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Genetic Influence on Foraging Behavior (Diet Selection) of Ruminants (Sheep and Goats)

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INTRODUCTION

The increasing human population will continue to place pressure on the world's resources for food and fiber production. In many areas the greatest priority will be placed on the production of grains or other food crops for direct human consumption, thereby relegating the grazing animal, even more so than at present, to the use of those resources not suitable for the production of food crops. Although animal agriculture may be secondary in demand for resources, foods of animal origin are recognized as being both desirable and important in the human diet.

Scruggs (1983) stated that "a surface study of archaeology seems to indicate that those civilizations that primarily depended on meat have been the most advanced". The author did not attribute this solely to nutritional qualities, but suggests that in addition, animals provide a means of food energy storage which could be readily transportable under their own power as early man migrated to new areas or developing population centers.

In the U.S., animal products, including fish, supply 69% of the protein, 80% of the calcium, 67% of the phosphorus, 66% of the Vitamin B_2 and 98% of the Vitamin B_{12} in the human diet (Fontenot, 1982). Although the percentage contribution to the diet by animal products is probably much lower in many countries, especially LDC countries, animal products are considered important to the diet. This is especially true for young people in terms of protein quality and for specific minerals and vitamins. In addition, there is strong presumptive or circumstantial evidence that foods of animal origin contribute to human welfare in a manner not yet fully understood. It is also clearly established that in most societies foods of animal origin are desired and their availability will be looked on as a measure of the quality of life.

Advances in research are essential for progress in optimizing animal production on native rangeland. One important concept to maximize the production from native or introduced forage species is to select between or within species for animals which utilize forage resources to the best advantage. In this connection it is important that the animals chosen will or can consume the available forage, but also that they produce products, such as meat or milk, which are acceptable, available, and valuable to man. This report is concerned with genetic influence on diet selectivity with emphasis on small ruminants and consists of a limited literature review as well as original research data.

SPECIES DIFFERENCES

The existence of important differences in diet selectivity is well documented, but not necessarily understood. This paper will cite a few studies to support the existence of species differences, but is not presented as a complete review of this subject.

According to Harrington (1982) mankind has domesticated only nine species of ruminant herbivores. It is not clear to the writers which nine species he

has classified as domesticated. Recognizing that domestication is a process which requires many years or generations (Squires, 1975), it can be stated that a number of species are in the process of being domesticated. For instance, red deer are being farmed in New Zealand, and the Eland is being milked on an experimental basis in the U.S.S.R. However, many species exist which have been domesticated and brought into a symbiotic relationship with man. The major species of domestic ruminants are cattle, sheep, and goats. The number of wild species are too numerous to mention at this point. To the extent that they have been studied, each species has some unique habits or preference in diet selection.

The data summarized in Table 1 generally confirms the well recognized differences among animal species relative to their intake of forage species as grouped by broad categories. Four of the six species included in Table 1 can be ranked in the following order relative to their tendency to browse: deer, goats, sheep, and cattle. In terms of grass intake, they would be ranked in the exact reverse order. Sheep and deer tend to take forbs more readily than cattle or goats.

MacCracken and Hansen (1981) compared the grazing behavior of cattle, domestic sheep, mule deer (Odocoileus hemionus), and elk (Cervus canadensis). The results are reported in Table 2 in terms of dietary overlap.

Table 2. Dietary overlap of four species grazing winter range in Colorado[1] (U.S.A.)

Relationship	% Overlap
Domestic sheep vs. cattle	53 ± 27
Domestic sheep vs. elk	46 ± 11
Domestic sheep vs. mule deer	15 ± 7
Cattle vs. elk	39 ± 0
Cattle vs. mule deer	10 ± 1
Mule deer vs. elk	30 ± 3

[1] Taken directly from MacCracken and Hansen (1981).

These data indicate that major diet differences exist between animal species especially between mule deer and domestic livestock. The grazing habits of a number of African ruminants have been reviewed by Hofmann and Stewart (1972). These authors also report large species differences.

This incomplete review confirms major species differences in foraging behavior or diet selectivity. Thus, on a broad basis there are important inherent differences in the ability and willingness of animals to consume various plant species. At this point, no attempt will be made to explain

7a

Table 1. Comparison of a number of animal species in foraging behavior.

Animal Species	Grasses	Browse	Forbs	Succulents	Reference
White-tailed Deer (*Odocoileus virginianus*)	7.3	72.1	20.9	--	Adapted from McMahan, (1964)
Cow (*Bos taurus*)	78.1	14.8	7.2	--	
Sheep (*Ovis aries*)	57.5	23.3	19.3	--	
Goat (*Capra hircus*)	18.5	70.9	10.6	--	
Sheep	60	22	18	--	Adapted from Bryant *et al.*, (1979)
Goats	46.5	41	12.5	--	
White-tailed Deer	8	61	31	--	
White-tailed Deer	1	94	1	4	Adapted from Warren *et al.*, (1981)
Cow	87	11	1	1	
Goat	36	54	5	5	
Cow	75	9	16	--	Adapted from Theurer, Lesperance and Wallace, (1976)
Sheep	38	34	28	--	
Sheep	66	15	19	--	Adapted from Warren, (1981)
Goats	47	40	12	Trace	
Bison (*Bison bison*)	96.6	0	3.2	--	Adapted from Schwartz and Ellis, (1981)
Cattle	76.8	8.4	14.4	--	
Pronghorn (*Antilocapra americana*)	41.4	0	58.6	--	
Sheep	49.0	17.8	32.2	--	

the mechanisms involved in this selectivity. However, it is significant to note that anatomical or morphological differences exist in the digestive systems of various ruminant species which permit differential utilization of alternative forage resources (Hofmann, 1968; Hofmann and Stewart, 1972). It is not clear to what extent this is a cause or effect relationship. For instance, bulk or roughage eaters (grass eaters), such as cattle have large subdivided rumens which permit time delay in food passage and increased digestibility of coarse fibrous feedstuffs. Other species, such as some types of goats and certain game species, have smaller simple rumens adapted to quick turnover and a possibility of reduced digestibility of coarse fibrous feeds. The latter are generally highly selective grazers (Huston, 1978; Ellis and Travis, 1975). Other species are intermediate between these types.

BREED DIFFERENCES

Important characteristics for consideration when evaluating breed performance include physiological state, previous level of nutrition and age. Each breed must have the same grazing opportunities under different pasture conditions. Differences in the nutritive value of the selected diet by animals grazing together may be an important source of variation in their productivity.

Warren (1981) used three different breeds of sheep and two breeds of goats on three different range types to determine diet similarity. The sheep breeds included in this study were the Rambouillet, descendents of the Spanish Merino of France, Karakul from Southeast Asia, and the Barbados Black Belly (Barbado) a hair sheep originally from the Barbados Islands (tropical)(Figure 1). The goat breeds were the Angora, originally from the Mediterranean region and the Spanish or meat-type goat. The term "Spanish" is used primarily to distinguish the animal from Angora goats and milk-type goats and infers that the species arrived in the United States through Mexico; however, this is not necessarily true in all cases.

All animals were of the same age and grazed together in three different plant communities in West Texas. The plant communities included a common curlymesquitegrass-threeawn-liveoak (*Hilaria belangeri*-*Aristida* spp.-*Quercus fusiformis*) community, a mixed grass-mesquite (*Prosopis glandulosa* var. glandulosa) community and a creosotebush-tarbush (*Larrea tridentata*-*Flourensia cernua*) community.

Botanical composition of sheep and goat diets was determined by analysis of fecal material using the microhistological technique as described by Sparks and Malechek (1968). The michrohistological technique involves the identification of plants by epidermal cellular characteristics. The main cellular characteristics used for identification of plant fragments are stomates, cell wall, asperites, trichomes, druses and silica-suberose couples along with cellular configurations, size and other morphological characteristics (Figure 2).

Figure 1. The various sheep and goat breeds used in this study.

