EFFECTS OF FORAGE QUALITY RESTRICTIONS ON OPTIMAL PRODUCTION SYSTEMS DETERMINED BY LINEAR PROGRAMMING*

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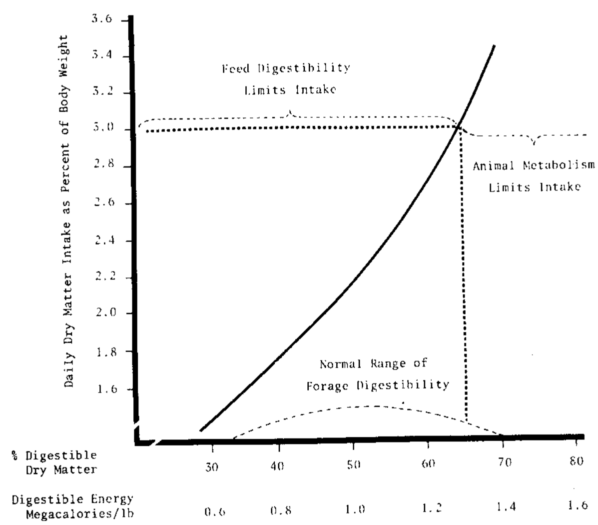
INTRODUCTION

Due to changing feed price relationships for beef production, it is anticipated that linear programming (LP) will be used to develop optimal feeding strategies for cow-calf operations in the South. An important relationship between forage quality and forage intake has been ignored in previous LP analyses [1, 3, 4, 6, 7, 8, 9]. Forage quality and cows' intake of it are inversely related; i.e., as forage quality decreases with maturity, a cow's or calf's consumption of a particular forage must increase to continue meeting the animal's nutritional requirements. However, as the quality of forage decreases, digestibility decreases, and the animal's maximum intake capacity of that forage decreases (Figure 1).[1] It is hypothesized that consideration of intake restrictions will change the optimal LP forage production system, livestock grazing system or supplemental feeding strategies when forages are an important nutrient source.

As forage quality declines, cow intake restrictions become more critical. Just how critical depends on weaning weights of calves, timing of the calving period within the year, and quality and quantity characteristics of alternative forages and supplemental feeds.

The principal objectives of this study were to illustrate a method of including forage intake restrictions in an LP model and to determine the impact by intake restrictions on an optimal LP solution.



[a]Data presented indicate the upper limits of dry matter consumption possible where cattle are receiving a balanced diet. Dry matter intake will be considerably less than indicated limits where nutrients such as protein, phosphorous or vitamin A are deficient [2, 4].

FIGURE 1. RELATIONSHIP BETWEEN PERCENT DIGESTIBLE DRY MATTER AND DAILY DRY MATTER INTAKE[a]

PROCEDURES

The LP model for considering intake restrictions is specified in Table 1. Monthly estimates were made

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[1] Additional details concerning development of Figure 1 can be obtained from Dr. Dennis B. Herd, co-author. This figure is assumed to generally apply to cows as well as calves.

TABLE 1. SPECIFICATIONS OF A LINEAR PROGRAMMING MODEL FOR CONSIDERING LIVESTOCK RESTRICTIONS[a]

Constraint	Forage activities[b] A	Forage activities[b] B	Livestock Activities: Cow consumption, Forage A 1	2	N	Forage B 1	2	N	Calf consumption, Forage A 1	2	N	Forage B 1	2	N	Cow and calf requirement	Relationship	RHS
Objective	-Y	-Y[c]													R[d]		
Acres	1	1														L[e]	S
Forage A production																	
Sub-period 1	-P[f]		T[g]						T							L	0
Sub-period 2	-P			T						T						L	0
Sub-period N[h]	-P				T						T					L	0
Forage B production																	
Sub-period 1		-P				T						T				L	0
Sub-period 2		-P					T						T			L	0
Sub-period N		-P						T						T		L	0
Nutrients for cows																	
Sub-period 1			-M[i]			-M									E[j]	L	0
Sub-period 2				-M			-M								E	L	0
Sub-period N					-M			-M							E	L	0
Nutrients for calves																	
Sub-period 1									-M			-M			E	L	0
Sub-period 2										-M			-M		E	L	0
Sub-period N											-M			-M	E	L	0
Cow intake restriction																	
Sub-period 1			1			1									-1	L	0
Sub-period 2				1			1								-1	L	0
Sub-period N					1			1							-1	L	0
Calf intake restriction																	
Sub-period 1									1			1			-1	L	0
Sub-period 2										1			1		-1	L	0
Sub-period N											1			1	-1	L	0

