Balancing Protein and Energy in Forages

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Introduction

Forages consumed by Florida beef cattle vary in quality due to differences in species, maturities, seasons, and management. When quality is low, forages alone may not support desired rates of animal performance. In such cases, it is necessary to supplement with protein and energy. The many combinations of forages and supplements make it difficult to determine the most economical supplementation program. It is necessary to know (1) requirements of the specific animal, (2) quality and composition of the specific forage, and (3) effects of supplements on utilization of that forage. Combining all this information is made easier by well-designed computer programs.

The objectives of this paper are to demonstrate the use of a computer model to (1) balance forage protein and energy with supplements, (2) determine the economic value of forages, and (3) compare costs of different programs for heifer development.

Forage Quality and Supplementation

Forage quality information is available from the Florida Forage Testing Program conducted by the Cooperative Extension Service and the laboratory at the Range Cattle Research and Education Center in Ona, Florida. That program reports forage crude protein (CP) and total digestible nutrient (TDN) concentrations. In addition, the report includes quality index (QI) which is an overall estimate of forage quality that includes voluntary forage intake as well as TDN. In effect, QI measures the voluntary intake of TDN above maintenance. When forages are fed without supplemental energy or protein, QI is related to the gain of growing cattle. When QI=1.0 the intake of TDN just meets the maintenance requirement, and when QI=1.8 average daily gains (ADG) are 1.3 lb for steers and 1.1 lb for heifers. Changes in voluntary intake do not always parallel changes in CP and TDN, so QI includes more information on overall forage quality than CP and TDN.

The authors have analyzed data from forage supplementation studies conducted over the past 30 years (Moore and Kunkle, 1995). Supplements generally (but not always) improved animal performance. In many studies, performance was not increased as much as was expected from the amount of supplement fed. In a few studies, however, performance increased more than was expected.

The reasons for the unexpected effects of supplements on animal performance are that forage intake and TDN may either be increased or decreased. The effects on intake and TDN depend on the quality and composition of the forage, as well as the composition and amount of the supplement. A major factor affecting the response to supplementation is the ratio of TDN to CP in forage. When the TDN:CP ratio of a forage is greater than 7, there is a deficit of protein relative to available energy. In many low-quality forages TDN:CP is greater than 7, and voluntary intake is depressed. In such cases, small amounts of supplement (up to .5% of body weight) will increase intake, and TDN of the forage plus concentrate ration will be higher than expected. When forage TDN:CP is less than 7 (no deficit of protein), and large amounts of supplement are fed (more than .8% of body weight), voluntary forage intake, TDN, and animal performance are generally less than expected.

Equations to predict effects of supplements on forage intake and TDN concentrations in mixed rations have been developed using the data set described above. These equations are used in a computer model that calculates the amount of supplement required to achieve a desired rate of gain with growing animals (Moore and Kunkle, 1995). Inputs to the model include type and weight of animal, forage QI, CP and TDN, and supplement CP and TDN. Model outputs include the amount of supplement required, the adjusted voluntary forage intake, and CP and TDN of the total ration. This model is unique in that it considers some of the interactions ("associative effects") between forage quality and supplements that affect forage intake and digestibility.

Heifer Development Programs

The model described above was used to simulate several programs to develop heifers to calve at two years of age. It was assumed that the heifers weighed 450 lb at weaning and gained an average of 1.1 lb/day to reach a breeding weight of 650 lb in 180 days (Kunkle et al., 1996).

Five programs using three forages were compared to a high-concentrate program where a complete ration was fed to meet the requirements for a continuous ADG of 1.1 lb (Table 1). Forage and concentrate intakes were computed over six 30-day periods and animal weights were recalculated every 30 days. All programs gave the same final weight after 180 days. It is assumed that all rations met requirements for minerals and vitamins, and were palatable. In order to avoid a deficit of protein relative to energy, supplemental CP was adjusted so that all rations were formulated to TDN:CP ratios less than 6.