Rambouillet

Black Bellied Barbados

Karakul (Some have been docked)

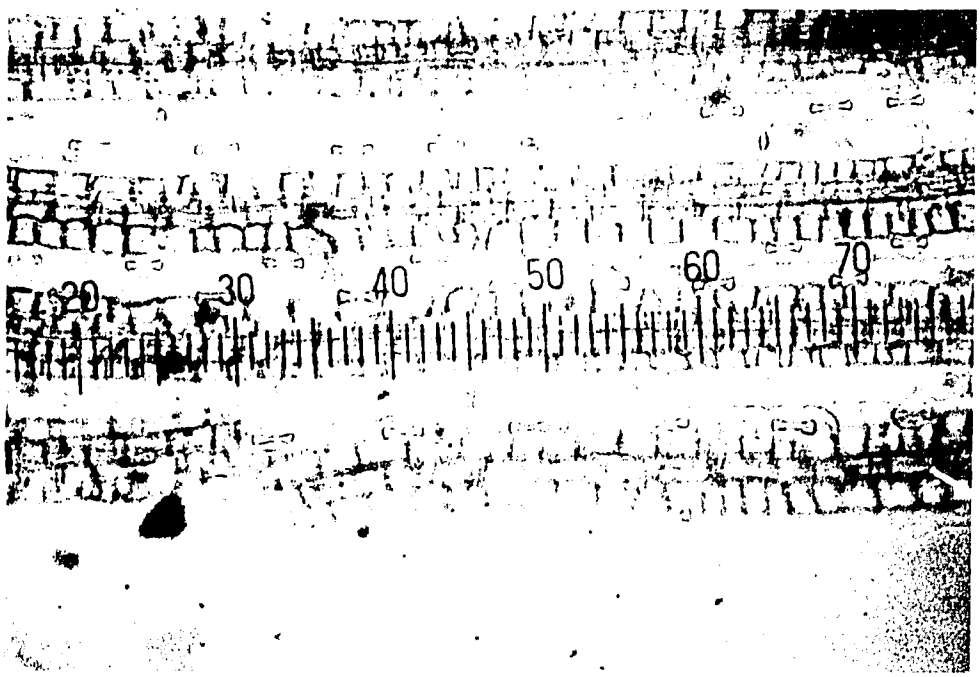
Figure 1. Continued

Spanish

Angora

Figure 2. Shown below are several epidermal plant characteristics used to identify plant fragments.

Photograph #1. Juniperus spp.; very luminescent, glandular texture, note large stomata.



Photograph #2. Bromus unioloides; very luminescent, silica-suberose couples, distinct stomata.

Rambouillet and Karakul sheep, along with Angora goats consumed significantly more grass and grasslike plants as compared to Spanish goats and Barbado sheep during November 1979 while grazing in the common curlymesquite-grass-threeawn-liveoak community, whereas Barbado sheep and Spanish goats consumed significantly more browse (Table 3). The sheep breeds consumed significantly more sedge (Carex spp.) than the goat breeds during November, while the goats consumed more Texas wintergrass (Stipa leucotricha). Spanish goat diets included significantly more oak (Quercus spp.) than Angora goats or Rambouillet and Karakul sheep.

The sheep breeds and Angora goats consumed significantly more grass and grasslike plants compared to Spanish goats in February 1980 (Table 3). All sheep breeds consumed more sedge than the goat breeds. Spanish goats consumed significantly more browse than all other breeds. Oak was more important to Spanish goat diets than to diets of all other breeds. Angora goats consumed significantly more browse than the sheep breeds.

Rambouillet and Karakul sheep diets contained significantly more grass than Barbado sheep or the goat breeds during April 1980 while grazing in the mixed grass-mesquite community (Table 4). Barbado sheep consumed more grass than the goat breeds. Forbs were more important in diets of the sheep breeds compared to Angora and Spanish goats. Karakul sheep diets contained significantly less forbs than Rambouillet or Barbado sheep. Spanish and Angora goats relied more heavily on browse in April 1980 than the sheep breeds and the Barbado sheep consumed significantly more browse than the other sheep breeds. Littleleaf sumac (Rhus microphylla) was the major browse plant utilized by all breeds. Honey mesquite was present in trace amounts in the diets of Karakul sheep and Angora goats.

During August 1980, Spanish goats also consumed significantly less grass and more browse than the other breeds (Table 4). Grasses contributed about half of the diets of the sheep breeds and the Angora goats. Grasses comprised only one-fourth of the Spanish goat diet. Forbs, primarily globemallow (Sphaeralcea spp.), were significantly more important in sheep diets. Littleleaf sumac remained to be the major browse of all breeds. Pricklypear (Opuntia spp.) occurred in trace amounts in the Spanish and Angora goat diets.

Diets of all sheep and goat breeds grazing on the mixed grass-mesquite community were most varied during the late winter and spring of 1981. Grasses were the staple food of all breeds during February (Table 5). Grasses made up about 80% of the sheep diets and Angora goats. Texas wintergrass was more important in the diets of Barbado sheep and the goat breeds than in Rambouillet or Karakul sheep. Rambouillet and Karakul sheep tended to rely more heavily on threeawns, common curlymesquitegrass, buffalograss (Buchloe dactyloides) and silver bluestem (Bothriochloa saccharoides). Forbs, primarily bladderpod (Lesquerella gracilis), contributed 11 to 14% of the diets of the sheep and goats. Browse, primarily Morman tea (Ephedra spp.), honey mesquite, and littleleaf sumac, was important in the diets of all sheep and goat breeds, but Spanish goats consumed significantly more browse than the other breeds.

Table 3. Mean (±2SE) diet composition (%) of five different breeds of sheep and goats grazing in a common curlymesquitegrass-threeawn-liveoak community in Edwards County, Texas.

	November 1979					February 1980				
	Sheep Breeds			Goat Breeds		Sheep Breeds			Goat Breeds	
Food Items	Rambouillet	Karakul	Barbado	Spanish	Angora	Rambouillet	Karakul	Barbado	Spanish	Angora
Grasses and Grasslike Plants										
Carex spp.	33±6.4	27±7.7	24±1.4	9±6.5	10±4.3	21±3.8	24±6.7	25±3.0	1±1.4	8±3.8
Stipa leucotricha	-	-	-	10±3.7	27±10.2	20±2.4	19±2.9	18±1.6	8±1.9	25±6.8
Aristida spp.	5±1.9	9±5.3	2±1.4	7±1.9	8±1.1	18±3.1	27±2.8	16±1.8	6±1.4	20±3.3
Panicum spp.	15±4.6	11±3.0	3±1.9	2±1.2	5±3.7	9±5.2	8±1.3	2±1.8	1±0.9	4±2.1
Bouteloua spp.	8±2.3	13±4.4	7±1.5	2±1.4	5±2.2	3±1.8	1±0.9	<1±0.6	-	<1±0.2
Bothriochloa saccharoides	4±2.8	1±0.6	4±1.2	3±2.1	5±3.0	2±1.3	2±1.0	4±1.2	<1±0.3	2±0.7
Hilaria belangeri	<1±0.3	<1±0.2	-	3±1.8	2±1.4	8±3.5	5±1.1	9±1.9	<1±0.2	7±1.9
Buchloe dactyloides	<1±0.3	1±1.2	<1±0.2	-	<1±0.2	<1±0.3	-	<1±0.3	-	<1±0.4
Hilaria mutica	<1±0.2	<1±0.2	-	-	-	1±0.5	<1±0.4	-	<1±0.1	-
Nolina texana	-	<1±0.2	-	-	-	-	<1±0.3	-	-	-
Tridens spp.	-	-	-	<1±0.2	-	-	-	-	-	-
Unknown grasses	-	-	-	-	-	<1±0.9	1±1.7	3±1.3	-	1±1.1
Total grasses	65±3.4	63±2.8	40±3.0	36±8.3	62±2.9	82±2.4	87±2.9	77±2.6	17±1.1	67±2.7
Forbs										
Croton spp.	2±0.8	2±1.5	3±1.6	<1±0.2	-	-	-	-	<1±0.6	-
Verbena spp.	-	-	<1±0.2	-	-	-	-	-	-	-
Yucca spp.	-	<1±0.2	-	-	-	-	-	-	-	-
Unknown forbs	-	-	-	<1±0.2	<1±0.3	1±1.1	1±0.5	2±1.4	1±0.5	1±0.8
Total forbs	2±0.8	2±1.0	3±1.2	1±0.2	<1±0.3	1±1.1	1±0.5	2±1.4	1±0.1	1±0.8
Browse										
Quercus spp.	24±5.3	30±4.5	38±7.9	50±6.0	27±4.5	6±1.7	3±1.7	6±0.8	74±5.5	20±6.5
Condalia obtusifolia	4±3.6	2±2.3	4±4.6	2±1.1	6±4.5	-	-	-	-	-
Juniperus spp.	<1±0.0	<1±0.8	<1±0.3	3±1.0	1±0.5	6±2.6	5±2.2	8±2.3	8±7.1	9±2.5
Acacia greggii	-	<1±0.2	10±8.6	1±1.7	4±2.9	-	-	-	-	-
Rhus microphylla	-	-	-	-	-	3±1.9	3±3.6	7±3.8	-	<1±0.3
Prosopis glandulosa	1±0.6	<1±0.8	3±1.7	1±0.9	<1±0.1	2±1.6	1±1.1	<1±0.8	-	<1±0.4
Diospyros texana	-	<1±0.2	<1±0.2	6±2.6	-	-	-	-	-	-
Zanthoxylum fagara	3±4.3	1±1.1	1±2.3	-	-	-	-	-	-	-
Forestiera pubescens	<1±0.9	<1±0.4	-	-	-	<1±0.2	-	-	-	-
Total browse	33±5.2	35±3.2	57±4.6	63±6.7	38±4.3	17±1.2	12±1.2	21±1.6	82±22.1	29±4.1
Succulents										
Opuntia spp.	-	-	-	-	-	-	-	-	-	3±2.8

Table 4. Mean (±2SE) diet composition (%) of five different breeds of sheep and goats grazing in a mixed grass-mesquite community in Tom Green County, Texas.