[a]Lower block represents critical specifications for restricting animal intake. These restrictions prevent the cow or calf from exceeding its consumption capacity during the specified subtime period to meet nutritional needs. Thus, an animal must meet its requirements from the forage, supplemental feed or combination in a given period of time, and with a given intake capacity.

[b]Each forage is considered as a separate activity. Supplemental feed would be included in the model in a similar manner as forages.

[c]Y represents cost of producing the forage.

[d]R represents net revenue of the cow-calf enterprise excluding forage costs.

[e]L represents a less than or equal constraint.

[f]P represents production of air dry forage.

[g]T represents the maximum consumption of an air dry quantity of a given forage or supplemental feed during the specified time period.

[h]N represents the number of subperiods within a given time period.

[i]M represents the nutrients provided by the animal's maximum monthly intake. The nutrients are megacalories of energy or pounds of protein, and separate rows would be used for each.

[j]E represents the minimum nutrients required by the cow or calf. The nutrients are megacalories of energy or pounds of protein and separate rows would be used for each.

of the digestible dry matter for each forage and supplemental feed used in the model. With this variable and knowledge of the animal's size, the maximum monthly intake of any forage or feed was estimated using Figure 1. The maximum monthly intake was expressed as pounds of air dry forage or supplemental feed. Crude protein and digestible energy ("M" values in Table 1) derived from this maximum consumption of forages and/or supplemental feed ("T" values in Table 1) were used to meet the animal's monthly nutritional requirements ("E" values in Table 1). Maximum consumption of forage or feed for a specified time period represented an additional production restraint to total megacalories or pounds of protein produced from an acre. The intake restrictions (lower area, Table 1) allow any combination of forages or supplemental feeds to meet livestock requirements within a specified period of time.[2]

Livestock requirements were expressed as monthly estimates of pounds of crude protein and megacalories of digestible energy. The livestock requirements were a function of the size of the cow, the rate of calf gain, total calf gain and cow weight gains and losses. The cow and her calf's monthly nutritional requirements were separated to observe effect of the intake restriction on each of them.

Activities in the model included production of

[2]Costs of forage production and supplemental feeds are considered in the objective function of the model.

weaned beef calves which had available for consumption (1) native bluestem range, (2) coastal bermudagrass, (3) coastal bermudagrass overseeded with ryegrass and (4) supplemental feed. The calves were born in October and sold in May. Supplemental feeds included coastal bermuda hay, grain sorghum and 41 percent cottonseed meal. Alternative forage combinations were considered to be feasible in the model by assuming cows could be rotated between pastures and supplemental feed or high quality forages could be provided to calves via a creep feeder or by creep grazing.[3]

The ratio of native rangeland to improved pasture was fixed at 3:1. Native forage could be utilized during the time of growth or transferred (with penalty) to other time periods. Coastal bermudagrass was assumed to be fertilized with 75:25:25 pounds/acre (nitrogen, phosphorous and potassium). Coastal bermudagrass, overseeded with ryegrass, available for winter forage consumption was assumed to be fertilized with 250:80:80 pounds/acre of nitrogen, phosphorous and potassium, respectively.

Forage and cow-calf activities were budgeted with cost, forage production and quality estimates considered as representative of producers in the central Texas area with annual rainfall of 32 or more inches. The objective function was specified to maximize profits from sale of weaned calves. Restrictions other than intake capacity included rangeland and improved pasture acreage.[4]

RESULTS

When intake restrictions were included in the model for all forage alternatives, a cow's ration was not significantly changed from a nonrestricted LP solution. As fertilizer rates decreased per acre, intake restrictions began to affect composition of the diet; i.e., hay consumption decreased slightly and cottonseed meal increased slightly.

