MATCHING PROTEIN AND ENERGY SUPPLEMENTS TO FORAGE QUALITY

by

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INTRODUCTION

The term "forage quality" has been defined in many ways. High-quality forages have often been described as green, leafy, high-protein, digestible, palatable, etc. One of the best definitions was stated by a hay producer who supplied alfalfa to dairies in the Midwest. When asked what forage quality meant to him, he replied immediately, "milk in the bucket." He knew very well, as do most livestock managers, that differences in forage quality have little meaning unless there are differences in animal performance.

In Florida's beef industry, managers are concerned with calf weaning weight, heifer development, and cow condition at calving and breeding. The tropical perennial grasses used as summer pasture or hay in Florida do not always have adequate nutrient composition or quality to meet the nutrient needs of these animals. These grasses are often high in fiber, especially when mature, and high-producing cattle are unable to consume them in adequate quantities to meet their requirements for crude protein (CP) and total digestible nutrients (TDN). Thus, protein and energy supplements are often required.

Supplements have varied effects upon animal performance depending upon how they affect intake and utilization of forages. When forages are fed free-choice or grazed, limited amounts of concentrate supplements may either increase or decrease intake of forage. An increase in forage intake may be desirable when forages are of low quality. A decrease in forage intake may be desirable, also, when the quantity of available forage is limited and must be extended. When supplement decreases forage intake (i.e., "substitution" of concentrate for forage), however, the amount of supplement required to meet an animal's requirement is greater than expected. Factors which affect the direction and extent of change in forage intake include the quality of forage, the amount of concentrate fed and the composition of the concentrate, but changes are difficult to predict. Prior knowledge of the effect of concentrate on forage intake is necessary in order to plan strategic supplementation programs when forage is fed free-choice or grazed.

The objectives of this paper are (1) to compare the composition and quality of warm-season improved grasses in Florida to the protein and energy requirements of selected beef cattle, and (2) to examine the reasons for inconsistent changes in forage intake when supplements are fed.

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NUTRIENT REQUIREMENTS VS COMPOSITION AND QUALITY OF FLORIDA'S GRASSES

Crude Protein

Crude protein is a common measure of the total protein required by an animal. The CP requirements of beef cattle females range from 7 to 11% (Table 1). Except for bermudagrass, most samples of Florida's grasses analyzed in the Florida Extension Forage Testing Program were in the range of 5 to 7% CP (Table 2). There was an equal proportion (34%) of bermudagrass samples in the ranges of 5 to 7% and 8 to 10% CP. There was less than 5% CP in a high proportion of digitgrass (35%) and limpograss (28%) samples. For levels of performance above maintenance, most samples of all grasses except bermudagrass were deficient in CP and would require protein supplement in order to meet requirements. The higher CP in bermudagrass may reflect the higher rate of nitrogen fertilizer applied to bermudagrass hay fields and harvesting at early stages of maturity.

Total Digestible Nutrients

Total digestible nutrients is a common measure of the energy required by animals. Required TDN percentages range from 54 to 62% (Table 1). For all grass species except limpograss, the largest proportion of samples had 48 to 51% TDN (Table 2). For limpograss, 68% of samples had more than 51% TDN. In contrast, only 11% of bahiagrass samples had more than 51% TDN. It is apparent that most samples analyzed at Ona were low in TDN. The low TDN percentages are expected because the grasses are of tropical origin and most samples are of hay made at late stages of maturity. Cattle can not increase consumption of these grasses enough to overcome the low TDN percentage, and the intake of TDN will generally be lower than needed.

TABLE 1. REQUIREMENTS FOR CRUDE PROTEIN (CP) AND TOTAL DIGESTIBLE NUTRIENTS (TDN) FOR TYPICAL FLORIDA BEEF CATTLE (from NRC, 1984), CORRESPONDING TDN:CP RATIOS, AND QUALITY INDEX REQUIRED TO MEET TDN REQUIREMENTS (Moore et al., 1991a).

