complicated and poorly understood. Part of the current interest in goats and wild browsers is on their potential as exploiters of the food value of naturally occurring plants in areas where there are constraints on cultivation. An understanding of how plant defense mechanisms function and the means by which an animal extracts the nutrients from a plant without being harmed may be an important key to understanding the nutritive strategy of the goat.

CONCLUSIONS AND RECOMMENDATIONS

The nutritive strategy of goats appears to be to select grasses when their protein content and digestibility are high, but to switch to browses when their overall-nutritive value may be higher. The ability to utilize browse species, which often have thorns, small leaves tucked among woody stems and an upright growth habit, is a unique characteristic of the goat compared to heavier, less agile ruminants. Goats are very active foragers, able to cover a wide area in search of scarce plant materials. Their small mouths and prehensile lips are able to pick off small leaves, flowers, fruits and other plant parts enabling them to choose only the most nutritious of the material available. Goats have been observed to stand on their hind legs and stretch up to browse tree leaves, throw their bodies against saplings to bring the tops within reach and even to climb trees on occasion.

The unique quality of the goat relative to other ruminant animals as a producer of meat and milk is its ability to utilize a broad range of forage species, spread over a wide area, and to select from among them the materials with the highest nutrient concentration. This ability is best utilized under conditions where there is a broad range in the digestibilities of the available feeds, giving an advantage to an animal which is able to select highly digestible parts and reject those materials which are low in quality. This situation occurs most prominently in the dry areas of the tropics due both to the variety of species present and to the tendency for greater differentiation among plant parts in tropical plants compared to temperate plants. The goat may be at a disadvantage on improved temperate pasture where the nutritive value of plants is quite uniform and digestibility is high. On temperate pastures, the animal with the largest mouth has an advantage since it can prehend more material per unit of time. A further ramification of the feeding habits of the goat is that it is not able to perform well where the available forage is uniformly poor in qualtiy, i.e. straw, since there is no material of high nutrient density to select.

The goat, due to a shorter rumen retention time, is not able to digest cellulose as well as the bovine. A distinction as to what is meant by

"poor quality roughage" is necessary in order to make policy decisions concerning which animal can best utilize a particular forage. Trees and shrubs, which represent poor quality roughage for cattle because of their highly lignified stems and bitter taste, may be adequate in quality for goats, which avoid eating the stems, don't mind the taste and benefit from the relatively high levels of protein and cell solubles in carefully selected parts of these plants. On the other hand, straws, which represent poor quality roughage for cattle because of a high percentage of cell walls and low protein, are an even poorer roughage for goats which are less able to utilize the cellulose. Also, goats must consume a more concentrated diet than cattle since their digestive tract size is smaller relative to their maintenance energy needs. Goats are best adapted to low stocking rates in areas where the density of high quality forage is low.

The advantages of the goat in feeding strategy must be weighed against its disadvantages. Being a browsing animal it stunts tree growth and prevents the regeneration of forests and thus should not be used in areas desired for forests. Goats could be very useful, however, in areas where regrowth of brush and trees is not desirable as in the tse-tse fly areas of Africa. The management strategy for goats should be different from that for cattle, hence people accustomed to one may have difficulty with the other. Goats like people and tend to try to be with people, resulting in difficulties. Coventional cattle fences (2-3 strands of barbed wire) will not hold goats. On the other hand, they respond well to herding and can easily be managed by experienced people. The small size of goats make them targets for theft and predation by dogs so that it is necessary for someone to herd them whenever they are not in tight corrals.

Having an "open hair coat", the skin of goats gets wet leading to chilling, hence they do not like rain and wet conditions and do not perform well in the humid tropics unless given protection from the rain and some means of allowing their hooves to dry (such as slatted floors). Pneumonia, intestinal parasites, screw worms and footrot are common among goats in humid areas. Even in dry areas it is necessary to treat goats periodically with a vermifuge to reduce intestinal parasite loads. The growth rate of goats is inferior to that of sheep and cattle, and their small size results in a larger labor requirement per unit of meat or milk produced. To counteract higher labor requirements, either labor must have a low opportunity cost, goat products must bring higher prices than those of cattle, or the extant ecological conditions must enable the goat to make uniquely efficient use of the available forage.

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