Intake restrictions had a larger impact on supplemental feed in the diet of unweaned calves when the forage program consisted of native rangeland and Coastal bermudagrass fertilized at the 75-25-25 rate (Table 2). Hay was reduced 362 pounds, but was replaced with 208 pounds of grain sorghum and 31 pounds of cottonseed meal per calf (Table 2).

TABLE 2. THE EFFECT OF INTAKE RESTRICTIONS ON THE COMPOSITION OF FEED RATIONS OF UNWEANED CALVES ON NATIVE FORAGE AND COASTAL BERMUDAGRASS FERTILIZED AT A LOW RATE, HEAVY CALVES[a]

Source of Nutrients	Unit	Optimal Diet Composition Per Calf[b]					
		Jan.	Feb.	Mar.	April	May	Total
Coastal	days						
Restricted		0	0	6	14	30	50
Non-restricted		0	0	6	13	21	40
Native	days						
Restricted		0	0	24	16	0	40
Non-restricted		0	0	24	17	9	50
Hay	lbs						
Restricted		84	106	0	0	0	190
Non-restricted		195	357	0	0	0	552
Grain Sorghum	lbs						
Restricted		47	106	0	0	55	208
Non-restricted		0	0	0	0	0	0
41% Cottonseed Meal	lbs						
Restricted		42	37	57	32	0	168
Non-restricted		33	15	57	32	0	137

[a]Coastal was fertilized at the rate of 75:25:25 of N, P and K, respectively.

[b]Calf requirements were based on average production of 528 pounds of calf per cow. The calf was born in October and sold at the end of May.

The influence of intake restrictions on composition of nonweaned calves' diets increased as forage quality was improved by overseeding Coastal bermudagrass with ryegrass in October for winter forage production, and applying 250-80-80 pounds of N, P and K, respectively. However, the effect was less than when the forage was of lower quality; i.e., use of the 72:25:25 N, P and K fertilizer program. The principal differences occurred during April and May, when 74 and 50 pounds of grain sorghum were required to supplement the unweaned calves' rations.

Increasing the quality of the cow-calf ration became necessary only during low-quality forage periods and/or as a result of noncoordinated forage growth and cow-calf nutritional requirement cycles during the year. As the soil fertility level and forage quality declined, intake restrictions had greater impact on ration and production cost. Added

[3]These practices are currently being carried out by some producers in Central Texas.

[4]The number of rows increases significantly when intake restrictions are included in the model. Number of rows depends on both number of subperiods within a year and number of forage and livestock alternatives in the model. Models for this study contained approximately 150 rows and 160 columns. The models were solved in three minutes or less. Depending on forage growth characteristics, the number of subperiods could likely be less than 12 and greater than five and still provide reasonably good estimates.

production costs were $7.89 per cow for the lower soil fertility program and $5.31 per animal for the higher soil fertility and winter forage program. These increased production costs were attributed to increased use of grain sorghum and cottonseed meal and reduced use of hay and standing forage by cows and calves.

SUMMARY AND CONCLUSIONS

A linear programming model was developed for the purpose of incorporating intake restrictions and evaluating the impact of these restrictions on optimal cow-calf production strategies. Comparisons were made for a cow-calf program in South Central Texas that utilized alternative improved forage programs (two soil fertility levels) and native bluestem rangeland.

Intake restrictions were found to have larger impact on optimal livestock rations as quality of forages decreased. As this occurred, supplemental feed concentrates in the ration were significantly higher than when the model was specified without intake restrictions. Greater use of supplemental feed in the ration increased production costs from approximately $5.00 to $8.00 per cow, depending on soil fertility levels.

It is recommended that intake restrictions be considered when developing linear programming models to evaluate alternative forages utilized in livestock production.

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