Efficiency of Utilization of Tropical Grass Pastures by Lactating Cows with and Without Supplement[1]

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ABSTRACT

Records of milk yield, fat percent, body weight, reproduction and health of 506 calvings of 362 cows were used for estimating the efficiency of utilization of tropical grass pastures by lactating cows fed on grazing alone or grazing with various types of supplement. There were seven feeding systems: grazing alone (T_1); grazing plus supplement with ground maize (T_2); with molasses (T_3); with concentrate (T_5); or with urea-molasses (T_6), at the rate of 1.0 kg per 2.0 kg milk in excess of 10 kg of milk per day and of 2.5 cows per ha; or grazing plus concentrate feeding of 1.0 kg per 2.0 kg milk irrespective of milk yield at a stocking rate either of 2.5 cows (T_4) or 5.0 cows (T_7) per ha. All supplement systems had significantly higher yields of milk, fat and fat-corrected milk than grazing alone. Level of fat percent paralleled dependence on intake of forage. Supplement also extended days in milk. System of feeding was significant for body weight gain, time to reach peak milk yield, the level of peak yield, persistency of milk yield, days open, time from first breeding to conception, and calving interval. High levels of supplement (T_4, T_7) increased weight gains, time to reach peak yield, and persistency, but lowered breeding efficiency. On medium levels (T_3, T_5, T_6), the efficiency (Mcal/kg dry matter) of utilization of supplement for milk production was satisfactory, but unsatisfactory on high supplement levels (T_4, T_7). Supplements as high or higher than those in the grass treatments supplemented with non-protein nitrogen (urea-molasses) or crude protein (concentrate) gave a more efficient utilization than either maize or molassses. During the first 150 days of lactation, cows on grazing alone averaged 14.3 kg pasture grass dry matter intake per day, or 2.9% of body weight. Cows on low supplement (T_2, T_3, T_5, T_6) averaged 24 to 29% less; and cows on high supplement, nearly 60% less intake. Type of supplement had little influence on pasture grass dry matter (PGDM) intake. When the genetic potential for milk yield of cows exceeds 3,000 kg, supplementary feeding appears economically feasible. Even under the high levels of nitrogen fertilization employed, there was a rise in average milk yield with intakes of protein from the supplementary feed. Supplementary feeding with tropical grass pastures caused a high rate of substitution; hence, the efficiency of use of PGDM is lowered unless stocking rate is carefully adjusted.

INTRODUCTION

A series of experiments was begun in 1969 at the Gurabo Agricultural Experiment Substation of the University of Puerto Rico to develop

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feeding systems for lactating cows on heavily fertilized grass pastures. The objectives were to explore the feasibility of grazing as the only source of feed and to determine the value of supplementary feeding, both in level of supplementation and types of feeds most suitable for complementing grazing. Four reports have been issued (10, 11, 21, 25) giving preliminary evaluations of 10 feeding systems. Six of the experiments were conducted to determine the value of supplementary feeding with molasses, ground maize or a concentrate feed (10, 11, 25), and three were concerned with the use of hay or dehydrated, pelleted forages for supplementing lactating cows on grazing (21).

The objective of this report is to provide a summation of the performance of lactating cows on grazing alone versus grazing plus concentrate supplements, efficiency of utilization of supplementary feeding, influence of type of supplementary feeding, and stocking rate on the intake and utilization of pasture grass dry matter (PGDM), and effects of system of feeding on reproductive efficiency and persistency of milk yield.

MATERIALS AND METHODS

All the trials were conducted at the Gurabo Substation (lat. 18° 16′ N and long. 66° 12′ W), located approximately 40 km southeast of San Juan. Prevailing climatic conditions, grasses utilized, fertilization rate, and management regimes for pastures and cows were described in previous reports (10, 11, 25).