The five forage programs were as follows:

1) **Forage A (QI=1.80) fed alone.** The voluntary TDN intake of this forage was adequate to achieve an ADG of 1.1 lb without supplement. The TDN:CP ratio of the forage alone was less than 6, indicating adequacy of protein relative to available energy.

2) **Forage B (QI=1.45) plus supplement for 1.1 lb/day.** The voluntary TDN intake of this forage fed alone was inadequate to meet requirements for 1.1 lb ADG. The model was used to determine the intake of supplement required to support a continuous ADG of 1.1 lb for 180 days. Decreases in forage intake and digestibility were taken into consideration. The supplement needed only 9% CP (DM basis) to keep the TDN:CP ratio of the ration below 6.

3) **Forage C (QI=1.10) plus supplement for 1.1 lb/day.** With this forage, a large amount of supplement was required to meet TDN requirements for 1.1 lb ADG. In addition, supplemental CP had to be increased to 14% (DM basis) to keep the TDN:CP ratio of the ration below 6.

4) **Forage B (QI=1.45) fed alone for 90 days then supplemented.** The intake of forage alone supported an ADG of only .66 lb. The TDN:CP ratio of the forage was adequate. During the last 90 days, an ADG of 1.55 lb was required to meet the target weight of 650 lb in 180 days. This rate of gain required a large amount of supplement, and the model required a supplemental CP of 18% in order to stay within limitations set by the data base. As a result, the TDN:CP ratio of the ration was 4.4, indicating an excess of protein relative to available energy. Note that, due to supplementation, forage intake during the last 90 days was 3.4 lb per day less than it was during the first 90 days.

5) **Forage C (QI=1.10) supplemented for 90 days, then fed high-concentrate ration.** The ADG was limited to .17 lb by the forage QI.

The TDN:CP ratio of this forage was 7.4, so it was supplemented with .5 lb/day of cottonseed meal (47% CP, DM basis) to correct the protein deficit. For the last 90 days, an ADG of 2.0 lb was required to reach 650 lb body weight in 180 days. The model would not, however, permit supplementing this forage with enough concentrate to achieve that ADG. Therefore, the complete high-concentrate ration was fed alone for the last 90 days (and is referred to as Program 6).

Economic Value of Forages

Moore and Kunkle (1995) showed that the economic value of forages could be estimated in relation to the cost of complete high-concentrate rations. Initially, the cost of a high-concentrate ration for a particular rate of gain is calculated. Next, the cost of supplement needed to achieve the same rate of gain with a particular forage is calculated. Then, a Concentrate Equivalent Value (CEV) on a dry matter (DM) basis is calculated as follows:

$$CEV = (TC - SC) / FDMI$$

where:

CEV = $/lb of DM

TC = total cost of gain, $
= cost of high-concentrate ration, $
= high-concentrate intake, lb × $/lb

SC = cost of supplement, $
= supplement intake, lb × $/lb

FDMI = forage DM intake, lb

The difference between TC and SC is the cost of the forage portion of the ration when the total feed cost is the same for the forage-plus-supplement ration as for the high-concentrate ration. Therefore, if the price of forage equaled its CEV, feed costs would be the same for both the forage-plus-supplement ration and the high-concentrate ration.

Intakes of concentrate, supplement, and forage may be expressed either on a daily basis or as total intakes, as long as they are all expressed the same. Prices per lb of concentrates and supplements should be calculated according to their specific formulations. The CEVs can be converted from $/lb of DM to $/ton of air-dried forage.

Programs 1, 2 and 3, giving continuous ADG of 1.1 lb, were used to calculate CEV of the three forages used in the feeding programs (Table 2). Commodity prices of January 1998, were used to calculate the prices of the high-concentrate ration and supplements.

These calculations show a definite difference in economic value among the three forages, in terms of CEV; the higher the QI, the higher the value. If the actual price of a forage is less than its CEV, then it would be economically advantageous to use the forage. On the other hand, if the actual price is equal to or higher than the CEV, feeding a limited amount of high-concentrate ration would be recommended.