	April 1980					August 1980				
	Sheep Breeds			Goat Breeds		Sheep Breeds			Goat Breeds	
Food Items	Rambouillet	Karakul	Barbado	Spanish	Angora	Rambouillet	Karakul	Barbado	Spanish	Angora
Grasses and Grasslike Plants										
Bouteloua spp.	46±3.7	46±2.8	36±3.2	9±2.6	12±5.5	36±10.2	36±3.4	31±2.6	12±3.8	24±7.8
Stipa leucotricha	-	<1±0.7	<1±0.5	2±0.9	1±1.0	-	<1±0.2	<1±0.3	<1±0.2	<1±0.3
Sporobolus cryptandrus	2±0.9	2±1.2	3±1.2	<1±0.8	2±1.2	2±1.0	4±1.8	2±1.2	6±0.9	13±2.9
Aristida spp.	2±2.8	2±1.9	<1±0.3	<1±0.5	<1±0.5	3±2.4	1±0.9	2±2.0	1±1.5	3±1.7
Hilaria belangeri	2±1.0	6±5.3	4±2.0	2±1.6	3±1.7	6±1.5	6±2.4	4±1.2	3±1.0	6±1.6
Limnodea arkansana	3±2.2	4±0.6	2±0.9	7±1.3	9±0.9	-	-	-	-	-
Buchloe dactyloides	6±3.2	6±1.9	2±1.2	<1±0.4	<1±0.3	<1±0.7	2±0.8	2±0.8	<1±0.2	<1±0.4
Hilaria mutica	6±4.5	7±1.8	2±0.8	<1±0.5	<1±0.3	1±2.5	2±2.1	2±1.1	<1±0.4	<1±0.2
Bothriochloa saccharoides	-	-	-	-	-	<1±0.3	<1±0.2	<1±0.3	<1±0.3	<1±1.0
Panicum spp.	3±2.0	2±1.3	-	-	-	<1±0.3	<1±0.2	<1±0.5	1±0.4	<1±0.9
Bromus unioloides	1±2.0	1±1.1	<1±0.7	1±0.6	2±1.7	-	-	-	-	-
Phalaris canariensis	<1±0.2	-	-	<1±0.4	2±0.7	-	-	-	-	-
Unknown grasses	2±1.4	<1±0.6	2±1.4	<1±0.4	<1±0.6	<1±0.6	-	<1±0.2	<1±0.2	<1±0.3
Total grasses	73±3.5	77±3.5	52±3.4	24±0.9	32±2.1	49±3.5	52±3.3	45±2.6	25±1.1	50±2.3
Forbs										
Sphaeralcea spp.	10±3.0	3±1.3	12±3.1	6±1.7	4±2.6	13±6.4	16±6.9	19±6.4	4±1.1	3±2.7
Plantago rhodosperma	<1±0.2	<1±0.4	1±0.5	-	<1±0.8	-	<1±0.2	-	-	-
Abutilon incanum	6±2.4	7±1.0	10±4.5	1±1.1	3±2.7	7±1.2	<1±1.1	1±1.1	1±1.5	2±1.6
Verbena bipinnatifida	<1±0.6	-	-	-	-	-	-	-	-	-
Unknown forbs	4±1.0	4±0.6	5±2.4	1±0.6	2±1.3	3±1.1	3±0.8	3±0.8	2±0.6	3±1.3
Total forbs	20±1.6	15±1.2	28±2.4	8±1.4	9±1.1	23±3.4	19±3.3	23±4.7	7±0.9	9±0.7
Browse										
Rhus microphylla	7±3.1	8±3.8	20±2.5	68±7.4	59±11.2	24±5.2	26±4.3	30±2.8	60±5.4	39±6.0
Prosopis glandulosa	-	<1±0.3	-	-	<1±0.2	4±1.6	3±2.9	2±1.5	<1±0.2	-
Condalia obtusifolia	-	-	-	-	-	-	-	-	2±0.8	-
Acacia greggii	-	-	-	-	-	-	-	<1±1.2	6±1.0	2±1.6
Celtis reticulata	-	-	-	-	-	-	<1±0.4	-	-	-
Total browse	7±3.1	8±3.1	20±2.5	68±7.4	59±20.3	28±7.2	29±6.3	32±8.9	68±11.5	41±12.5
Succulents										
Opuntia spp.	-	-	-	-	-	-	-	-	2±0.8	1±1.3

Table 5. Mean (±2SE) diet composition (%) of five different breeds of sheep and goats grazing in a mixed grass-mesquite community in Tom Green County, Texas.

	February 1981					April 1981				
	Sheep Breeds			Goat Breeds		Sheep Breeds			Goat Breeds	
Food Items	Rambouillet	Karakul	Barbado	Spanish	Angora	Rambouillet	Karakul	Barbado	Spanish	Angora
Grasses and Grasslike Plants										
Bouteloua spp.	9±4.4	6±5.7	9±0.7	4±2.7	5±3.3	10±1.8	13±2.9	9±1.3	3±1.2	10±1.0
Stipa leucotricha	17±4.7	17±8.9	42±4.5	38±5.8	42±7.3	8±1.8	14±4.0	15±2.2	11±5.1	11±4.9
Sporobolus cryptandrus	5±2.1	9±3.1	8±2.4	13±4.3	13±3.0	13±3.4	11±2.0	7±1.9	1±1.0	1±0.9
Aristida spp.	18±4.0	12±2.5	10±2.2	6±2.1	7±3.0	5±2.1	5±2.5	7±2.3	4±1.3	4±2.4
Hilaria belangeri	10±3.4	17±5.5	6±3.5	3±2.0	4±1.9	2±1.0	1±0.4	<1±0.7	<1±0.7	<1±0.7
Tridens spp.	-	-	<1±0.2	-	<1±0.2	7±4.0	18±2.8	19±1.4	16±14.0	12±1.5
Limnodea arkansana	<1±0.5	2±2.2	-	1±0.7	<1±0.3	9±1.8	5±1.1	7±1.9	3±2.0	6±2.7
Buchloe dactyloides	4±2.9	7±2.6	2±2.0	2±1.2	1±0.9	1±0.4	<1±0.3	2±1.2	<1±0.5	1±1.0
Hilaria mutica	2±1.5	3±0.9	<1±0.7	<1±1.1	1±1.0	<1±0.3	<1±0.3	<1±0.2	1±0.9	<1±0.3
Bothriochloa saccharoides	10±5.5	3±1.5	1±1.2	<1±0.3	1±1.3	<1±0.5	<1±0.8	-	<1±0.5	-
Panicum spp.	3±2.4	1±0.5	2±1.3	1±1.1	<1±0.6	1±1.0	<1±0.3	<1±0.2	<1±0.5	<1±0.2
Total grasses	78±3.5	77±2.0	80±3.5	68±3.2	76±3.2	56±1.2	70±1.8	67±1.8	40±1.5	45±1.4
Forbs										
Sphaeralcea spp.	<1±0.8	1±1.0	3±1.5	2±1.4	3±1.1	2±1.2	4±1.8	4±1.3	3±1.1	2±2.8
Lesquerella gracilis	9±3.4	9±2.2	9±2.6	7±1.9	9±2.0	7±2.3	6±1.0	6±1.1	3±2.4	3±2.7
Plantago rhodosperma	-	-	-	-	-	8±2.3	8±2.9	7±2.1	8±2.3	7±2.8
Chenopodium album	-	-	-	-	-	7±2.0	3±0.5	2±1.3	-	-
Solanum elaeagnifolium	1±0.9	<1±0.4	<1±0.6	2±1.3	2±1.6	<1±0.7	<1±0.7	1±1.2	2±0.5	3±0.5
Corydalis aurea	-	-	-	-	-	6±1.4	3±1.2	2±1.6	<1±0.7	<1±0.3
Descurania pinnata	-	-	-	-	-	4±2.7	1±1.6	2±1.4	-	<1±0.2
Linum lewisii	-	-	-	-	-	3±2.9	-	-	-	-
Perezia nana	-	-	-	-	-	-	<1±0.4	<1±0.6	1±1.1	<1±1.1
Erodium texanum	-	-	-	-	-	-	<1±1.0	<1±0.7	<1±0.2	<1±0.4
Draba cuneifolia	-	-	-	-	-	<1±1.2	<1±0.3	<1±0.4	<1±0.2	<1±0.2
Amblyolepis setigera	-	-	-	-	-	-	-	<1±0.3	<1±0.3	<1±0.2
Astragalus nuttallianus	<1±0.7	-	-	-	-	-	-	<1±1.5	<1±0.3	-
Ambrosia spp.	<1±0.2	-	-	-	-	-	<1±0.2	-	-	-
Verbena bipinnatifida	-	-	-	-	-	<1±0.5	-	-	-	-
Englemannia pinnatifida	-	-	-	-	-	<1±0.2	-	-	-	-
Unknown forbs	<1±0.8	<1±0.2	-	<1±0.9	<1±0.6	3±1.0	3±1.3	4±0.4	1±0.4	1±1.6
Total forbs	12±2.1	11±1.7	13±2.1	11±1.3	14±1.7	40±1.0	30±0.7	29±0.6	21±1.6	17±0.7