Animal (BW = body weight)	Requirement (% of DM)		TDN:CP Ratio	Quality Index
	CP	TDN		
Heifer, 800 lb BW:				
Non-Pregnant, 0 lb gain/day	7	54	7.7	1.0
Pregnant, 1.0 lb gain/day	8	55	6.9	1.3
Heifer, 600 lb BW, 1.25 lb gain/day	9	59	6.6	1.9
Lactating Beef Cow, 1000 lb BW, 15 lb milk/day	11	62	5.6	1.4

Total Digestible Nutrients:Crude Protein Ratio

When TDN:CP ratios are low (less than 8), it is considered that there is a balance between TDN and CP; that is, there is adequate protein to match the energy in the forage. Low TDN:CP ratios are expected with immature hays when both TDN and CP percentages are high (e.g., when TDN=60% and CP=12%, TDN:CP=5). In mature grasses, TDN:CP ratios may be low because both TDN and CP percentages are low (e.g., when TDN=49% and CP=7%, TDN:CP=7). On the other hand, high TDN:CP ratios (above 8) indicate that there is a deficiency of protein relative to energy (e.g., when TDN=54% and CP=6%, TDN:CP=9).

TABLE 2. RANGE OF FORAGE QUALITY CHARACTERISTICS OF SAMPLES SUBMITTED TO FLORIDA EXTENSION FORAGE TESTING PROGRAM, AREC, ONA (Moore et al., 1991a).

Item[a]	Range	Forage				
		Bahia	Bermuda	Digit	Star	Limpo
(Number of Samples)		(69)	(246)	(71)	(182)	(69)
CP, %	<5	5.8[b]	3.3	35.2	10.4	27.6
	5 to 7	68.2	33.8	49.4	53.4	50.9
	8 to 10	23.2	34.1	9.8	24.2	11.5
	11 to 13	1.4	23.6	1.4	11.0	7.2
	14 to 16	1.4	4.0	4.2	0	2.8
	>16	0	1.2	0	1.0	0
TDN, %	<44	5.7	1.6	0	1.6	1.4
	44 to 47	33.5	19.5	16.9	14.2	2.8
	48 to 51	49.4	41.1	43.8	47.9	27.7
	52 to 55	8.6	31.8	29.5	32.6	44.9
	56 to 59	2.8	4.8	7.0	3.7	21.8
	>59	0	1.2	2.8	0	1.4
TDN:CP	<6	5.7	40.2	9.8	22.5	11.5
	6 to 7	45.2	35.0	16.9	22.6	7.2
	8 to 9	36.4	17.5	14.1	32.0	32.0
	10 to 11	8.7	4.9	25.5	16.4	18.9
	12 to 13	4.0	2.4	25.3	6.0	7.2
	>13	0	0	8.4	.5	23.2
QI	0.9 to 1.0	39.2	17.1	15.5	26.9	7.2
	1.1 to 1.2	40.7	36.6	39.5	37.5	40.7
	1.3 to 1.4	11.5	25.2	28.2	18.8	32.0
	1.5 to 1.6	5.8	13.0	4.2	13.7	11.5
	1.7 to 1.8	1.4	6.5	8.4	2.1	7.2
	>1.8	1.4	1.6	4.2	1.0	1.4

[a]CP = crude protein, % of dry matter; TDN = total digestible nutrients, % of dry matter; TDN:CP = TDN divided by CP; QI = quality index.

[b]Percent of samples.

The TDN:CP ratios calculated from CP and TDN requirements range from 5.6 to 7.7 (Table 1). Among the Florida grasses, there were marked differences in TDN:CP ratios (Table 2). Low ratios (less than 8) were very common for bahiagrass (51% of samples) and bermudagrass (75% of samples). Most bahiagrass samples were low in both CP and TDN while most bermudagrass samples were intermediate in both CP and TDN. High ratios (above 8) were very common for digitgrass (73% of samples), stargrass (55% of samples), and limpograss (81% of samples) because of their higher TDN percentages.

Quality Index

The Florida Extension Forage Testing Program has used "Quality index" (QI) as an overall indicator of forage quality (Moore et al. 1991b). Laboratory analyses used to calculate QI include CP, TDN and fiber percentages of the forage. Quality index is defined as the voluntary intake of forage TDN divided by the animal's maintenance TDN requirement. It is assumed that the forage is fed free-choice without energy supplementation, and that energy and protein are balanced (i.e., low TDN:CP ratio). Thus, if a forage has a QI of 1.0, the animal would just maintain itself when the forage was the only source of dietary energy. Forages with QI values above 1.0 support animal performance in proportion to the QI value (Moore et al., 1991b) and QI may be used to estimate the performance of cattle when a forage is fed alone. Daily gains by steers at QI values of 1.2, 1.5 and 1.8 were about .5, 1.0, and 1.5 lb per day, respectively.

The forage QI required to meet an animal's requirement for TDN is determined by the size and production level of the animal (Table 1). The low requirements of an 800 lb non-pregnant, non-growing heifer could be met with a forage having a QI=1.0, but if the same heifer was pregnant and gaining 1 lb/day the TDN requirement is increased, and a forage having a QI=1.3 would be required. A smaller heifer weighing 600 lb and gaining at 1.25 lb/day cannot eat enough forage to meet her TDN requirement unless the forage has a QI=1.9. A lactating cow producing 15 lb milk/day requires a forage with QI=1.4 to meet her TDN requirements. When the forage offered has a lower QI than needed, supplemental TDN is required.

In all Florida grass samples, a high proportion (37 to 40%) of QI values were in the range of 1.1 to 1.2 (Table 2). Bahiagrass had a high proportion of samples (39%) below 1.1. In the range of 1.3 to 1.6 QI, the proportions of samples were 17% for bahiagrass, 38% for bermudagrass, 32% for digitgrass and stargrass and 43% for limpograss. Only 7% of all samples had QI values above 1.6.

There is a place in beef production for forages of different qualities. For example, low-quality forages (QI=1.0) can be fed to animals at maintenance, while high-quality forages should be reserved for animals with higher requirements or lower intake capacity. When the forage being fed does not support desired rates of animal performance, however, supplements of energy and(or) protein must be considered.

Literature Review

In an attempt to understand the effects of supplements upon forage intake, and to determine if our results on bermudagrass (Golding et al, 1976; Moore and Kunkle, 1991) were consistent with other data, an extensive review of the literature was undertaken. A number of reviews of the subject have been published recently (Jarrige et al., 1986; Horn and McCollum, 1987; Osuji, 1987; Cronjé, 1990; Minson, 1990; Lusby and Horn, 1991). None of these reviews attempted, however, to quantify forage and concentrate characteristics that might help to explain the variation in results. Therefore, data on 81 comparisons of forage intake with and without supplementation involving 36 different forages were obtained from 16 publications in the literature or our own unpublished data (Table 3). Forages were limited to grasses or cereal straws. In most cases, the supplements were based on high-starch concentrates such as corn or barley with varying amounts of supplemental protein. Both sheep and cattle were used to obtain the data, but no data on lactating animals were included. Organic matter percentage and digestibility of dry matter or organic matter were used to estimate TDN percentage of forage and TDN intake.

The forage intake change due to feeding concentrate was calculated by subtracting the forage intake when fed alone from the forage intake when fed with concentrate; it was expressed as a percent of body weight (BW) to minimize effects of differences in animal size. A positive intake change indicates that the supplement increased forage intake while a negative intake change indicates a decrease in forage intake due to feeding concentrate (i.e., substitution).

There was a wide range in forage intake change among forages, from a negative 1.48 to a positive .65 percent of BW (Table 4). Examination of the data showed no consistent differences in forage intake change between sheep vs. cattle, or temperate vs. tropical grasses. Florida data were similar to those published by others. Also, there was a wide range in forage quality among all forages as shown by TDN intakes, and percentages of CP and TDN (Table 4). The level of concentrate feeding ranged from .17 to 1.85 percent of BW (Table 4).

It was apparent that there were two distinct groups of forages as indicated by the TDN:CP ratio (Tables 3 and 4). About one-half the forages had a TDN:CP ratio greater than 8, indicative of an imbalance of protein relative to digestible energy. All bermudagrasses had a TDN:CP ratio less than 8 even though CP concentrations were low in some cases. The quality (TDN intake, percentages of CP and TDN) of the forages with high TDN:CP tended to be lower than that of the other forages (Table 4). There was no consistent difference between the two groups with respect to concentrate feeding level, but the average CP percentage of concentrates was higher when forages with high TDN:CP ratios were fed. Those forages with unbalanced TDN:CP ratio (8 or higher) had a smaller average change in intake due to feeding concentrate (-.10 percent of BW) than did those with low TDN:CP ratio (-.50 percent of BW; Table 4).

Regression analysis of the data described in Table 3 was performed in order to determine relationships between change in forage intake and characteristics of forages and concentrates (Tables 5 and 6). The results of the data analyses are discussed below.

TABLE 3. SUMMARY OF EXPERIMENTS USED TO ANALYZE FACTORS AFFECTING FORAGE INTAKE CHANGE (FIC)[a]

Forage			Concentrate				
TDN:CP[b]	Type	TDNI[c]	Type	n	% BW[d]	FIC (%BW)	References
3.2	Bermudagrass	1.94	Corn	1	.92	-.84	Golding, et al., 1976
3.3	Ryegrass	1.29	Barley	3	.62 to 1.74	-1.48 to -.63	Tayler and Wilkinson, 1972
3.6	Timothy/Fescue	1.93	Barley	2	.44 to .88	-.50 to -.27	Forbes et al., 1967
3.9	Ryegrass	1.54	Barley	3	.74 to 1.85	-1.41 to -.71	Tayler and Wilkinson, 1972
4.0	Bermudagrass	1.51	Corn	1	.69	-.31	Golding et al., 1976
4.1	Bermudagrass	1.38	Corn	1	.48	-.20	Jones et al., 1988
4.2	Bermudagrass	1.51	Corn	1	.90	-.48	Moore and Kunkle, 1991
4.4	Bermudagrass	1.26	Corn	1	.73	-.33	Moore and Kunkle, 1991
4.5	Bermudagrass	1.58	Corn	1	.86	-.36	Moore and Kunkle, 1991
4.6	Ryegrass	1.40	Barley	3	.30 to .81	-.40 to -.17	Vadiveloo and Holmes, 1979
4.7	Bermudagrass	1.31	Corn	1	.54	-.31	Golding et al., 1976
4.9	Bermudagrass	1.48	Corn	1	.76	-.42	Moore and Kunkle, 1991
5.1	Bermudagrass	1.56	Corn	1	.87	-.11	Moore and Kunkle, 1991
5.2	Bermudagrass	1.86	Corn	1	.84	-.41	Moore and Kunkle, 1991
5.3	Orchardgrass	1.42	Corn	1	.48	-.23	Jones et al., 1988
5.4	Bermudagrass	1.06	Barley	1	1.03	-.19	Brake et al., 1989
5.4	Bermudagrass	1.06	Corn	1	.93	-.35	Brake et al., 1989
5.4	Ryegrass	1.37	Barley	2	.47 to .90	-.56 to -.33	Vadiveloo and Holmes, 1979
5.6	Bermudagrass	1.00	Corn	1	.50	.16	Golding et al., 1976
5.6	Bermudagrass	1.22	Corn	1	.71	-.61	Moore and Kunkle, 1991
5.9	Bermudagrass	1.08	Corn	1	.77	-.41	Moore and Kunkle, 1991

TABLE 3, CONTINUED

6.0	Bermudagrass	1.28	Corn	1	.86	-.37	Moore and Kunkle, 1991
6.1	Bermudagrass	1.23	Barley	1	1.05	-.39	Brake et al., 1989
6.1	Bermudagrass	1.23	Corn	1	.99	-.61	Brake et al., 1989
6.1	Ryegrass	1.33	Barley	5	.33 to 1.54	-.95 to -.23	McCullough, 1976
6.2	Ryegrass	1.05	Barley	2	.47 to .91	-.45 to -.28	Vadiveloo and Holmes, 1979
6.3	Bermudagrass	1.12	Corn	1	.87	-.26	Moore and Kunkle, 1991
8.1	Orchardgrass	1.17	Mixture	3	.41 to 1.63	-.73 to -.24	Crabtree and Williams, 1971a
8.4	Bluestem	1.17	Sorghum	3	.17 to .66	-.04 to -.11	Vanzant et al., 1990
8.6	Meadow hay	.76	Corn	3	.23 to .69	-.26 to -.03	Sanson and Clanton, 1989
8.6	Ryegrass	1.06	Barley	3	.33 to .95	-.29 to -.05	Vadiveloo and Holmes, 1979
9.5	Barley straw	.46	Mixture	5	.34 to 1.74	-.61 to -.14	Horton and Holmes, 1976
10.3	Orchardgrass	.70	Barley	8	.53 to 1.81	-.27 to .65	Crabtree and Williams, 1971b
10.5	Barley straw	.61	Barley	4	.78 to 1.26	-.53 to -.05	Andrews et al., 1972
10.5	Ryegrass	.89	Barley	3	.33 to 1.03	-.17 to .12	Vadiveloo and Holmes, 1979
10.7	Prairie Hay	1.02	Soybean meal	1	.29	.21	Ovenall et al., 1991
10.7	Prairie Hay	1.02	Middlings	1	.73	-.02	Ovenall et al., 1991
10.7	Prairie Hay	1.02	Corn	1	.73	-.07	Ovenall et al., 1991
10.9	Oat straw	.49	Mixture	3	.41 to 1.63	-.37 to .18	Crabtree and Williams, 1971a
11.2	Meadow hay	.87	Corn	3	.22 to .66	-.21 to .27	Sanson et al., 1990

[a]FIC = change in voluntary forage dry matter intake (% of body weight) due to feeding concentrate.

[b]Total digestible nutrients (TDN, % of dry matter) divided by crude protein (CP, % of dry matter) in forage.

[c]Voluntary TDN intake when forage was fed alone (as % of body weight).

[d]Concentrate fed (% of body weight).

TABLE 4. AVERAGES AND RANGES OF FORAGE INTAKE CHANGE (FIC), FORAGE QUALITY VARIABLES, CONCENTRATE PROTEIN PERCENTAGE AND CONCENTRATE LEVEL

Data Set[a]		n	FIC[b]	Forage				Concentrate	
				TDNI[c]	CP[d]	TDN[e]	TDN:CP[f]	CP[g]	% BW[h]
All	Avg.	81	-.30	1.08	8.7	53.5	7.4	16.9	.83
	Low		-1.48	.46	3.8	39.0	3.2	8.3	.17
	High		.65	1.94	21.0	75.6	11.2	54.0	1.85
TDN:CP>8	Avg.	41	-.10	.80	5.0	48.4	9.8	19.5	.83
	Low		-.73	.46	3.8	39.0	8.1	8.3	.17
	High		.65	1.17	7.8	67.1	11.2	54.0	1.81
TDN:CP<8	Avg.	40	-.50	1.38	12.5	58.7	4.9	14.2	.85
	Low		-1.48	1.00	7.4	41.4	3.2	8.9	.30
	High		.16	1.94	21.0	75.6	6.3	19.4	1.85

[a]See Table 3.
[b]Change in voluntary forage dry matter intake (% of body weight) due to feeding concentrate.
[c]Voluntary total digestible nutrients (TDN) intake when forage was fed alone (% of body weight).
[d]Forage crude protein (% of dry matter).
[e]Forage TDN (% of dry matter).
[f]Forage TDN divided by forage crude protein.
[g]Concentrate crude protein (% of dry matter).
[h]Concentrate fed (% of body weight).

TABLE 5. CORRELATIONS OF FORAGE INTAKE CHANGE[a] WITH FORAGE QUALITY VARIABLES, CONCENTRATE PROTEIN PERCENTAGE AND CONCENTRATE LEVEL

Data Set[b]	n	Forage				Concentrate	
		TDNI[c]	CP[d]	TDN[e]	TDN:CP[f]	CP[g]	% BW[h]
All	81	-.45	-.60	-.33	.62	.37	-.57
TDN/CP>8	41	-	-	-	.29	.57	-.58
TDN/CP<8	40	-	-.41	-	.38	-.47	-.82

[a]Change in voluntary forage dry matter intake (% of body weight) due to feeding concentrate.
[b]See Table 3.
[c]Voluntary total digestible nutrients (TDN) intake when forage was fed alone (% of body weight).
[d]Forage crude protein (% of dry matter).
[e]Forage TDN (% of dry matter).
[f]Forage TDN divided by forage crude protein.
[g]Concentrate crude protein (% of dry matter).
[h]Concentrate fed (% of body weight).

Forages with High TDN:CP Ratios

Intake of some forages with an unbalanced TDN:CP ratio was increased by feeding concentrate, especially when low levels of high-protein concentrates were fed (Table 3). At higher levels of concentrate, however, there tended to be a decrease in forage intake due, perhaps, to a substitution of grain for forage (Tables 5 and 6). Also, there was less increase, or a decrease, in intake of forages of lower TDN:CP ratio, and when concentrates had lower CP percentages.

These observations are consistent with several other published reports. Protein supplementation of Floralta limpograss pasture (Rusland et al., 1988; Holderbaum et al., 1991), a forage with high TDN:CP ratio, increased animal performance. In other studies in Florida of Pensacola bahiagrass (Moore, et al., 1970), Pangola digitgrass (Ventura, et al., 1975) and Suwannee bermudagrass (unpublished) hays, supplemental protein increased forage intake only when TDN:CP ratio was high. When native grass hay (TDN:CP ratio = 8.0) was supplemented with protein, hay intake by cattle was depressed by feeding an additional 2 and 3 kg of corn per day (Chase and Hibberd, 1987). With high TDN:CP digitgrass hays (Fick et al., 1973), small amounts of energy concentrate increased hay intake but larger amounts decreased intake. Additional nitrogen in the form of biuret increased hay intake at both low and high levels of energy supplement.

TABLE 6. EQUATIONS DESCRIBING THE RELATIONSHIPS OF FORAGE INTAKE CHANGE (FIC)[a] WITH FORAGE AND CONCENTRATE CHARACTERISTICS.

Data Set[b]	N	Equation[c]	R^2
All	81	$FIC = -1.01 - .25\ (CONBW)^2 + .17\ (TDN:CP) - .0065\ (TDN:CP)^2 + .0016\ (CONCP)^2$	.75
TDN:CP>8	41	$FIC = -.53 - .16\ (CONBW)^2 + .049\ (TDN:CP) + .00019\ (CONCP)^2$	.67
TDN:CP<8	40	$FIC = -3.4 - .30\ (CONBW)^2 + .91\ (TDN:CP) - .089\ (TDN:CP)^2 + .15\ (CONCP) - .0061\ (CONCP)^2$	.84

[a]Change in voluntary forage dry matter intake (% of body weight) due to feeding concentrate.
[b]See Table 3.
[c]Abbreviations:
CONBW = Concentrate fed as a percent of body weight.
TDN:CP = Forage total digestible nutrients (TDN, % of dry matter) divided by forage crude protein (CP, % of dry matter).
CONCP = Concentrate CP (% of dry matter).

Forages with Low TDN:CP Ratios

In general, when TDN:CP ratio was balanced, the voluntary intake of forage was decreased by feeding concentrate, i.e., "substitution" occurred (Table 3). Also, the extent of substitution tended to be greater with forages of lower TDN:CP ratio and with concentrates of higher CP percentage (Tables 5 and 6). Generally, it has been concluded that substitution is higher with higher quality forages and higher levels of concentrate feeding (Jarrige et al., 1986; Horn and McCollum, 1987; Osuji, 1987; Minson, 1990; Lusby and Horn, 1991). Substitution rates (decrease in forage intake change per unit of concentrate fed) reported for bermudagrass hays were not, however, affected by forage quality (Goetsch et al., 1991; Higgins et al., 1991). When substitution is high, the increase in animal gains due to feeding concentrate may be the same with high as with low levels of supplemental energy (Rittenhouse et al., 1970).

When substitution occurs, it is not possible to meet an animals TDN requirement by just offering an amount of TDN equal to the difference between requirement and intake. The following is an example of how substitution affects the need for supplemental TDN. The 600 lb heifer gaining 1.25 lb/day (Table 1) has a TDN requirement of 10.1 lb/day. If the forage being fed had a QI = 1.3, then expected TDN intake would be 7.3 lb/day, or 2.8 lb/day less than required. Assuming a substitution rate of 50%, forage TDN intake would decrease 2.8 lb/day, and it would require 5.6 lb/day of supplemental TDN in order to meet the requirement of 10.1 lb/day. If the supplement was 80% TDN, 7 lb/day of supplement would be needed to meet the TDN requirement.

OTHER SUPPLEMENTS

Recent reviews (Bates, 1990; Cronjé, 1990; Lusby and Horn, 1991) have discussed the potential of "escape" proteins as supplements to forage. Proteins that are not degraded in the rumen may increase animal performance by providing increased amounts of digestible high-quality protein compared to the protein synthesized by rumen microorganisms. The responses have been somewhat unpredictable, however, and seem to depend upon forage quality (Kunkle, 1990). If the effect of supplemental concentrates upon forage intake is to be predicted accurately, the form of supplemental protein and its rumen degradability must be taken into account.

In addition, recent studies (Lusby and Horn, 1991) show that there may be less depression in intake when energy concentrates consist of highly-digestible fiber rather than starch. Examples of such feeds are soybean hulls, wheat middlings, corn gluten feed and rice bran. Fibrous feeds such as rice hulls, peanut hulls and cottonseed hulls are not highly-digestible, however, and should not be used as sources of energy (Lusby and Horn, 1991). Any attempt to predict the effect of supplement upon forage intake must consider the level of feeds with highly-digestible fiber that are used in the concentrate.

SUMMARY

The samples of grasses submitted to the Florida Extension Forage Testing Program were frequently low in nutrient composition and overall quality. The few samples of higher nutrient composition and quality may have represented less mature forage at the time of harvest for hay. For many samples, CP percentage was lower than that required by growing and lactating cattle. Of the samples submitted, bahiagrass tended to have the lowest quality even though TDN and CP were in balance for most samples. Most bermudagrass hays were of intermediate quality, and their TDN and CP were in balance. High TDN and low CP in many samples of digitgrass, stargrass and limpograss led to a deficiency of protein relative to energy. The low QI of most of the grasses analyzed suggests that low TDN intake may be a major factor limiting animal performance of growing and lactating cattle. In order to meet nutrient requirements of cattle fed or grazing on Florida's improved pasture grasses, supplemental protein and energy would be required in many instances.

The literature shows that responses to supplemental concentrate feeds in terms of animal performance are quite variable depending on how the concentrate changes the intake of forage. Forage intake may either be increased, decreased or unaffected by the feeding of concentrate, and many factors affect the direction and extent of the change. A major factor affecting the change in intake due to feeding concentrate is the TDN:CP ratio of the forage. When TDN:CP ratio is high (>8) then there is a deficiency of protein relative to energy and small amounts of concentrate may increase intake. Larger amounts of concentrate, particularly those containing starch, may counteract the effect of protein and decrease forage intake. When TDN:CP ratio is balanced (<8), however, supplemental concentrate generally decreases forage intake in proportion to the amount of concentrate fed. Factors which modify the effect of concentrate level on forage intake include the TDN:CP ratio of the forage, CP percentage of the concentrate and type of concentrate (e.g., starch vs. highly-digestible fiber, or escape vs. ruminally-degraded protein).

Even though general principles of the effect of concentrates on forage intake are known, there is still much variation that remains unexplained. Quantitative prediction of the effect of supplemental concentrates on forage intake and animal performance is necessary in order to develop accurate and efficient supplementation programs which meet the protein and energy requirements of cattle on forage-based diets. At present, prediction of the effect of concentrates on forage intake may not be accurate. More accurate measures of forage quality and the interactions of forage quality, concentrate level and concentrate type are needed. A more thorough review of the literature followed by specific experiments may provide the necessary data.

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