Nutrition Management, Nitrogen Efficiency, and Income Over Feed Cost on Dairy Farms in Costa Rica

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ABSTRACT

Twenty-two dairy farms in two ecologically different zones were visited repeatedly during the dry and wet seasons of 1995 to evaluate nutrition and pasture management, N efficiency on the farm, and income over feed costs with the use of a management support program. Excessive amounts of concentrates were fed, and no differences in amounts were detected between seasons. Utilization of forage was consequently low and even negligible on some farms. The amount of crude protein in the diet was generally too high. The removal of N from the farms via milk and culling represented 27 and 31% of the total N input for the two regions, respectively. The income over feed costs per cow ($3.04 and $1.84/d, respectively) was considered reasonable despite the high amount of concentrates.
(**Key words**: concentrates, income over feed cost, nitrogen, Costa Rica)

Abbreviation key: **DC** = dry cows, **DE** = digestible energy, **IOFC** = income over feed costs, **LC** = lactating cows, **SC** = San Carlos, **VAMPP** = Veterinary Automated Management and Production Control Program, **YS** = young stock.

INTRODUCTION

Appropriate and definitive standards for nutrition and pasture management are indispensable for the dairy farm. In tropical countries, these standards are usually lacking because of varying climatological conditions, varying forage availability, and limited research experience. In an earlier study of a milk producing region in Costa Rica (19), a significant variation in the amount of concentrates and an excess of N in the diet was found.

Nitrogen purchased through fertilizers and concentrates is an essential but costly nutrient on dairy farms. Ecological stability on the farm can be evaluated using the balance of the annual input and output of nutrients at the farm or regional level. Nitrogen balance can be monitored easily by recording purchased and sold N, which helps to improve N efficiency. However, such a N balance ignores available soil reserves, accumulations through biological fixation, and losses through volatilization, run-off, dinitrification, and leaching (9).

A simple model to evaluate nutrition and pasture management on dairy farms was developed (5). The present study was carried out to evaluate nutrition and pasture management, to quantify the N efficiency on the farm, and to indicate reasons for major economic losses.

MATERIALS AND METHODS

Farms in the Survey

The farms were located on the slopes of the volcano Poás (n = 11) and in the lowland of San Carlos (**SC**) (n = 11), both of which are important milk production areas in Costa Rica. In Poás, pure *Bos taurus* breeds grazed Kikuyu (*Pennisetum clandestinum*) pasture in a humid temperate climate. In SC, pure *B. taurus* and crosses of *B. taurus* and *Bos indicus* breeds grazed pastures of *Brachiaria* spp. and African Stargrass (*Cynodon nlemfuensis*) in a humid hot climate.

The average farm consisted of 84 ha of which 40 ha were dedicated to lactating cows (**LC**); the remainder was dedicated to young stock (**YS**) and dry cows (**DC**). On several farms, YS and DC grazed together for at least part of the year. The LC were milked twice daily during which time concentrates and byproducts were fed. In Poás, farms were larger, and daily milk production per cow, number of cows in lactation, and total farm production were higher than those in SC (Table 1). Between milkings, LC in both regions rotationally grazed nearby paddocks year-round. In Poás, 60 paddocks ($\overline{X}$ = 0.8 ha each) were grazed in 30 d, and, in SC, 8 paddocks ($\overline{X}$ = 3.6 ha each) were grazed in 32 d. The mean stocking rates did not differ greatly between the two regions, but the variation among individual farms was great. The high

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TABLE 1. Mean area, stocking rate, and milk production of dairy farms in two regions of Costa Rica.

	Farms		
	All	Poás	San Carlos
Farm area, ha			
Lactating cows	40	48[a] (4–145)[1]	29[b] (9–60)
Young stock and dry cows	45	67[a] (1–385)	18[b] (1–50)
Total herd	84	115[a] (5–470)	47[b] (10–110)
Stocking rate, AU[2]/ha			
Lactating cows	3.6	3.4 (0.9–14.6)	3.7 (1.9–8.8)
Young stock and dry cows	7.6	6.9 (0.5–57.5)	8.5 (1.4–36.2)
Total herd	4.1	4.0 (0.9–20.6)	4.3 (1.7–8.3)
Milk production			
Cows in lactation, no.	74	80[a]	67[b]
Milk per cow, kg/d	17.8	21.7[a]	13.0[b]
Milk per farm, kg/d	1302	1648[a]	879[b]
Milk fat, %	3.6	3.6	3.5
4% FCM per farm, kg/d	1181	1504[a]	785[b]

[a,b]Means within rows with different superscripts differ ($P < 0.05$).

[1]Numbers in parentheses represent ranges.

[2]Animal unit = 400 kg of BW.

stocking rates for YS and DC on some farms can be explained by the use of a cut and carry system.

Data Collection and Analyses

The farms participated in the Veterinary Automated Management and Production Control Program (**VAMPP**) in which individual milk production, reproduction, changes in herd structure, BW data, and other information were entered and stored at 2-wk intervals (8).

The VAMPP contains a pasture and nutrition module to evaluate management at the herd level (5). This module uses digestible energy (**DE**) because data on DE is widely available in Central America. The module calculates the intake of DE from pasture as follows: DE requirements – DE from concentrates. This method was recommended by several researchers (7, 12). The formula depends neither on the type and quality of the forage consumed nor on the amount of substitution of forage by concentrate. Requirements for DM, DE, and CP were based on NRC (13) recommendations.

Farm visits, data collection, and analyses took place every 2 mo in 1995: twice during the dry season (January to April) and four times during the wet season (May to December). Data on the amount and price of concentrates, fertilizers, milk production, milk fat, and milk protein were derived from weekly pay slips and invoices from the cooperatives. Data on the composition of commercial concentrates and fertilizers were obtained from the labels or from the database of other concentrates (e.g., green bananas, brewers grain, molasses) that were incorporated in the module [based on Vargas (20)]. In vitro digestibility and N concentration of forages were obtained from analyses of grab samples, simulated grazing bites, or from default values present in the module for several combinations of forage types and amounts of N fertilization.

Collected data were analyzed by the pasture and nutrition module of VAMPP. The output was transferred to the Panacea database program (15) for statistical analyses. Farm inventory and N efficiency data were analyzed within each region with one-way ANOVA; season was the main effect. All other data were analyzed with ANOVA; region, season, and the interaction of region and season were included in the model. No interactions were observed except for CP balance. Variables used in multiple regression analyses were daily milk production (dependent) versus amount of supplements in the diet (independent) and income over feed costs (**IOFC**) (dependent) versus daily milk production, amount of supplements in the diet, and stocking rate (independent). Differences were considered significant at $P < 0.05$.

Definition of N in Products

The N efficiency on the farm was calculated as N output/N input. The N input consisted of N purchased as fertilizers and concentrates and the amount of N deposited from the atmosphere for which a fixed amount of 8 kg/ha was used (11). The N output consisted of the N that was removed from the farm through the sale of cattle and milk.

The number of cattle that had been sold was obtained from the VAMPP database from 1994 to 1995 and was divided by 2. Cattle that died were excluded because they were considered to have remained on the farm. Table 2 assumes that other breeds and YS had the same tissue composition as did adult Holsteins (3).

RESULTS AND DISCUSSION

Milk Production

Milk production per LC in Poás and SC differed (21.7 vs. 13.0 kg/d, respectively; $P < 0.05$). In Poás,

TABLE 2. Live BW[1] and total amount of N in tissues[2] of dairy cattle used in the study.

	Adults		Young stock[3]	
Breed	BW	Tissue N	BW	Tissue N
	(kg)	(kg per animal)	(kg)	(kg per animal)
Holstein[4]	550	13.6	255	6.3
Holstein, Pardo Swiss, Guernsey, or	500	12.4	230	5.7
Jersey	380	9.4	175	4.3
Bos taurus × *Bos indicus*	450	11.1	210	5.2

[1]The software verified the existence of BW data; if not available, default values were used (5).

[2]Based on the study of Andrew et al. (3).

[3]Birth to 24 mo of age.

[4]In Poás only.

the higher milk production per cow and the higher number of LC resulted in a higher milk production per farm (Table 1). Milk production was not affected by season. The mean milk fat percentage per farm ranged from 2.9 to 3.4 for Holsteins and from 4.2 to 4.4 for Jerseys, but no differences between regions and seasons were found.

Amount of Supplementation

The mean amount of concentrates fed per LC was 10.5 kg of DM/d in Poás and 5.1 kg of DM/d in SC (Table 3). The variation among farms was high. On 2 farms in Poás, the supplement satisfied 100% of the DE requirements for LC, YS, and DC (Table 4). One of these farms had an exceptionally high stocking rate because 36 LC plus YS and DC were kept on 5 ha, and feed products, including mostly forage, were purchased. The other farm had abundant but underutilized forages. The mean amount of DE obtained from forage by LC was 33 and 56% of the diet in Poás and SC, respectively. No differences in the amounts of supplementation between the dry and wet seasons were observed.

The ratio of concentrate to milk for LC in Poás was 1:2.1. A similar ratio was reported for dairy farms in Louisiana: 8.08 kg of supplements for 16.5 kg of milk per LC (2). Those researchers concluded that, on average, use of concentrates was excessive because the top 10% of the farms used 8.0 kg of concentrate to produce 21.5 kg of milk (ratio of concentrate to milk: 1:2.7). Although high producing cows can have a ratio of 1:2, the mean ratio of concentrate to milk on several farms should be below that. The ratio of 1:2.5 for SC also seemed high considering the relatively low milk production (13.0 kg/d per LC). No differences in the ratio of concentrate to milk were observed between the dry and wet seasons.

TABLE 3. Daily diet for lactating cows.

	Requirements[1]		Supplements[2]		Pasture[3]	
	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
All farms						
DM, kg/d	17.1	2.2	8.1	4.7	9.0	4.0
DE, Mcal/d	43.9	7.4	25.4	13.3	18.5	7.8
CP, kg/d	2.2	0.6	1.6	0.8	1.1	0.6
Poás						
DM, kg/d	18.1	1.9	10.5	4.6	7.6	3.7
DE, Mcal/d	49.1	5.6	32.8	11.9	16.3	7.8
CP, kg/d	2.7	0.3	2.1	0.7	1.3	0.6
San Carlos						
DM, kg/d	15.8	1.8	5.1	2.8	10.7	3.7
DE, Mcal/d	37.5	3.3	16.4	8.8	21.1	6.9
CP, kg/d	1.6	0.3	1.0	0.6	0.9	0.4

[1]Estimated based on NRC (13) recommendations.

[2]Estimated from labels of commercial concentrates and from Vargas (20).

[3]Calculated as digestible energy (DE) from pasture = DE requirements – DE from supplements.

TABLE 4. Digestible energy and CP in supplements[1] fed to dairy cattle in two regions of Costa Rica.

	Lactating cows	YS and DC[2]	Total herd
	(% of requirements[3])		
Digestible energy			
All farms	58	36	49
	(16–100)[4]	(4–100)	(13–100)
Poás	67	44	60
	(40–100)	(20–100)	(38–100)
San Carlos	44	27	37
CP	(16–89)	(4–87)	(13–78)
All farms	56	34	46
	(15–117)	(8–108)	(10–116)
Poás	63	46	58
	(36–111)	(20–108)	(26–116)
San Carlos	48	23	39
	(15–117)	(8–87)	(10–104)

[1]Estimated from labels of commercial concentrates and from Vargas (20).

[2]Young stock and dry cows.

[3]Estimated based on NRC (13) recommendations.

[4]Numbers in parentheses represent ranges.

For all herds, milk production (Y) and the amount of concentrate supplementation (X) were related (Y = 9.18 + 1.06X; r^2 = 0.77). The r^2 for herds in Poás and SC were 0.68 (Y = 13.40 + 0.79X) and 0.72 (Y = 8.97 + 0.77X), respectively. In Louisiana, r^2 = 0.20 (2), but Stone et al. (18) reported a much higher r^2 (0.84) for DHIA records.

Two reasons contributed to the high amount of supplementation. First, some farmers used fixed ratios of concentrate to milk to calculate the amount of concentrates required per individual cow. The actual ratio, however, was different from the intended one, because some concentrates, such as green bananas, brewers grain, and molasses, fed in considerable quantities, were frequently not taken into account. Second, records in the VAMPP database suggested that the BW of an adult Holstein LC was about 550 kg in Poás and about 500 kg in SC. However, the BW used for the calculations of rations, practiced on only a few farms, was 600 kg.

The shortage of roughages in the diet resulted in relatively low fat concentrations (3.2 to 3.4%) in the milk of Holsteins. An in depth study of one of the Poás farms (4) revealed 2.9% fat in the tank milk during 4 mo. On this particular farm, metabolic diseases occurred as well. In Poás, ketosis and other metabolic diseases are encountered frequently (16). In the present study, on 4 of 11 farms in Poás, hay was fed ($\overline{X} \pm SD = 1.8 \pm 0.4$ kg of DM/d) to LC to increase the fat percentage of the milk. On these farms, the ratio of concentrate to milk was 1:2.2. Because the hay was of poor quality and had to be purchased because it cannot be produced in the wet climate of Poás, less concentrates and no hay may improve the utilization of available pasture more economically and beneficially.

CP Balance

The daily diet for LC had a wide range of CP in relation to requirements. However, the overall tendency was an oversupplementation of CP (13, 20), especially in Poás; in both regions, however, a shortage of CP occurred on some farms (Table 5).

An interaction between region and season was observed ($P < 0.05$) for CP balance. In the dry season, the mean amount of CP in the diet was 20% above requirements in Poás; in SC, the mean amount of CP was near the required amount. The lack of adjustment of the diet from the dry season to the wet season, resulted in a 30% oversupplementation of CP in the wet season in both regions. The nutritional and economic efficiency, especially during the wet season, could be improved by the use of supplements with correct CP concentrations.

TABLE 5. Crude protein balance of the diet of lactating cows.[1]

	Whole season	Dry season	Wet season
	(%)		
All farms	21	10.9[b] (−20–48)[2]	30.1[a] (−10–62)
Poás	25[x]	19.6[x] (−11–48)	30.5 (−10–62)
San Carlos	15[y]	0.3[b,y] (−20–22)	29.6[a] (5–54)
		(no.)	
Farms in Poás with positive CP balance		10	10
Farms in Poás with negative CP balance		1	1
Farms in San Carlos with negative CP balance			

[a,b]Means within rows with different superscripts differ ($P < 0.05$).

[x,y]Means within columns with different superscripts differ ($P < 0.05$).

[1]Calculated as [(CP pasture + CP concentrates)/CP requirement − 1] × 100. Requirements based on NRC (13) recommendations.

[2]Numbers in parentheses represent ranges.

N Efficiency

The annual amount of N purchased through fertilizers was about 120 kg/ha; a small difference did exist between regions. In Poás, the amount of N input from concentrates was three times higher than that in SC. The total mean N input was also higher in Poás. The output of N in milk was four to six times higher than the output of N as a result of culling. The annual surplus of N (N input − N output = losses to the environment and soil accumulation) was 249 kg/ha in Poás and 147 kg/ha in SC. The N efficiencies (N output/N input) were 27 and 31%, respectively (Table 6).

Calculations of N balances in The Netherlands showed a N surplus of 435 kg/ha and an efficiency of 16% (1). Low efficiencies are normal for highly intensive systems. The higher efficiency for the present study was mainly caused by lower amounts of N fertilizer. The relatively high amount of atmospheric deposition of N in The Netherlands is due to high ammonia emission rates (1).

Nitrogen intake that exceeds cow requirements can be reduced by feeding management. Inevitable losses are those that are biologically inherent in protein synthesis (10). The avoidable loss as a result of oversupplementation in the diet was estimated at

TABLE 6. Annual N balance of Costa Rican and Dutch dairy farms.

	Poás	San Carlos	The Netherlands[1]
	(kg of N/ha)		
N Input			
Concentrate	218	73	137
Fertilizer	114	131	331
Atmospheric deposition[2]	8	8	48
N Output			
Sold livestock	13	13	14
Milk	78	52	67
N Input – N output	249	147	435
N Efficiency, %	27	31	16

[1]Data from Aarts et al. (1); mean values for farms on sandy soils from 1983 to 1986.

[2]Data from Holding (11).

TABLE 7. Daily economic parameters of Costa Rican dairy farms.

	Poás		San Carlos	
	$\overline{X}$	SD	$\overline{X}$	SD
Milk per LC,[1] kg/d	21.7[a]	4.4	13.0[b]	2.5
Milk per farm, kg/d	1648[a]	850	879[b]	418
Milk price, $/kg	0.27	0.02	0.27	0.02
Gross income, $ per farm	448[a]	234	236[b]	114
Feed cost, $ per LC	141[a]	85	62[b]	42
Feed cost, $ per YS and DC[2]	42[a]	21	16[b]	9
Feed cost, $ per LC + YS and DC	183[a]	102	77[b]	48
IOFC,[3] $ per Farm	265[a]	140	159[b]	83
IOFC, % of Gross income	59[b]	6	68[a]	10
IOFC, $ per Cow	3.04[a]	0.66	1.84[b]	0.44
IOFC, $/ha	11.7[a]	12.3	7.5[b]	4.5
IOFC, $/kg of Milk	0.19	0.02	0.20	0.03

[a,b]Means within rows with different superscripts differ ($P < 0.05$).

[1]Lactating cow.

[2]Young stock and dry cows.

[3]Income over feed cost.

25% of the total CP in Poás and at 15% in SC, corresponding to an excess intake of 35 and 6 kg of N/ha per yr, respectively.

Nitrogen efficiency can be improved through an increased utilization of the forage grown on the farm and through proper adjustments to the diet between seasons. The overall economic outcome on the farm, however, will depend on the costs of N in fertilizers and concentrates, the use of N fertilizer by grass, and the degradability of N grass and N concentrate.

IOFC

In Poás, more money was spent on concentrates, but the milk production per LC and per farm was higher than that in SC, resulting in a higher IOFC for the total farm, per cow and per ha (Table 7). The total feed cost per total amount of milk produced per farm was comparable (0.11 $/kg of milk in Poás and 0.09 $/kg of milk in SC), resulting in a similar IOFC per kilogram of milk in the two regions. The temperate climate of Poás is probably an important factor in the explanation of the higher IOFC per cow ($3.04) compared with the IOFC per cow in SC ($1.84). The IOFC per cow in Poás is also higher than $2.71, which was the mean IOFC for a farm in Louisiana with daily milk production of 16.5 kg per cow (2). The high IOFC per cow in Poás cannot be explained by more favorable prices in Costa Rica; the price of 1 kg of commercial concentrates was approximately 50% of the price of 1 kg of milk. This ratio (1:2) is less favorable than the ratio in New York [1:3.5; (14)]. However, IOFC increases as milk production increases (17) because of the increased efficiency of feed conversion for high producing cows (6). Season did not affect IOFC expressed on a farm, cow, or hectare basis.

Regression analysis of IOFC per cow per day (Y) against kilograms of milk per cow per day (X) resulted in $r^2 = 0.63$ ($Y = 0.47 + 0.11X$); that of IOFC per cow per day against kilograms of milk per cow per day and DMI from supplements (Z) resulted in $R^2 = 0.79$ ($Y = -0.23 + 0.22X - 0.15Z$). Inclusion of stocking rate (SR) increased the R^2 to 0.81 ($Y = -0.49 + 0.24X - 0.19Z + 0.05SR$). Oversupplementation with CP had no effect on IOFC per cow.

CONCLUSIONS

The nutritional management of farms in this study was poor for the following reasons: 1) oversupplementation of concentrates and underutilization of the cheaper forage resource; 2) lack of adaptive nutritional management because the diets of LC were the same in the dry and wet seasons, regardless of the available quantity and quality of the forage; and 3) an overabundance of CP in the diet, although a few diets had negative protein balances. To improve nutritional management, local standards on the utilization of concentrates and tropical grasses must be developed for each region for the different seasons of the year.

The high IOFC in Poás was remarkable considering the oversupplementation and the underutilization of the cheaper available forage.

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