Table 5. (Continued)

Food Items	February 1981					April 1981				
	Sheep Breeds			Goat Breeds		Sheep Breeds			Goat Breeds	
	Rambouillet	Karakul	Barbado	Spanish	Angora	Rambouillet	Karakul	Barbado	Spanish	Angora
Browse										
Rhus microphylla	<1±1.0	3±2.2	<1±0.8	9±2.2	1±1.9	<1±0.2	-	1±1.3	32±7.4	32±4.5
Prosopis glandulosa	6±1.6	5±1.8	1±1.5	6±1.7	3±1.6	<1±0.4	<1±0.2	-	<1±0.6	<1±0.2
Ephedra spp.	4±3.4	4±2.2	6±2.0	6±2.0	6±3.3	<1±0.7	<1±0.2	2±1.0	<1±0.4	<1±0.2
Condalia obtusifolia	-	-	-	-	-	<1±0.5	-	1±1.0	6±2.3	5±0.8
Acacia greggii	-	-	-	-	-	<1±0.2	-	<1±0.4	<1±0.5	-
Berberis trifoliolata	-	-	-	<1±0.2	<1±1.4	-	-	-	<1±0.3	<1±0.2
Total browse	10±1.4	12±1.2	7±1.4	21±1.3	10±1.3	4±2.1	<1±0.2	4±0.7	39±4.4	38±5.5
Succulents										
Opuntia spp.	-	-	-	-	<1±1.0	-	-	-	<1±0.2	-

During April 1981, grasses continued to be the staple food of all breeds, but forbs increased considerably in dietary importance (Table 5). Karakul and Barbado sheep consumed significantly more grass than all other breeds, while Rambouillet sheep consumed more grass than the goat breeds. Forbs were more important in Rambouillet sheep diets compared to diets of the other breeds. Karakul and Barbado sheep ate significantly more forbs than did the goat breeds. Browse, primarily littleleaf sumac and lotebush (Condalia obtusifolia), were major foods of Spanish and Angora goats. The goat breeds consumed significantly more browse compared to sheep breeds, while Karakul sheep tended to consume less browse than Rambouillet and Barbado sheep.

A variety of grasses comprised the major diet component of all sheep and goat breeds during September 1980 in the creosotebush-tarbush community (Table 6). Grasses were significantly more important in sheep diets than in goat diets. Spanish goats tended to rely more heavily on forbs, primarily spreading sida (Sida filicaulis), than other breeds. Littleleaf sumac was the major browse plant of both goat breeds and Barbado sheep. Browse was significantly more important in goat diets compared to sheep diets, and Barbado sheep consumed more browse than the other sheep breeds.

Forbs increased considerably in importance in the diets of all breeds during November 1980 in the creosotebush-tarbush community (Table 6). Rambouillet sheep ate significantly more forbs than the other breeds, while Karakul sheep ate more forbs than Barbado sheep or the goats. Forbs were least important in the diets of Spanish goats. Grasses were significantly more important in diets of Barbado sheep and Angora goats compared to the other breeds, while they were least important in Rambouillet sheep diets. Spanish goats consumed significantly more browse than all other breeds, while Angora goats and Barbado sheep consumed more browse than Rambouillet and Karakul sheep.

Dietary similarity indices computed over sampling periods within plant communities indicated that diets of Rambouillet and Karakul sheep overlapped considerably, while the diets of Rambouillet sheep and Spanish goats were least similar (Table 7). Barbado sheep generally utilized more browse than Rambouillet or Karakul sheep, thereby, occupying a food niche intermediate between those of Rambouillet and Karakul sheep and Spanish and Angora goats.

The mean number of different plant species in the diets of Rambouillet, Karakul and Barbado sheep, averaged across all three plant communities and sampling periods were 18, compared to 18.5 for Angora goats and 19 for Spanish goats, indicating no biological important deviation among these breeds in respect to the number of different food plants (Table 8). However, considerable variation was observed in numbers of different foods in diets of all breeds among plant communities and among sampling dates within plant communities. These differences were attributed to (1) difference in relative abundance of plant species among the three communities and among sampling dates, (2) changes in acceptability of certain plants to sheep and goats over time, and/or (3) inherent tendencies of the herbivores to voluntarily shift grazing behavior over time.

Table 6. Mean (±2SE) diet composition (%) of five different breeds of sheep and goats in a creosotebush-tarbush community in Pecos County, Texas.

	September 1980					November 1980				
	Sheep Breeds			Goat Breeds		Sheep Breeds			Goat Breeds	
Food Items	Rambouillet	Karakul	Barbado	Spanish	Angora	Rambouillet	Karakul	Barbado	Spanish	Angora
Grasses and Grasslike Plants										
Tridens spp.	19±4.6	34±2.7	15±4.5	32±5.5	26±5.2	3±1.4	4±1.4	1±1.1	1±0.6	6±3.0
Muhlenbergia spp.	31±1.4	11±4.1	21±4.2	4±1.9	17±4.5	8±1.2	9±2.5	7±1.6	9±4.2	3±3.1
Bouteloua spp.	12±3.5	13±3.0	15±6.1	7±1.2	5±1.3	9±3.0	12±2.9	15±3.4	9±2.3	16±6.4
Scleropogon brevifolius	5±0.6	12±2.6	12±3.5	8±2.2	10±2.1	2±1.0	3±1.4	7±1.4	5±0.8	6±3.1
Erioneuron puchellum	7±3.5	4±3.0	18±4.5	3±0.7	5±2.3	<1±0.4	1±0.9	8±3.1	4±1.2	2±0.7
Enneapogon desvauxii	9±2.6	4±1.5	4±1.1	6±1.1	4±2.3	<1±0.3	1±0.8	2±1.3	3±3.2	3±2.8
Eragrostis spp.	5±2.1	6±2.7	1±2.1	<1±0.5	3±1.9	<1±0.3	<1±0.6	3±2.1	2±1.5	<1±0.8
Aristida spp.	1±1.8	5±3.0	<1±0.7	1±1.6	2±2.2	<1±0.8	4±2.6	1±0.8	<1±0.2	<1±0.2
Sporobolus cryptandrus	–	<1±0.9	1±0.8	1±1.2	1±0.8	2±1.0	2±1.9	2±2.1	<1±0.2	4±1.4
Setaria leucopila	2±2.7	<1±0.8	–	–	<1±0.2	<1±0.2	<1±0.5	–	<1±0.6	<1±0.2
Bothriochloa saccharoides	<1±0.9	<1±0.3	<1±0.2	<1±0.5	2±0.8	–	–	<1±0.3	<1±0.2	<1±0.2
Stipa leucotricha	–	–	–	<1±0.3	–	<1±0.2	–	<1±0.3	–	<1±0.2
Unknown grasses	<1±0.2	<1±0.4	–	2±0.9	<1±0.4	<1±0.2	1±0.2	<1±0.3	<1±0.5	<1±0.3
Total grasses	92±2.5	90±2.4	87±2.4	65±2.2	76±2.1	26±0.8	37±1.1	46±1.2	34±0.9	42±2.1
Forbs										
Sphaeralcea spp.	–	–	–	–	–	51±4.9	35±7.0	22±8.2	14±3.2	6±1.3
Sida filicaulis	6±1.2	8±4.0	7±1.4	13±5.2	10±0.5	6±0.5	10±2.8	3±0.2	6±2.8	14±3.7
Lesquerella gracilis	–	–	–	–	–	5±1.5	6±0.9	5±2.5	11±5.3	19±12.4
Abutilon incanum	–	–	–	–	–	7±1.7	5±2.8	2±1.4	<1±0.7	–
Solanum rostratum	–	–	–	–	–	4±2.0	5±0.7	2±0.8	<1±0.4	3±2.6
Erodium texanum	–	–	–	–	–	–	1±0.7	2±0.7	<1±0.6	–
Dyssodia acerosa	–	–	–	–	–	–	–	3±0.9	–	–
Plantago rhodosperma	–	–	–	–	–	–	<1±0.2	–	<1±0.7	<1±0.2
Zinnia anomala	–	–	–	–	–	–	–	–	–	<1±0.2
Coldenia canescens	–	–	–	–	–	–	–	–	–	<1±0.2
Unknown forbs	<1±0.5	1±0.8	2±0.6	1±1.1	<1±1.1	<1±0.2	<1±0.4	1±0.8	<1±0.4	–
Total forbs	7±1.9	9±3.0	9±2.0	14±4.6	10±2.3	73±6.5	62±3.6	40±2.3	32±1.8	42±3.4

Table 6. (continued)

Food Items	September 1980					November 1980				
	Sheep Breeds			Goat Breeds		Sheep Breeds			Goat Breeds	
	Rambouillet	Karakul	Barbado	Spanish	Angora	Rambouillet	Karakul	Barbado	Spanish	Angora
Browse										
Rhus microphylla	<1±0.3	-	3±2.8	18±3.6	11±1.5	<1±0.2	-	6±3.5	13±3.7	12±4.7
Lycium texanum	-	-	-	-	-	-	-	6±2.0	10±4.0	-
Juniperus pinchotii	-	-	-	-	1±0.5	-	-	-	5±1.9	3±3.1
Microrhamnus ericoides	-	<1±0.3	<1±0.3	2±1.5	<1±0.6	-	-	-	4±2.6	<1±0.3
Prosopis glandulosa	-	-	<1±0.3	<1±0.3	-	<1±0.2	<1±0.3	-	-	-
Bernardia obovata	-	-	-	-	-	-	-	1±1.2	2±2.1	-
Flourensia cernua	-	-	-	-	-	-	-	<1±0.2	-	-
Larrea tridentata	-	-	<1±0.5	-	-	-	-	-	-	-
Dalea formosa	-	-	-	-	-	-	-	-	-	<1±0.3
Total browse	<1±0.3	<1±0.3	4±0.7	20±4.5	13±2.9	<1±0.1	<1±0.3	14±1.6	34±1.9	16±2.2

Table 7. Mean similarity indices of diets of various breeds of sheep and goats grazing in three plant communities in western Texas, 1979-1981.

Breed Relationship	Edwards County	Tom Green County	Pecos County	Means
Spanish vs. Angora	57	75	71	69
Spanish vs. Barbado	46	58	62	55
Spanish vs. Karakul	41	61	62	55
Spanish vs. Rambouillet	41	46	51	46
Angora vs. Barbado	66	81	62	70
Angora vs. Karakul	64	57	67	63
Angora vs. Rambouillet	65	54	53	57
Barbado vs. Karakul	81	78	68	76
Barbado vs. Rambouillet	76	74	65	72
Karakul vs. Rambouillet	85	83	76	81

Table 8. Number of different foods eaten by different breeds of sheep and goats in selected plant communities.

	Edwards County			Tom Green County			Pecos County		
Breed	Nov.1979	/ Feb.1980	/May 1980	/Aug.1980	/Feb.1981	/Apr.1981	/Sept.1980	/Nov.1980	Means
Rambouillet sheep	16	16	17	14	19	28	14	20	18
Karakul sheep	19	15	17	16	17	25	15	20	18
Barbado sheep	16	14	15	16	16	27	16	24	18
Spanish goats	18	11	15	18	18	30	17	25	19
Angora goats	14	15	17	16	19	25	17	25	18.5
Means	16.6	14.2	16.2	16	17.8	27	15.8	22.8	

In concluding this study, one of the most noteworthy observations was that Barbado sheep generally utilized more browse and less grass than Rambouillet or Karakul sheep, thereby occupying a food niche intermediate between the other sheep and goat breeds studied. In two cases, the Barbado sheep and Angora goats consumed browse and forbs in similar proportions. The goat breeds, mainly Spanish goats, consistently utilized browse as staple food, especially when forbs were not plentiful. Spanish goats exhibited the greatest tendency to utilize browse, even when availability appeared low due to an elevated browse line. Barbado sheep tended to consume more undesirable brush species, specifically lotebush, juniper (Juniperus spp.) and catclaw acacia (Acacia greggii), than other sheep breeds. However, the major undesirable brush species on the study areas, including honey mesquite, creosotebush, tarbush, juniper, lotebush, catclaw acacia, and algerita (Berberis trifoliolata) were not consumed in appreciable quantities by any of the sheep or goat breeds studied. Karakul sheep could apparently be substituted for Rambouillet sheep in most range types with little effect on the resource; however, they offer no advantage over Rambouillet sheep for suppressing undesirable shrubs.

Other studies related to diet differences between various sheep breeds have been conducted. Arnold (1975) used Corriedales, Merinos, Border Leicester X Merinos and Dorset Horns to conclude that the breeds behaved similarly in response to a change in physiological state and pasture conditions. Langelands (1969) observed selectivity differences between sheep differing in age, breed and in previous grazing history on specific occasions, however, differences averaged over all pastures and on all occasions appear to be little more than variation between individual sheep.

No significant differences were found between the effect of age or breed on botanical diet composition of Hereford, Angus X Hereford and Charolais X Hereford cows while grazing in northeastern Colorado (Table 9)(Walker et al. 1981). Small differences were detected in the cattle diets but effect of age and breed were not large enough to be of value in understanding the dietary habits of cattle (Table 10). Herbel and Nelson (1966) determined that there was no apparent differences in the total percentage of coarse plants grazed by Hereford and Santa Gertrudis cows during a 3-year period. The Santa Gertrudis tended to consume more of the coarse grasses whereas, the Herefords ate more russianthistle (Salsola kali) and soaptree yucca (Yucca elata). Small amounts of honey mesquite beans (Prosopis juliflora var. glandulosa) were eaten on 3 occasions. Honey mesquite constituted 0.2 and 0.8% of the Hereford cow diets during the winter and summer respectively, and 1.2% of the Santa Gertrudis cow diet during the summer. In another study, Galt (1972) indicated that steers consumed an average of 9% velvet mesquite (Prosopis juliflora var. velutina) leaves and twigs when they were grazing desert grassland pastures with an 18% canopy cover of mesquite.

WITHIN BREED VARIATION

Species or breed differences have been shown to exist in forage selectivity and can be of considerable importance in exploiting vegetative resources.

Table 9. Average botanical composition (%) of diets selected by cattle of various age and breed groups on sandhill range of northeastern Colorado.[2]

Major food categories[1]	Mean Diets (% + SD)				
	Cow	Calf	Hereford	Angus X Hereford	Charolais X Hereford
Western wheatgrass	3±1	3±2	2±1	4±3	3±2
Sand bluestem	2±1	6±3	3±3	4±4	4±4
Sideoats grama	1±2	1±2	2±3	1±1	1±1
Blue grama	9±4	11±5	8±6	12±3	10±5
Brome	1±1	1±1	1±1	1±1	1±1
Prairie sandreed	55±14	53±14	60±16	50±11	53±13
Sun sedge	1±1	1±1	1±1	1±1	1±1
Sand dropseed	9±5	10±7	8±5	9±5	12±8
Needle-and-thread	14±8	11±8	11±8	15±10	11±6
Scarlet globemallow	2±2	2±1	1±2	2±1	2±1

[1]Major feed categories include species which composed 2% or more of an individual diet.