Costs of Development Programs

Costs of heifer development were calculated for the six programs using a range of forage prices from $40 to $100/ton as fed (Table 3). Forage prices used in the calculations covered the approximate range of CEVs for the three forages used in these simulations.

The cost of feeding only the high-concentrate ration for 200 lb of gain (Program 6) was $138, or $.69 per pound of gain. In Table 3, total cost values are in bold face when the cost of a forage program was less than the cost of Program 6. Forage Program 3 (QI=1.10, supplemented for continuous ADG=1.1 lb) was more costly than Program 6 even at $40/ton. Program 3 would have had the same cost as Program 6 if its CEV of $36/ton had been used.

Within all forage price ranges, Program 1 (QI=1.8, fed alone) was less costly and Program 3 the most costly. The costs of other forage programs varied in relative ranking depending on forage price. When supplemented to give ADG=1.1 lb, costs were greater with Forage C (QI=1.10) than with Forage B (QI=1.45).

With Forages B and C, costs of supplementation programs were inconsistent. With forage B (QI=1.45) it was less costly to supplement for a continuous ADG of 1.1 lb (Program 2) than to feed the forage alone for 90 days followed by supplementation (Program 4). With forage C (QI=1.10), it was less costly to supplement with cottonseed meal for 90 days, then feed the high-concentrate ration (Program 5), than to supplement for continuous gain (Program 3). Program 5 may, however, be undesirable because of the possibility of excessive body condition at breeding and digestive disorders.

Costs of all programs were influenced by forage prices. When prices were $80 or $100 per ton, only Program 1 (QI=1.8 fed alone) was less costly than the high-concentrate ration. When prices were $40 and $60/ton, however, all programs except Program 3 were less costly than Program 6. Furthermore, there was a wider range in costs among programs as forage prices declined. When forage price was $100/ton, the difference between the costs of Programs 1 and 3 was $53, compared to a difference of $87 when forage price was $40/ton.

Implications

This paper describes six heifer development programs using three forages differing in quality. The data were generated using a computer model that includes associative effects between forages and supplements. Only one type of program was simulated, 200 lb of gain in 180 days. Simulations of other levels of performance and forage qualities may give different results. If the assumptions underlying this model are correct, then the simulations support the following:

1) Forage quality has a major impact on the economic value of forages for livestock production. Generally, high-quality forage costs more to produce than low-quality forage, and a higher price is required in order to make a profit. High-quality forage may be worth a

Table 1. Six feeding programs for growing heifers from 450 lb to 650 lb in 180 days

Program	Forage (QI[a])	Days	Concentrate	Daily gain, lb	Daily Intake, lb[b]		Total Feed, lb[b]	
					Forage	Concentrate	Forage	Concentrate
1	A (1.80)[c]	1 to 180	None	1.10	13.3	0	2390	0
2	B (1.45)[d]	1 to 180	9% CP supplement	1.10	12.0	2.5	2170	450
3	C (1.10)[e]	1 to 180	14% CP supplement	1.10	7.6	6.9	1370	1240
4	B (1.45)	1 to 90	none	.66	11.7	0	1050	0
		91 to 180	18% CP supplement	1.55	8.3	7.9	750	710
5	C (1.10)	1 to 90	47% CP supplement	.17	10.3	.5	930	45
		91 to 180	high-concentrate ration	2.03	0	13.1	0	1180
6	none	1 to 180	high-concentrate ration	1.10	0	9.5	0	1710

[a]QI = Quality Index.
[b]Feed intakes on dry-matter basis.
[c]CP = 14%, TDN = 60%, dry-matter basis.
[d]CP = 10%, TDN = 56%, dry-matter basis.
[e]CP = 7%, TDN = 52%, dry-matter basis.

high price for livestock production, but no forage is worth more than its Concentrate Equivalent Value.