FEEDING REGIMES

From October 1969 until late 1977, all cows calving at the Gurabo Substation were assigned to a feeding regime for each lactation:

- T_1—Grazing alone, 2.5 cows per ha
- T_2—Grazing with 2.5 cows per ha, plus 1.0 kg of ground maize per 2.0 kg of milk in excess of 10 kg per day
- T_3—Grazing with 2.5 cows per ha, plus 1.0 kg of molasses per 2.0 kg of milk in excess of 10 kg per day
- T_4—Grazing with 2.5 cows per ha, plus 1.0 kg of commercial concentrate mix, 20% crude protein (CP) and 72.5% total digestible nutrients (TDN), per 2.0 kg of milk irrespective of level of daily yield
- T_5—Grazing with 2.5 cows per ha and 1.0 kg of commercial concentrate per 2.0 kg of milk in excess of 10 kg per day
- T_6—Grazing with 2.5 cows per ha and 1.0 kg of urea (4%) plus molasses per 2 kg of milk in excess of 10 kg per day
- T_7—Grazing with 5.0 cows per ha plus 1.0 kg of commercial concentrate per 2 kg of milk irrespective of daily yield.

Because of limitations in number of cows, pastures, and feeding facilities, it was not feasible to have all seven systems under evaluation simultaneously. Grazing alone (T_1) was continued throughout the 9 years and served as the control with two or more of the other systems under test each year. The same pastures were used over all years. The grazing offered consisted of mixed grass stands, principally Pangola (*Digitaria decumbens*), Star (*Cynodon nlemfuensis*), Pará (*Brachiaria purpurascens* (Raddi) Henr.) and some native species. Fertilizer, analysis 15-5-10, was applied at the rate of 2240 kg per ha per year in four applications; and lime was applied at 2240 kg per ha per year in one application. The pastures were grazed for a 7-day interval with at least 21 days between grazings.

The cows were on pasture all the time except for milking twice per day. Supplementary feed was offered prior to each milking with level being adjusted according to milk yield at 10-day intervals. Feed refusals were recorded. A mixture of 1:1 common salt and dicalcium phosphate was available in the holding area adjacent to the milking parlor. Water was available both in the pastures and in the milking parlor. During their dry period, cows remained on the same pastures but without supplement.

ANIMALS AND RECORDS

Beginning October 1969, all cows and heifers calving in the herd at the Gurabo Substation were assigned to one or more treatment groups. There were 362 cows with 506 calvings. Of these, 472 records were used for analysis. The herd consisted of 83% high grade Holsteins, 10% Brown Swiss, and 7% crossbreds.

Lactations continued 300 days or until daily milk yield declined below 5 kg per day. Heifers or cows which did not produce at least 300 kg in the first 30 days of lactation were removed. Also, cows not pregnant by 300 days were culled. Health disorders were recorded. Body weights were taken on the day of parturition, monthly during lactation, and on the final day of lactation.

METHOD OF ANALYSIS

Records for study included both actual and projected records. The actual records were used when no abnormalities were recorded. Projected records were substituted when an identified health disorder resulted in a 25% or greater decline in milk yield for 3 or more days and there was evidence that the disturbance influenced daily milk yields for 10 days or longer. When a serious problem occurred after the first 30 days of lactation, the record was extended from the last normal day to a 300-day basis using age-season of calving extension factors derived from DHIA records of Puerto Rico and compared to the actual record. Where the difference exceeded ± 13%, the projected record was substituted.

Since it was not possible to balance age of calving among treatments, the lactation milk and fat yields were adjusted to a mature equivalent basis with consideration of factors appropriate to Puerto Rico (2). Adjusted age-month of calving records were used for milk, fat and fat-corrected milk (FCM) yields, but actual records were used for all other traits. FCM was determined as 0.4 × kg of milk + 15 × kg of fat.

Sires were ignored in the analysis since sire progeny was assumed to be randomly distributed across treatments. Since year, month of calving, and age effects became non-significant after adjustment, a one-way analysis of variance model with treatment effects fixed was appropriate for determining treatment effects (19).

RESULTS AND DISCUSSION

PRODUCTION AND LACTATION LENGTH

For all lactation factors, the *F* statistics for treatment effects were significant ($P < .01$) (table 1). Table 2 shows that cows receiving supplement produced more milk and fat and had more days in lactation than cows on grazing alone (T_1). Yields of milk, fat and FCM were related to level of supplementary feeding, with groups T_4 and T_7 having the highest yields. That the T_7 cows grazing at twice the stocking rate of T_4 cows produced slightly more milk indicates that with higher level of supplementation, without change in stocking rate, PGDM intake and the percentage of total energy consumed from PGDM was less.