[2]Taken directly from Walker *et al*. (1981).

Table 10. Average dietary overlap and Spearman's rank correlation coefficients with the corresponding confidence values for foods of cattle of different ages or breeds on sandhill range of Northeastern Colorado.[1]

Relationship	Percentage similarity	Spearman's RHO values	P values
Cow vs calf	84	.97	.01
Hereford vs Angus X Hereford	84	.92	.01
Hereford vs Charolais X Hereford	85	.91	.01
Angus X Hereford vs Charolais X Hereford	85	.97	.01

[1]Taken directly from Walker *et al*. (1981).

However, these differences have evolved over hundreds, thousands, or even millions of years. A logical followup question is what differences exist within breeds and is it feasible to select for animals which will forage on given plant species or type of vegetation. This may be of particular significance in attempting to select between species, between breeds, or within breeds for animals which will utilize abundant, invading, or problem species. This is a pertinent question as applied to the Edwards Plateau of Texas. No doubt this is also true of many other grazing areas as well. In the Edwards Plateau, "increaser" grass species such as tobosagrass (Hilaria mutica), which are rarely utilized by the grazing animals, are abundant. In the case of forbs, horehound (Marrubium vulgare) is utilized very little by the grazing animal and causes problems of defect in the fleeces of sheep and Angora goat. However, the most noted examples are in the browse plants. In this case, long continued grazing and fire control has encouraged the incursion of a number of browse species such as honey mesquite, algerita, catclaw acacia, etc. The foliage of each of these is high in protein and would appear to have significant nutritional value if the animal could be induced to consume these plants (Huston, Rector, Merrill and Engdahl, 1981).

To the writer's knowledge, the (within breed) genetic variability and hereditary control of dietary habits of the grazing animal has not been studied. With this in mind, a study was conducted at the Texas Agricultural Experiment Station near San Angelo during the summers of 1980 and 1981. Young Spanish goat males (7-9 months) with known sires were grazed on a mixed grass-mesquite plant community. Botanical composition of goat diets was determined by analysis of fecal material using the microhistological technique as described by Sparks and Malechek (1968). Grazing periods were in July and August with samples being collected in August. The sampling method and forage data collection procedure generally followed that of Warren (1981).

Sixty young males were used in 1980 and 95 in 1981. The kids used in 1980 were sired by seven different sires while 10 sires were represented in 1981. One of the sires used to produce the 1981 kid crop was by a 1/2 Ibex male (No. 50) resulting in kids which carried 1/4 Ibex breeding. Sire effects were evaluated by paternal half-sib analyses on a within year basis.

The plant species identified in the diets of goats for the 2 years are shown in Table 11. This table also shows the level of significance of sire effects on the intake of individual plant species. As expected, browse made up the larger portion of the diet (61.3% in 1980 and 49.3% in 1981). Grasses composed about 28% of the goat diets in both years. Moisture conditions improved in 1981, resulting in a number of forbs replacing some of the browse plants in the goat diets. The sampling methods for determining dietary analysis leads to considerable variability. However, it is reasonably clear that among the browse species the goats were selecting littleleaf sumac and lotebush, while avoiding mesquite. Indianmallow (Abutilon

Table 11. Plant species identified in the diets of male goats grazing near San Angelo, Texas in August 1980 and 1981.

Food Plants		% of Diet		Level of Significance of Sire Effect
Common Name	Scientific Name	1980	1981	
Grasses				
Grama	Bouteloua spp.	6.6	3.3	**
Sand dropseed	Sporobolus cryptandrus	5.1	3.2	*
Buffalograss	Buchloe dactyloides	8.3	3.8	--
Curlymesquitegrass	Hilaria belangeri	3.5	7.0	--
Tobosagrass	Hilaria mutica	1.5	1.6	+
Texas wintergrass	Stipa leucotricha	0.2	0	--
Tridens	Tridens spp.	0.9	7.2	**
Threeawn	Aristida spp.	0.6	1.1	*
Muhly	Muhlenbergia spp.	0.5	0.1	*
Panicum	Panicum spp.	0.5	0.7	*
Bluestem	Bothriochloa spp.	0.3	0.7	**
Ozarkgrass	Limnodea arkansana	0	0.1	--
	Total grasses	28.0	28.8	
Browse				
Morman tea	Ephedra sp.	1.5	1.3	--
Littleleaf sumac	Rhus microphylla	33.3	43.0	--
Lotebush	Condalia obtusifolia	15.6	0.7	**
Persimmon	Diospyros texana	0	0.02	--
Catclaw acacia	Acacia greggii	0.2	0.6	--
Honey mesquite	Prosopis glandulosa	0.6	0.7	*
Juniper	Juniperus pinchotii	0.2	0.2	+
Wolfberry	Lycium texanum	1.6	0	+
Whitebrush	Aloysia lycioides	0.5	0	**
Algerita	Berberis trifoliolata	7.8	2.8	**
	Total browse	61.3	49.32	
Forbs				
Indianmallow	Abutilon incanum	0.8	16.0	--
Globemallow	Sphaeralcea spp.	5.5	2.2	*
Plaintain	Plantago spp.	0	1.4	--
Nuttalls milkvetch	Astragalus nuttallianus	0.1	1.2	--
Solanum	Solanum spp.	1.7	0.2	**
Bladderpod	Lesquerella gracilis	0	0.04	--
Huisachedaisy	Amblyolepis setigera	0	0.6	*
Horehound	Marrubium vulgare	0	0.02	--
Sage	Salvia sp.	0.1	0.04	+
Croton	Croton sp.	0.1	0	--
	Total forbs	8.3	21.7	
Succulents				
Pricklypear	Opuntia spp.	2.4	0.6	--

-- not significant
+ sig. at .10 level
* sig. at .05 level
** sig. at .01 level

incanum) and globemallow were the most commonly selected forbs. Grass consumption appeared to be more closely related to availability except that the goats were avoiding tobosagrass.

Intake variability by sire groups for three browse species are shown in Figure 3 and 4. The conclusions to be drawn from this data are not clear. The goats consumed noticeably more algerita in the dry year 1980 than 1981.

Nested analyses of variance were used to test for significance of year and sire effect on the level of intake on 33 different plant species. Year effects were significant for most species. The results with respect to sire are shown in Table 12.

These data seem to confirm that there was a sire effect on diet selectivity. It may be of interest to note that there was a significant sire effect for the undesirable plant species algerita, mesquite, lotebush, and whitebrush (Aloysia lycioides). There was not a significant sire effect on a highly palatable species such as littleleaf sumac. Apparently, all the goats tended to feed on this plant.

These data are generally inadequate to provide heritability estimates with any degree of confidence. Heritability estimates based on half-sib analyses were calculated for the intake of those species which showed a significant sire effect. The mean of these values was approximately 30% which would be moderate to high, but this mean ignores plant species which did not show a significant sire effect.

The authors interpret these data to confirm that even within breeds within species, heredity is playing a part in diet selectivity. However, we are not yet ready to propose a program to select for animals which would more readily consume a plant species such as mesquite. It should be of interest to look at dietary habits of animals which have lived in a given resource area or plant community for a number of generations to see if they have altered their grazing habits relative to more recently introduced animals. This also may be a factor to consider in developing animals specifically adapted to a given resource area.

MECHANISMS OR SENSES INVOLVED IN DIETARY PREFERENCES

As previously presented, animals exhibit definite dietary preferences both between plant species and plant parts. One might logically ask what senses are involved in this selection and what options exist to influence this process. It might also be of interest to know if the animal is acting in its own behalf or can be depended to select those plant species or plant parts which provide the safest or most nutritious diet. This portion of the report will be based largely on literature as the authors have not conducted original work in this area.