2) Total cost of heifer development is less with a high-quality forage (QI=1.80) fed alone than with forages of lower quality that must be supplemented. A forage program will be less costly than a high-concentrate program when the price of the forage is less than its Concentrate Equivalent Value. When forage quality is low and forage prices are high, forage programs can be more costly than a high-concentrate program.

References

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Table 2. Concentrate Equivalent Value (CEV) of three forages in comparison to a high-concentrate ration for growing heifers from 450 lb to 650 lb in 180 days

Program	Forage (QI)[a]	Concentrate	Total Feed, lb[b] Forage	Total Feed, lb[b] Concentrate	Concentrate Cost, $[c]	Forage Cost, $[d]	CEV, $/ton as fed[e]
1	A (1.80)	none	2390	0	0	129	97
2	B (1.45)	9% CP supplement	2170	450	35	94	79
3	C (1.10)	14% CP supplement	1370	1240	102	27	36
6	none	high-concentrate ration	0	1710	129		

[a]QI = Quality Index.
[b]Feed intake on dry-matter basis; assume all feeds are 90% dry matter as fed.
[c]Prices of concentrates per ton as fed: 9% CP = $137, 14% CP = $148, high-concentrate ration = $136.
[d]Difference between total feed cost ($129) and supplement cost.
[e]Forage cost divided by forage intake, corrected to 90% dry matter as fed.

Table 3. Effect of forage price on total cost of five forage programs in comparison to a high-concentrate ration for growing heifers from 450 lb to 650 lb in 180 days

Program	Forage (QI)[a]	Concentrate	Feed Cost, $ Forage[b]	Feed Cost, $ Concentrate[c]	Feed Cost, $ Total	Feeding Cost, $[d]	Total Cost, $[e]
6	none	high-concentrate ration	0	129	129	9	138
Forage price = $100 per ton as fed							
1	A (1.80)	none	133	0	133	0	**133**
2	B (1.45)	9% CP supplement	120	34	154	9	163
3	C (1.10)	14% CP supplement	76	101	177	9	186
4	B (1.45)	none, then 18% CP supplement	100	61	161	5	166
5	C (1.10)	47% CP, then high-concentrate	52	94	146	9	155
Forage price = $80 per ton as fed							
1	A (1.80)	none	106	0	106	0	**106**
2	B (1.45)	9% CP supplement	96	34	130	9	139
3	C (1.10)	14% CP supplement	61	101	162	9	171
4	B (1.45)	none, then 18% CP supplement	80	61	141	5	146
5	C (1.10)	47% CP, then high-concentrate	41	94	135	9	144
Forage price = $60 per ton as fed							
1	A (1.80)	none	80	0	80	0	**80**
2	B (1.45)	9% CP supplement	72	34	106	9	**115**
3	C (1.10)	14% CP supplement	46	101	147	9	156
4	B (1.45)	none, then 18% CP supp.	60	61	121	5	**126**
5	C (1.10)	47% CP, then high-conc.	31	94	125	9	**134**
Forage price = $40 per ton as fed							
1	A (1.80)	none	53	0	53	0	**53**
2	B (1.45)	9% CP supplement	48	34	82	9	**91**
3	C (1.10)	14% CP supplement	30	101	131	9	140
4	B (1.45)	none, then 18% CP supplement	40	61	101	5	**106**
5	C (1.10)	47% CP, then high-concentrate	21	94	115	9	**124**

[a]QI = Quality Index.
[b]Forage dry matter intake from Table 2 times forage price, assume 90% dry matter as fed.
[c]Concentrate dry matter intake from Table 2 times concentrate price: 9% CP = $137, 14% CP = $148, 18% CP = $156, 47% CP = $195, high-concentrate ration = $136 per ton as fed; assume 90% dry matter as fed.
[d]Assume $.05 per day when feeding concentrate.
[e]Costs in bold face are less than costs of Program 6, the high-concentrate ration.

Notes: