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COMPARATIVE INTAKE AND DIGESTIBILITY OF FORAGES AND BYPRODUCTS BY SHEEP AND GOATS

A Review

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Comparative Intake and Digestibility of Forages and Byproducts by Goats and Sheep: A Review

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Abstract

Comparisons of intake and digestibility of various feedstuffs by goats and sheep were reviewed. From existing data, conclusions about the comparative utilization of feeds by these species are impeded by a lack of uniformity in experimental conditions. Nevertheless, a hypothesis of differential species advantage is presented which could be tested in future experiments. This hypothesis is based on evidence that species differences in intake and digestibility are relatively unimportant when the diet is relatively low in fiber concentration. On low quality, high fiber diets, on the other hand, sheep tend to digest the dry matter (and fiber) more completely than goats, but their voluntary intake levels tend to be lower. These observations support the suggestion of a possible faster rate of turnover of the solid phase of rumen contents (shorter retention time) for the goat. Other factors which may contribute to species differences include feeding behavior, salivary secretion, rumination, rumen capacity, and nitrogen recycling.

KEY WORDS: Goats, Sheep, Comparative efficiency, Digestibility, Intake, Forages, Crop residues

Introduction

Ruminants are receiving increased attention in today's changing agricultural economy, because of their recognized ability to process the structural carbohydrates of plants into a form utilizable by man. "Energy sinks" in the form of plant cellulose, lignin and hemicellulose, are "irretrievable" not only to the plant (Van Soest, 1980) but to man. The ruminant renders this energy available to man through fermentation processes. As the margin between the supply and demand of retrievable energy sources narrows, the ruminant becomes more important.

Factors influencing the intake and digestibility of forages by cattle have been well profiled. The small ruminant, however, has received far less research attention, often for economic or cultural reasons. As economic pressures change, however, and labor-intensive production systems become more attractive, there will be increased incentive to study small ruminants.

At present, seemingly conflicting data on sheep and goat parameters can be found in the literature. Prior to 1972 very few studies were published comparing the two species. In the United States, experiments designed to compare the intake and digestibility of feeds by the two species were practically nonexistent up until very recently. More information on the two species has been reported since 1979.

Each animal species including those domesticated by man have evolved into a position in the food chain which can be referred to as an "ecological niche." In some situations gross anatomical or physiological differences separate closely related species; in others only very subtle differences support the existence of the two species in a similar ecosystem. Inevitably, two species cohabiting the same ecosystem occupy different niches based on these subtle or not so subtle differences. Understanding and manipulating the factors which define the

"ecological niche" of various ruminant species will allow the animal producer to more efficiently exploit the conversion of feed sources not digestible by man into food which man can utilize.

The present review deals mainly with confined or stall-fed animals. For the free-ranging animal in extensive situations, the recent review by Malechek and Provenza (1981) summarizes many of the pertinent considerations for goats including some comparative information relative to other ruminant species.

Dry Matter Intake

Comparisons of dry matter (DM) intake were available from 14 experiments reported by 13 authors, involving a total of 39 separate ration situations. There was no way to compare all experiments on the same basis, due to differences in breed, weight, and production class of experimental animals, and differences in method of reporting the data.

In the largest group of papers the tendency was for higher intakes to be reported for sheep, or for no significant differences to be found between animal species. Jones et al. (1972) represents a case in point, in two separate experiments (see Table 1).

In his first experiment two ten-month-old non-pregnant Toggenburg does were compared to two yearling non-pregnant Cheviot ewes. Two different ewes were used for each period and a different silage was fed during each period. Hence animal, silage and period effects were confounded. A 65/35 Medicago sativa/Phleum pratense (alfalfa/timothy) wilted silage and early cut (low DM) and late cut (high DM) corn silages were fed in the first experiment. Significant differences in intake between the two animal species were found only on the mixed alfalfa/timothy silage, with sheep consuming 78% more DM than the goats (data expressed on metabolic weight basis). In the second experiment four six-month-old non-pregnant Toggenburg does and six non-pregnant Cheviot X Suffolk ewes (age not reported) were used. A 65/35 alfalfa/timothy wilted

Table 1. Digestibility of several forages by goats and sheep.[a]

Forage	Percent digestibility of									
	Dry matter		Gross energy		Cellulose		Lignin		Crude protein	
	Goats	Sheep	Goats	Sheep	Goats	Sheep	Goats	Sheep	Goats	Sheep
Experiment I										
Alfalfa (65%), Timothy (35%) silage	64	60	60	57	67	67	19	14	74[b]	60[b]
Corn silage, 33% DM	69	74	69	75	56	63	17[b]	-8[b]	60	59
Corn silage, 21% DM	58	58	59	58	66	67	23	15	54	49
Experiment II										
Alfalfa (65%), Timothy (35%) silage	60	58	57	55	70	70	41	39	46	43
Corn silage (high DM)	65	66	65	65	59	58	8	10	46	49
Alfalfa hay (2nd cut)	54	51	52	54	57	59	1	-1	61	64

[a]From Jones *et al*. (1972).

[b]Species difference significant ($P<.01$).

silage, a late maturing corn silage, and a second-cutting alfalfa hay were compared. Each forage was fed within a separate period; therefore, period and forage effects were again confounded. When late maturing corn silage was fed, the sheep consumed 46% more DM than the goats (metabolic weight basis). Differences were not significant for other treatments.

Ademosum (1970) used four native Nigerian pygmy castrate male sheep and four male goats, average weight 10 and 12 kg, respectively. The age of the animals was not reported. Pennisetum purpureum (napier grass) from four cutting dates was fed. The sheep consumed 73, 8, 27, and 25% more herbage than the goats at the four different maturities; mean intake by sheep was 31% greater than for goats for the four cuttings combined ($P<.01$).

In an experiment reported in 1972, Chenost fed Festuca arundinacea (tall fescue), alfalfa, and Digitaria decumbens (pangola) to 18 to 24-month-old Alpine X Saanen bucks and 18-month-old native Guadeloupe rams, average weight 45 and 35 kg, respectively. Significant differences in intake were found only with the pangola, for which consumption by the sheep averaged 75% higher than goats.

Geoffrey (1974) compared five Poiterine five-year-old dry does averaging 45 kg and five Texel two-year-old wethered sheep averaging 55 kg in weight. Rations were composed of chopped Lolium multiflorum (ryegrass) (CRG), CRG + Saccharum officinarum (cane) molasses, CRG + urea, CRG + molasses and urea, and ensiled ryegrass + molasses and urea. Differences in intake of total DM between the goats and sheep were not significant.

Grieve (1976), on the other hand, found highly significant differences in intake of total DM by sheep and goats. He fed three levels each of Oryza sativa (rice) straw, Saccharum officinarum (sugar cane) tops and Sorghum bicolor (sorghum) tops to three each of West African dwarf two-year-old male

castrate sheep and goats. The sheep consumed 128, 52, and 28% more than the goats on the three fiber sources, respectively. As only means for each fiber source were reported, the presence of a species X diet interaction could not be determined.

Haryanto et al. (1982) measured the intake of mixed diets with 8 Priangan sheep and 8 native "Kacang" goats in West Java. Animals were 8 months old and weighed 12 to 13 kg (average) at the start of the trial. Diets consisted of napier grass, Manihot esculenta (cassava) foliage, Ipomoea batatas (sweet potato) foliage, and Musa sapientem (banana) leaves, with or without 200 g per day of concentrate. The goats refused most of the concentrate offered. Total forage DM intake was about equal for goats with or without concentrate and sheep with concentrate, but about 10% higher for the sheep without concentrate offered.

Finally in this first group, Sharma et al. (1982) observed a higher DM intake per unit metabolic weight in sheep than in goats when both were fed either Trifolium alexandrinum (Egyptian clover) hay or mixed dry grass. Statistical significances, ages, and body weights were not reported.

In a second group of three papers, either sheep or goats were sometimes observed with higher intakes. Devendra's early paper (1974) is an example. He compared the performance of four Barbados Blackbelly rams housed in metabolism cages to three British Alpine bucks housed in pens. The two species averaged 32 to 36 kg in weight at the onset of the trial. Napier grass cut at four, five, and six weeks was used as the forage. Intakes (g/kg metabolic weight) varied significantly and were 56, 79 and 83 per day for the sheep and 88, 89 and 61 for the goats, respectively, for the three cuttings. The goats consumed more than the sheep on the earlier cutting, but the reverse was true for the more mature, less digestible material.

Singh and Bhatia (1982) fed Prosopis cineraria (mesquite) to kids and lambs of unreported sex and to adult male goats and sheep (age and weight not reported). Intake of total DM was 672 and 537 g per animal per day by the kids and lambs, respectively. The bucks and rams consumed 34 and 38 g of DM per kg of body weight per day, respectively. No statistics were reported.

Brown and Johnson (1981) compared the DM intake of nine Suffolk X Barbados Blackbelly wether lambs and nine Saanen X Toggenburg wether kids averaging 23±3 and 45±4 kg, respectively. Wheat straw was fed at 35, 50 and 65% of the ration. The goats consumed 12, 19 and 21% more DM per kg of body weight than did the sheep ($P<.01$). When intakes were adjusted for metabolic weight a species X treatment interaction resulted ($P<.01$) with the goats consuming relatively more of the high wheat straw ration and relatively less of the low wheat straw ration.

Finally, there are three recent reports in which goats consistently had a higher intake. The first of these was by Devendra and Kuan (1979), who fed Cajanus cajan (pigeon pea) to three adult goats and three adult sheep of unreported production class. The goats consumed 380 g of DM per day, the sheep 338 g. Corrected for body weight, the goats still consumed 30 g more DM per kg body weight (per day) than the sheep. This translated to 33 and 28 g/kg metabolic weight (per day) for goats and sheep.

Luginbuhl and Johnson (1982) fed 7 and 12 wk Cynodon dactylon (coastal bermudagrass) and 6 and 9 wk Festuca arundinacea (tall fescue) hays to young Toggenburg goat wethers (average weight 18 kg) and young Suffolk X Dorset X Barbados sheep wethers (average weight 30 kg). Dry matter intakes of the four hays were 82, 74, 74 and 69 g/kg metabolic weight for goats, and 64, 52, 58 and 55 g/kg metabolic weight for sheep. Species differences were significant ($P<.05$).

Owen and Ndosa (1982) fed high (HH), medium (MH) and low (LH) quality grass hay (species not designated) and chopped Hordeum vulgare (barley) straw (ST) supplemented with Glycine max. (soybean) meal to eight British Saanan goats and eight Welsh Mountain sheep averaging 25 kg in weight. Intakes of total DM (g/kg metabolic weight/day) for the goats and sheep, respectively, were HH, 121, 99; MH, 78, 59; LH, 74, 54; and ST, 65, 48. Statistics were not reported.

It is difficult to discern a consistent pattern from these data, except that nearly every one of the reports of no difference in intake involves a relatively high quality forage or mixed diet. Likewise there is a distinct pattern for goats to show higher relative intakes only with lower quality forages and roughage byproducts. Very few of the papers reported whether or not diet selectivity was a factor; if the hypothesis of Van Soest (1982) is correct, the goats were selectively choosing a higher quality diet than they were offered whenever the opportunity for selection may have been present. This would have important beneficial implications, especially for diets relatively high in total cell wall constituents.

Dry Matter and Organic Matter Digestibility

Comparative digestibility data has been published by 16 authors, presenting a total of nearly 50 separate comparisons on a wide range of feed materials. About half of the comparisons were made on dry matter (DM) digestibility, and about half on organic matter (OM) digestibility.

The most frequent observation from these comparisons was that of no significant difference between the two species; this result was reported in about half of the instances of comparison. The remaining comparisons were split nearly equally between higher coefficients of digestibility for sheep or higher for goats. Since animal numbers were small in most experiments, one interpretation is that the sampling of possible outcomes described in published reports

represents a normal distribution of individual animal differences. In most cases where mean differences between species were significant, the numerical value of the mean difference was 5 digestibility units or less.

In the cases where sheep showed a higher digestibility, the diet consisted mainly of materials that normally have medium to high fiber concentration. For example, Jones et al. (1972) found one instance (out of six comparisons) of higher (but non-significant) digestibility of DM by sheep (Table 1), when both species were fed a high dry matter corn silage. Adeyanju et al. (1972) and Chenost (1972) also found instances of higher digestibility by sheep (Table 2). Adeyanju's report was of DM digestibility of rations containing coco husks; the statistical significance of the small differences was not reported. Chenost reported significant differences in OM digestibility of pangola grass in two out of three comparisons.

Geoffrey (1974) reported a significant difference ($P<.01$) in favor of sheep for the digestibility of OM in chopped ryegrass (sheep 64%, goats 61%). When the ryegrass was supplemented with urea and/or molasses, or when it was ensiled and supplemented, mean differences among animal species were not significant. There were design problems in these trials which resulted in some confounding of period, diet and species effect, however.

Ademosum (1970) fed napier grass cut at four stages of maturity to sheep and goats, and reported mean OM digestibilities of 59 and 55%, respectively ($P<.05$). Owen and Ndosa (1982) fed chopped barley straw supplemented with soybean meal to sheep and goats; he reported mean DM digestibilities of 39 and 32%, respectively. The level of significance was not reported. Luginbuhl and Johnson (1982) reported digestibilities of DM that were significantly ($P<.01$) higher for sheep than goats on ad libitum feeding of coastal bermudagrass or tall fescue hays, each at two stages of maturity; 8 young wethers of each

Table 2. Digestibility coefficients for dry matter or organic matter of various feedstuffs in goats and sheep.

Feed description	Digestibility coefficient (%) Goats	Sheep	Reference
	Digestibility of dry matter.		
Medicago sativa	61	62	El Hag, 1976
Dianthium annulatum	59	57	El Hag, 1976
"Hummra" (desert grasses)	55	52	El Hag, 1976
Coco husk (25%)	76	77	Adeyanju *et al.*, 1975
Coco husk (50%)	73	76	Adeyanju *et al.*, 1975
Coco husk (100%)	68	69	Adeyanju *et al.*, 1975
Coastal bermudagrass, 7 wk	56	63	Luginbuhl and Johnson, 1982
Coastal bermudagrass, 12 wk	49	56	Luginbuhl and Johnson, 1982
Tall fescue, 6 wk	60	63	Luginbuhl and Johnson, 1982
Tall fescue, 9 wk	53	59	Luginbuhl and Johnson, 1982
	Digestibility of organic matter		
Pangola grass, 1st cut	66	71 (P<.05)	Chenost, 1972
Pangola grass, 2nd cut	68	67	Chenost, 1972
Pangola grass, 3rd cut	65	68 (P<.01)	Chenost, 1972
Casuarina cristata	35	29	Wilson, 1976
Acacia pendula	47	43	Wilson, 1976
Medicago sativa	63	63	Wilson, 1976
Heterodendrum oleiforum	43	40	Wilson, 1976

animal species were used.

In most of the instances of higher digestibility by goats the diet also consisted mainly of medium-to-high fiber materials. In two reports, however, goats showed a higher digestibility of low fiber feeds than sheep. For example, as shown in Table 1, Jones et al. (1972) found a non-significant advantage in favor of goats in the digestibility of DM in alfalfa hay or mixed grass/legume silage. Also, as shown in Table 2, Wilson (1976) found a slight advantage for goats over sheep (significance level not reported) with Heterodendrum oleiforum herbage which was only 44% in neutral-detergent fiber (NDF) concentration.

Other cases of advantage for the goat include the data of Wilson (1976) for C. cristata and A. pendula (Table 2), for which the NDF concentrations were 62 and 61%, respectively. Also, Devendra (1974) found an advantage of 9, 15 and 24% in favor of the goat over the sheep ($P<.05$) in the digestibility of DM in napier grass harvested at 4, 5 or 6 weeks regrowth, respectively. Devendra and Kuan (1979) also reported 16% higher digestibility of DM in pigeon pea forage for goats than sheep ($P<.05$). In a recent report Frinton (1982) found higher ($P<.05$) digestibility of DM for goats (64%) than sheep (58%) on a diet of Alnus rubra (alder) herbage mixed with a mill refuse screening; four animals of each species were used, but details of age, weight, production class, intake levels, and whether intake was restricted or ad libitum were not reported.

In the remaining papers that were reviewed, mean differences in OM or DM digestibility were small and not statistically significant. These include reports by Chenost (1972) for OM in tall fescue or alfalfa; Wilson (1976) for OM in alfalfa (Table 2); El Hag (1976) for the DM of alfalfa (Table 2); Gallagher and Shelton (1972) for the OM in a complete ration of ground alfalfa hay, dry rolled sorghum, and Gossypium spp. (cotton) seed hulls; Jones et al. (1972) for the DM of corn silage (Table 1); Gihad (1976) for the DM of Hyparrhenia spp.; Grieve (1976) for the DM of rice straw, sugar cane tops, or sorghum tops; and

Brown (1982) for the DM of rations with 35, 50 and 65% wheat straw.

Devendra (1978), in a previous review, stated that "present evidence suggests that there are certain differences between goats and other species with regards to factors such as feeding behavior, rumination, salivary secretion, pattern of rumen fermentation and rate of movement along the alimentary tract." Based on these hypothesized differences, he suggested that separate digestibility data for different ruminant species should be published rather than using common coefficients. Gihad et al. (1980), on the other hand, concluded that the literature offers insufficient data to determine whether the digestive efficiency of goats is different from other ruminant species. In the same paper a report was given on in vitro digestibility of cellulose with rumen inoculum from sheep or goats. Goat inoculum had larger population of cellulose-digesting bacteria than did that obtained from sheep at 0 and 4 hours after feeding (Table 3).

Van Soest (1980) has stated that differences in species are reflected in the fraction of the feces which can be attributed to microbial products and endogenous secretions from the animal body (i.e., the difference between true and apparent digestibility). He also stated the necessity of considering the negative relationship between intake and digestibility when comparing digestibility trials among animal species, pointing out that the feed refused by the more selective ruminant (i.e., goat) is probably the more nondigestible portion which, if not taken into account, would inflate the digestibility coefficients. Van Soest suggested that much of the work reported to date comparing species must be treated with skepticism for this reason. The more selective species will consume less cellulose, and this may result in a higher proportion of less cellulolytic bacteria in the rumen. This hypothesis was not substantiated, however, in the instance reported by Gihad et al. (1980) cited above. Clearly, more research is needed to clarify the comparative rumen microbiology of sheep

and goats.

Haryanto and Johnson (1982) used rumen inoculum from both sheep and goats for *in vitro* incubation with alfalfa and coastal bermudagrass, reporting that neither DM nor cell wall disappearance were influenced by the animal species of the inoculum donor, at six time intervals of incubation ranging from 3 to 96 hours.

Fiber Digestibility

Ten papers were reviewed in which some estimate of fiber digestibility was reported. Seven of these papers reported crude fiber (CF) data; only three authors had used the Van Soest detergent fiber procedures or other estimates of cellulose and lignin content.

The data of Jones et al. (1972) for cellulose and lignin apparent digestibility are shown in Table 1. Differences between means for sheep and goats were not significant, except for one instance regarding lignin which is probably an artifact of sampling or analytical procedures.

Wilson (1976) reported digestibilities of neutral detergent fiber (NDF) of 32, 23 and 7% for goats fed *A. pendula*, *C. cristata*, and *H. oleifolium*, respectively. Sheep fed the same three forages had digestibilities of NDF of 28, 14 and 1%. While not subjected to statistical analysis, these data represent an advantage of 4, 9 and 6 percentage units for the goats. Digestibilities of acid detergent fiber (ADF) in the same experiment were 21, 12 and 4% for the goats and 14, 4 and -7% for the sheep.

In contrast to these reports, Brown (1982) obtained significantly ($P<.01$) higher digestibilities for NDF, ADF, cellulose and lignin fractions by sheep, compared with goats, when fed complete blended rations with 35, 50 or 65% wheat straw.

The various authors who reported CF digestibility have found results which

Table 3. Cellulolytic bacteria in rumen liquor of goats and sheep.[a]

Media	Hours post feeding	Bacterial count X 10^5 per ml rumen liquor	
		Goats	Sheep
Rumen liquor + biotin + B vitamins	0	8.8	1.8
	4	4.1	2.2
Rumen liquor + yeast extract	0	2.2	1.3
	4	0.4	0.2

[a] From Gihad (1980).

Table 4. Digestibility coefficients for crude fiber (CF) in several feedstuffs by goats and sheep.

Feed description	Digestibility of CF (%)		Reference
	Goats	Sheep	
Napier grass, 4 wk	86	73	Devendra, 1974
Napier grass, 5 wk	79	72	Devendra, 1974
Napier grass, 6 wk	73	69	Devendra, 1974
Coco husk (25%)	39	37	Adeyanju *et al.*, 1975
Coco husk (50%)	36	44	Adeyanju *et al.*, 1975
Coco husk (100%)	40	39	Adeyanju *et al.*, 1975
Tall fescue (compacted)	61	60	Chenost, 1972
Tall fescue (compressed)	68	67	Chenost, 1972
Alfalfa (compacted)	34	34	Chenost, 1972
Alfalfa (compressed)	53	46 ($P<.05$)	Chenost, 1972
Pangola grass, 1st cut	70	74 ($P<.05$)	Chenost, 1972
Pangola grass, 2nd cut	72	72	Chenost, 1972
Pangola grass, 3rd cut	69	73 ($P<.05$)	Chenost, 1972

are just as conflicting. About 25 separate comparisons have been reported; some of these are shown in Table 4. About half of these comparisons showed non-significant differences between means for sheep or goats. For the remainder, goats showed an advantage in 8 comparisons and sheep in 3. Most of the diets investigated consisted of medium-to-high fiber materials.

A 7% advantage in CF digestibility by goats over sheep (P<.05) was reported by Gihad (1976) with Hyparrhenia spp. El Hag (1976) likewise reported an 11% advantage for goats (P<.01) consuming "hummra" (a mixture of native grasses); the values were 50 and 54% for goats and sheep, respectively. In the same report, no significant differences were found for CF digestibility in Trifolium alexandrium (berseem) hay or Dianthium annulatum (lokh grass).

While a statistical analysis was not reported, Devendra (1974) found the digestibility of CF to be 18, 10 and 6% higher in goats (over sheep) for napier grass harvested at three stages of maturity. Devendra and Kuan (1979) also found a large advantage (P<.05) for goats (62% digestibility of CF) over sheep (43%) when fed pigeon pea forage. Chenost (1972) reported comparative digestibilities of CF for several forages (Table 4); in one lot of alfalfa, the mean for goats was significantly higher than for sheep. However, for two cuts of pangola the opposite was true, and for three forages there was no significant difference between sheep and goats.

Ademosum (1970) reported mean CF digestibilities of 67 and 70% for goats and sheep, respectively, on napier grass at four maturities; these means were not significantly different. Adeyanju et al. (1975) likewise showed no clear inter-species trend, when feeding diets based on coco husks (Table 4).

Some of the authors reported the same trends with CF digestibility as with DM digestibility (Devendra, 1974; Adeyanju et al., 1975; and Devendra and Kuan, 1979) or OM digestibility (Chenost, 1972), which is to be expected. What is not as easy to explain, however, is the fact that several authors (Ademosum,

1970; Chenost, 1972; Devendra, 1974; and Devendra and Kuan, 1979) found similar trends with DM intake as with CF digestibility: when goats had higher intakes than sheep, they also showed higher CF digestibility, and vice versa. The normal expectation would be for a lower apparent net digestibility (faster rate of passage) to accompany a higher intake level. One explanation for this anomaly could rest in experimental procedure: if daily feed offered greatly exceeded actual intake, the animals would have more opportunity for selection, leading to higher intake and higher digestibility of the selected portion. A second possible explanation is that the manner by which the two animal species function with respect to intake, passage, and digestion rates could be different.

Crude Protein Digestibility

Six investigators have compared crude protein (CP) digestibilities in goats and sheep. Jones et al. (1972) found that goats digested the CP of a 65/35 alfalfa/timothy mixed hay 23% better than sheep. No significant differences were found with five other forages in the same trial (Table 1). El Hag (1976) reported a 7% higher ($P<.05$) digestibility of CP for goats fed hummra (a mixture of desert grasses). No significant differences in the digestibility of CP were found when goats and sheep were fed berseem or lokh grass. Digestibilities for the berseem, lokh grass and hummra were 73, 67 and 75% for the goats and 73, 66 and 70% for the sheep, respectively.

The results from the remaining four papers which reported CP digestibilities are presented in Table 5. Of these reports, the mean differences were presented without statistical analysis in the case of Devendra (1974) and Adeyanju et al. (1975); the other two authors (Gihad, 1976, and Devendra and Kuan, 1979) reported non-significance of mean differences.

No important trend is obvious from these limited data. If the two species

Table 5. Digestibility coefficients for crude protein (CP) in several feedstuffs by goats and sheep.

Feed description	Digestibility of CP (%) Goats	Sheep	Reference
Napier grass, 4 wk	77	82	Devendra, 1974
Napier grass, 5 wk	76	78	Devendra, 1974
Napier grass, 6 wk	76	66	Devendra, 1974
Coco husk (25%)	88	90	Adeyanju *et al.*, 1975
Coco husk (50%)	86	89	Adeyanju *et al.*, 1975
Coco husk (100%)	84	86	Adeyanju *et al.*, 1975
Hyparrhenia spp. (hay)	44	44	Gihad, 1976
Pigeon pea	59	46	Devendra and Kuan, 1979

have important differences in their relative efficiencies of utilizing nitrogenous materials, as has been suggested by Huston (1978) and Sands and McDowell (1978), the biological basis is apparently at some other level than rumen degradation or gastrointestinal absorption rates.

Discussion and Conclusions

Conflicting and inconclusive results from various of the reviewed reports may be due in part to factors other than inter-species differences in digestive physiology. It became apparent that a wide variation of experimental conditions was represented by these several reports. A few of these factors are listed and discussed, in the hope of demonstrating the need for greater uniformity in experimental protocol and for more complete reporting of experimental conditions.

Production class of experimental animals. At least one-fourth of the papers reviewed did not specify a production class for the animals or did not clearly explain the classes used. Also, in some cases comparisons were made using production classes which are known to have different requirements, thereby diluting the strength of conclusions due to the confounding of production classes with species.

Age of experimental animals. About half of the reports reviewed did not mention the age of the experimental animals. In many cases age was probably difficult to estimate; however, considering that requirements vary for animals of different ages (particularly growing animals) this factor might explain part of the variation in performance. Animals of unknown age probably should not be used in metabolism studies.

Breed of experimental animals. The breed was reported in most cases. As there is recent evidence suggesting differences in nutrient utilization by crossbreed versus purebred animals (Brasfield, 1980), this factor should be

carefully considered when making species comparisons. Also, it is likely that breeds adapted to marginal feeding situations may have evolved different mechanisms or efficiencies of nutrient utilization compared to those breeds whose ability to merely survive is less often challenged by their environment. It has been suggested, for example, (but as yet with no concrete evidence) that the tropical hair sheep of Northeast Brazil may have evolved so that their nutritional efficiencies are closer to those of the native tropical goat of the same region, than to their distant cousins in Europe or North America (Johnson, 1981).

Weight of experimental animals. Animal weights were not reported in several of the experiments. Approximations were reported in other trials and in very few instances were the standard errors of mean weights reported.

Number of experimental units per treatment. Given the known variability among individual animals in apparent digestibility estimates, and the even higher degree of variability for voluntary intake, the reader should expect to know how many animals were used, and in what sort of design (e.g., Latin square) that might reduce the among-animal variance component. Surprisingly, authors did not always report this information and reviewers did not always insist that it be given.

Feeding management. The majority of papers reviewed did not mention the number of times the animals were fed per day, whether intake was *ad libitum* or restricted, and what amount of feed was allowed in the refusal. Given the known interaction of intake level with apparent digestibility, this information is needed for complete interpretation.

Feed sources and chemical composition. More than twenty separate feeds or diet combinations were used, collectively, in the work reviewed. For maximum information it would be desirable to be able to relate animal performance pa-

rameters (intake or digestibility) to a common characteristic of the feeds or diets. However, there was no single parameter related to the animals or the feeds that was common to all reports. A more complete chemical profile of the feeds would be useful.

Animal selectivity. Van Soest (1982) has presented a lucid discussion of the implications of selective intake, and suggests that comparisons of apparent digestibility where composition of the orts is not considered should be discounted. Brown (1982) has shown that sheep and goats may consume rations of different composition, even when offered a ground, blended ration of identical composition. In cases of this sort the digestibility coefficients will be influenced by their method of calculation, that is, whether differential composition of orts and therefore of feed consumed is taken into account.

Criteria for inter-species comparisons. The limited perspective of ruminant performance which is offered by digestibility comparisons may not be adequate to evaluate differences in such a complex system as the ruminant digestive tract. A more integral evaluation could help elucidate inter-species differences or indicate reasons for similarities. Parameters such as rumen turnover, fluid/solid passage rates, rumination time, salivation levels, nitrogen recycling, and rumen motility need to be measured in order to better characterize the digestive systems of these small ruminants (Devendra, 1978; Gihad et al., 1980; Brown, 1982).

A working hypothesis. Until more complete evidence is available, we suggest that for diets low in fiber concentration very little difference in digestibility might be expected between goats and sheep, and intake levels may be proportional to metabolic body size in both species. For low quality, high fiber diets, on the other hand, there may be differential, partially compensatory advantages: more complete digestion of fiber in the sheep, made possible

by a longer retention time; but, higher intake levels by the goat (Brown, 1982; Luginbuhl and Johnson, 1982), possibly related to a faster rate of removal of non-digested fiber particles from the rumen, as suggested by Huston (1978). The importance of selectivity to inter-species comparisons will depend greatly on the situation: stall-fed versus free grazing, ratio of feed on offer to optimum daily intake, palatability, and individual preference. The field is open for future research on many such useful topics.

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