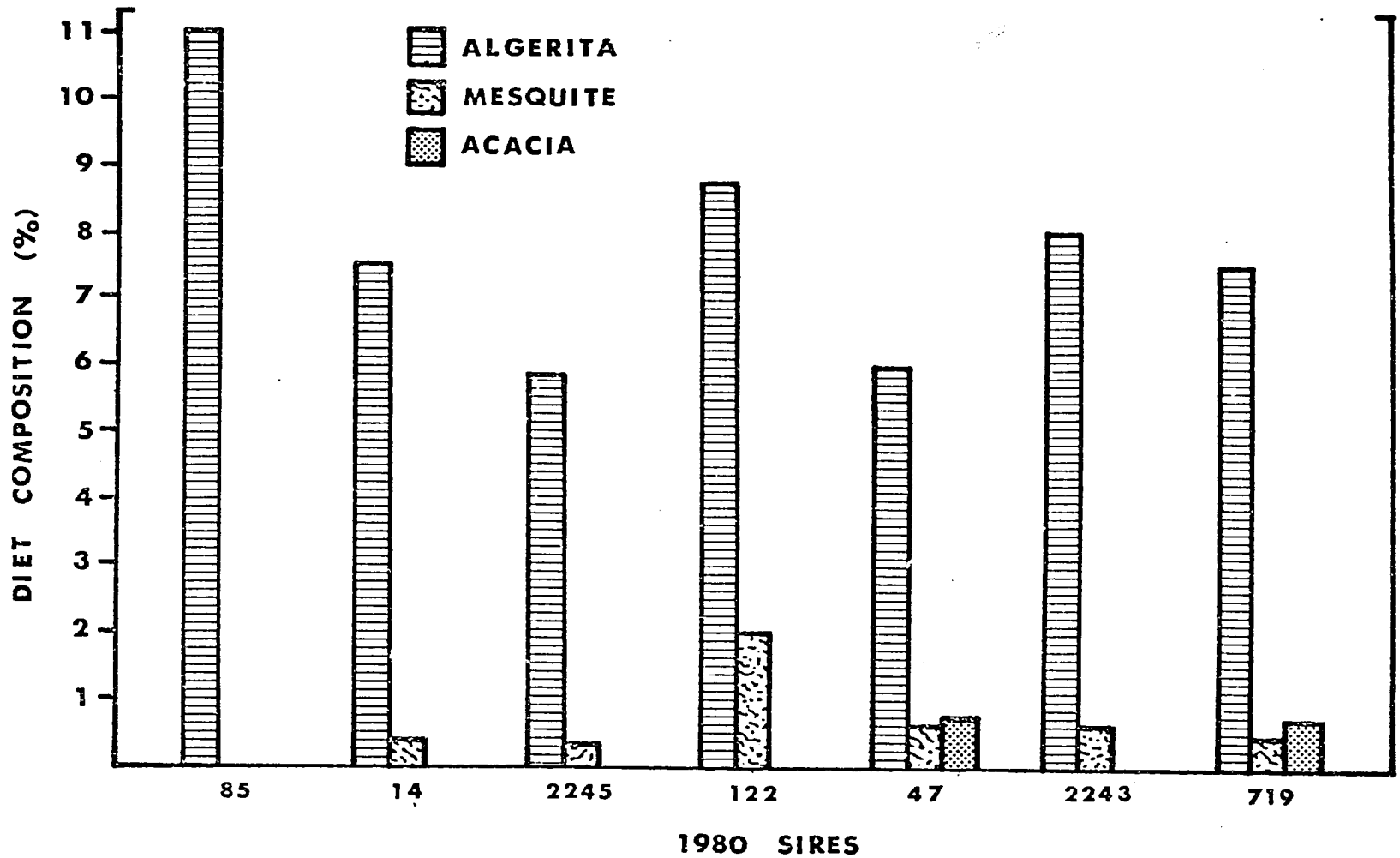


Figure 3. Variability in intake of three plant species by the offspring of seven sires studied in summer of 1980.

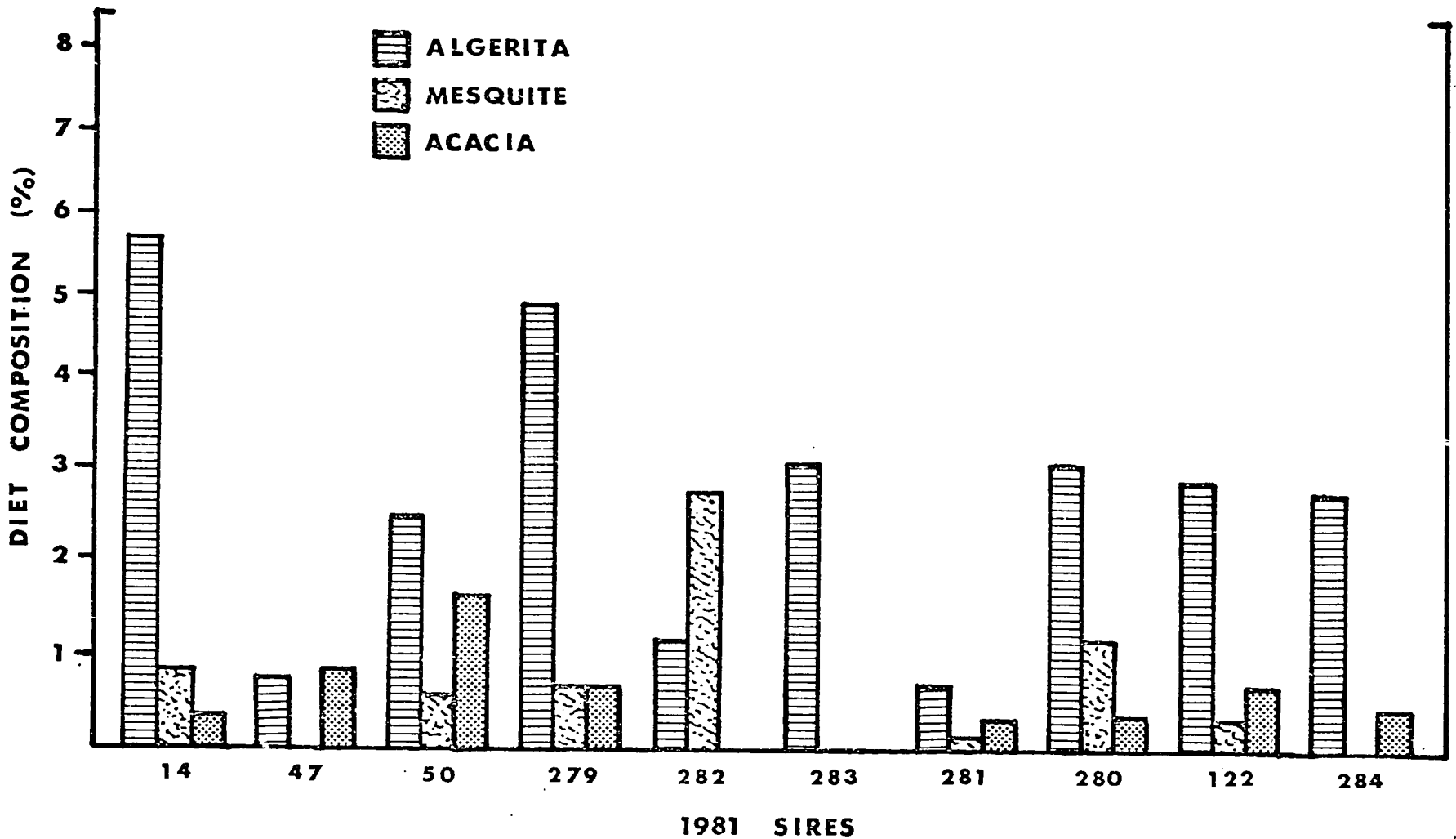


Figure 4. Variability in intake of three plant species by the offspring of ten sires studied in the summer of 1981.

Table 12. Significance of sire effects on the intake level of different plant species.

Number of plants with significant sire effect	Level of significance	Expected frequency without sire effect
18	P±0.10	3-4
14	P±0.05	1-2
7	P±0.01	1

Several authors have studied the special senses in the grazing animal (Arnold, 1966ab; Milne, et al., 1982; Krueger, Laycock and Price, 1974). Some of the speical senses which have been studied include sight, smell, taste, and touch. Krueger, Laycock and Price (1974) studied all four senses for a group of sheep grazing on the range of southwestern Montana (U.S.A.). These workers report that all four senses were related to diet preferences at some level. However, they report that "taste was the special sense most influential in directing forage preference". The other senses appeared to supplement taste and may have been critical as applied to preference for or descrimination against individual plant species. According to these authors, "sheep preferred sour or sweet plants and generally rejected bitter plants". Simultaneous impairment of all four senses did not result in complete random selection, but increased the intake of otherwise unpalatable plants and reduced the intake of those normally most palatable. Arnold (1966a) studied the effect of sight on grazing sheep under pasture conditions. This study does not support the view that sight is a major factor in plant selection. It may be a major factor in permitting the animals to properly orient themselves while grazing or foraging efficiency, but under the conditions of this study had little effect on animal performance. The same author (Arnold, 1966b) studied the sense of smell, taste, and touch on the dietary habits in sheep. This author reports that marked changes occur in the relative acceptability of plant species when each of the senses are impaired, and that all of the senses are of some importance when all pasture conditions are considered. In special situations a single sense may be of a paramount importance. In this study, impairment of any or all senses was not critical, but under other conditions this conclusion would no doubt be different. Milne, et al. (1982) found that ablation of the olfactory bulbs of sheep had little effect on diet selectivity. Tribe (1949) also found little effect of the sense of smell in foraging behavior. The above studies suggest that taste is a dominant sense, but that sight and smell facilitate the animals gaining access to or identifying specific plant species. Touch may be important in those cases where some attribute such as spines reduce acceptability.

In addition to the above senses, it must be realized that such physical attributes as size, reach, physical dexterity or ability to travel can influence diet selection through simply providing access to the desired species. For instance, it must be true that the nimble goat or the tall giraffe can select or reach materials not accessible to many other species. Dudzinski and Arnold (1973) showed that sheep consumed a higher quality or more nutritious diet than cattle, but they attributed this to differences between sheep and cattle to their mechanical ability to be selective.

If one accepts the thesis that taste is the dominant sense involved in diet selection, this sense should receive further study or emphasis.

It has been suggested (Goatcher and Church, 1970) that taste sensations fall into four basic categories, i.e., sweet, salty, bitter, and sour and

that the wide range of sensations observed in nature derive from combinations of these. Of the four listed, sweet would appear to be the primary positive incentive although salty materials may also be searched out at least in small quantities or at a low level. Plice (1952) has shown that cattle at least have a sweet tooth and will search out plants or plant parts that are higher in sugar or to which sugar has been applied. Mitchell and Hosley (1936) suggest a similar finding for deer and Bell (1959) suggests that the goat also has a sweet tooth. Several workers (Heady, 1964) have called attention to the negative relationship between lignin and fiber and palatability, but this could also be interpreted as a response to the absence of soluable carbohydrates or sugars. Livestock producers have for decades made use of this information in increasing consumption of poor quality materials. This same worker showed that sugar alone was not the only attractant, but that it was the sweet taste since other agents such as saccharin evoke the same response. In his original observations animals were shown to be selecting forages which were higher in phosphorus, but it was strongly suggested that this was because these plants also had a higher sugar content.

It should be pointed out that Goatcher and Church (1970) questioned the existence of a sweet tooth in sheep as with other species, but their methods were different to that of other workers.

Perhaps one of the more significant plant components affecting palatability are tannins. Tannins, which are usually deposited in vacules near the leaf surface where they will not interfere with the functioning of plant protein, are responsible for the astringent or bitter taste of many plant tissues which make them unpalatable to man and other animals (Sondheimer and Simeone, 1970). Tannins have been intensively studied because of their close association or interference with digestibility (Feeny, 1976) particularly in decreasing protein digestibility and inhibiting microbial protein fermentation (Donnelly and Anthony, 1969; Driedger and Hatfield, 1972) and cellulose digestibility (Tagari et al., 1965; Lyford et al., 1967). The negative influence of tannins may not be noticed if protein levels are maintained at high levels, therefore emphasizing the importance of high consumption levels of browse (Lyford et al., 1967; Glick and Joslyn, 1970). Tannic acid causes excessive production of proteolytic enzymes in the gut, resulting in considerable loss of nitrogen in feces, a negative nitrogen balance and loss of weight (Freeland and Jazen, 1974). With most plant species, a high tannin content retards intake (Bell, 1959). To some degree the reverse of this can be shown to be true with the goat in which they often, or to some degree, show a preference for tannin-containing plants. Bell (1959) has explained this by the goat having a high threshold or tolerance for a bitter taste as compared to other animals. It is not clear if this also presents an explanation for the browsing tendency of several wild species.

Several authors have reported an adverse effect of essential oils on both palatability and digestibility of potential forage plants. The lower terpenes (hemi-, mono-, sequi and diterpenes) are the major components of essential oils

of many plants and among the plant scents to which animals respond. They are segregated from protoplasm in globules within cells or in dead cells or specialized ducts (Ricklefs, 1979). Data indicates that essential oils of sagebrush have antibacterial properties of a broad spectrum, acting on gram-positive and gram-negative organisms (Nagy, Steinholt, and Ward, 1964). Results indicate that cellulose digestion will be slowed down slightly if the diet contains 15-30% sagebrush. Eberhard (1975) suggests that essential oils may radically inflate the caloric density of some plants and appear as digestible energy because of their absence in the feces. This group of compounds have been further refined in studies by Schwartz, Regelin and Nagy (1980) which suggest that it was the oxygenated monoterpenes which have the greatest inhibitory effect on the utilization of junipers by deer. Other animals such as the koala bear feed on extremely restricted ranges of plants containing high amounts of essential oils and phenols.

The above discussion relates to the taste of sugars as a positive response. However, for the grazing animal, especially in an arid environment, the existence of negative or inhibitory factors may be of greater importance. Many plant species contain materials which have the effect of reducing foraging by animals or reducing moisture loss through evaporation. For obvious reasons, these plants would be favored on evolutionary development of grazed lands. The chemical nature of these inhibitory materials are no doubt very complex, but some information is available.

Other groups of compounds which no doubt inhibit intake are the wide variety of toxic materials, phenolic acids (Pedersen and Ollgaard, 1982), and resins (Zavarin, et al., 1982). Time and the lack of more adequate or definitive information prevents the authors from attempting a more detailed discussion of this subject.

Do animals select those plants or plant parts which are most useful to them?

The question of whether an animal posses nutritional wisdom might be pertinent to devising the most efficient animal production systems. Plice (1952) states that "animals, like people, often eat what they like best before they eat what is best for them". This statement derives from his work in which animals selected materials with a high sugar content and could be fooled by applying non-sugar sweetness to poor quality feeds or forages. However, this seems to be an overstatement or overgeneralization of the conclusions to be drawn from his experiments. The fact that animals perform very well on ranges with mixed vegetation tends to belie the fact that they do not in general select those plants that are good for them. Also, a few of the plants found on arid ranges are toxic; yet animals are successfully produced in these areas. The above examples support the fact that animals are, in general, able to select those plants with better nutritional qualities and to avoid those which are toxic. Westoby (1974) surveyed extensive literature and reported that sugars, soluble carbohydrates, protein fat or either extract, minerals and carotene were either positively related to animal preference or

had no relationship. By contrast, crude fiber and cellulose were negatively related in those studies where a relationship was found. These data strongly support the fact that the animals are generally selecting the more nutritious plants. It is not clear that the animal is selecting for protein, minerals, vitamins, etc., but only one nutrient such as sugar may be the cue and the other benefits derive from the fact that they themselves tend to be related in growing forage. The case for the grazing animal possessing "nutritional wisdom" in which they respond to "specific hungers" by the animal searching out and detecting specific nutrients is not very strong. However, the examples of cattle searching out bones as a source of phosphorus can be cited as an example of animals responding to "specific hungers".

The case for avoidance of toxic plants is even more obvious, but it is difficult to support this with literature citations. The alternative to large scale avoidance of toxic plants would be the absence of grazing animals on many ranges. This avoidance may be due to sensory factors (taste, smell, feel, or sight) of which taste appears to be the most likely or avoidance based aversive conditioning. The latter implies some type of animal intelligence or conditioned avoidance based on prior intakes of sublethal amounts. The latter is difficult to visualize in an animal such as a ruminant which is consuming a variety of materials. There is almost a total absence of documented conditioned aversion in the grazing animal. On the other hand, the reverse of this is known to occur in which individual animals become habitual grazers of toxic plants.

One of the more difficult situations to explain is the apparent preference of goats, and to some other extent other browsing animals, for tannin-containing plants. It can be shown that goats will preferentially utilize some tannin-containing plants. However, the available data do not permit one to be specific about the level of intake of high-tannin plants when other more nutritious forage resources are available. It would be difficult to provide a phylogenetic explanation for an animal developing a dietary preference for forage material, such as high-tannin plants, with low digestibility. A tolerance for high tannins would be much more easily explained.

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