TABLE 1.—*Mean squares and* F *values from analysis of variance and test of significance for lactation factors*

Source	Error df[1]	Mean squares		*F*
		System[2]	Error	
ME[3] milk	465	29931520.0	740195.0	40.44**[4]
ME fat	465	22354.0	875.7	23.53**
Fat %	465	1.11	0.14	8.00**
ME fat-corrected milk	465	16865280.0	596258.0	28.22**
Days in milk	353	5309.3	924.3	5.73**
Efficiency[5]	359	737.0	24.3	30.27**

[1] Degrees of freedom.
[2] Treatment df = 6.
[3] Mature equivalent.
[4] Significant at the 1% level.
[5] Efficiency = kg FCM/kg TDN consumed.

Groups T_2 and T_3, receiving ground maize or molasses, were similar for yield traits, but averaged significantly higher ($P < .05$) than the non-supplemented cows (T_1). The groups on limited supplement, but with more CP (T_5 and T_6), had higher yields (table 2) than the groups on low CP supplements (T_2, T_3); thus the higher intake of CP increased intake and/or utilization of PGDM, or alternatively the low CP, high energy

TABLE 2.—*Means, tests of significance, and standard errors for lactation statistics by feeding system*

Source	Feeding System						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
			Means and tests of significance[1]				
Number of records	107	73	48	101	96	26	21
ME[2] milk (kg)	3189^{a}	3627^{b}	3660^{b}	4671^{c}	4338^{d}	3819^{d}	5302^{e}
ME fat (kg)	111^{a}	125^{b}	129^{b}	155^{c}	145^{d}	130^{b}	157^{cd}
Fat %	3.49^{a}	3.43^{ab}	3.51^{a}	3.34^{b}	3.35^{b}	3.39^{ab}	2.94^{c}
ME fat-corrected milk (kg)	2810^{a}	3187^{b}	3211^{b}	3966^{c}	3841^{c}	3452^{b}	4040^{c}
Days in milk	268^{a}	279^{b}	278^{ab}	290^{bc}	288^{bc}	277^{ab}	299^{c}
Efficiency		10.4^{a}	9.0^{a}	2.7^{bc}	7.0^{b}	10.6^{a}	2.3^{c}
			Standard errors of the means				
ME milk (kg)	72.2	71.2	99.8	115.4	84.9	149.8	226.4
ME fat (kg)	2.5	2.8	3.9	3.8	2.8	5.2	7.9
Fat %	0.03	0.04	0.05	0.04	0.04	0.05	0.08
ME fat-corrected milk (kg)	64.6	73.1	96.5	102.9	69.8	143.8	200.6
Days in milk	4.6	3.9	5.0	2.5	2.6	7.2	1.1
Effiency		0.6	1.6	0.1	0.2	0.9	0.1

[1] Mean values in the same row with one or more letters in common do not differ significantly at the 5% level.

[2] Mature equivalent.

ratio of the molasses and maize supplements may have decreased intake and/or utilization of the forage.

Fat percentage was lowest for the T_7 group reflecting a limited contribution of grazing to total dry matter (DM) intake. Percent fat for the other 6 groups fell into 2 groupings: high (T_1, T_2, T_3) and medium (T_4, T_5, T_6). The groupings parallel the dependence on intake of forage. Table 2 shows that the level of FCM production was also on 3 levels (low, T_1; medium, T_2, T_3, T_6; high, T_4, T_5, T_7). Since the response to level of feeding of the commercial concentrate did not differ among groups T_4, T_5 and T_7, it may be that feeding of a complete formula is more important than level of feeding; however, the level of CP in the diet did not appear as important for FCM production as for fat percent.

Supplementary feeding extended days in milk (DIM) by 10 to 30 days (table 2). Similar to FCM yield, the type of supplementation influenced DIM more than the level of supplementation.

TABLE 3.—*Mean squares and F values from analysis of variance and test of significance for lactation curve statistics*

	Error df[1]	Mean square		*F*
		System	Error	
Cycle for peak yield	453	10.7	2.9	3.68**[2]
Yield, peak cycle	459	36885.3	1456.8	25.31**
Yield, 1st five cycles	459	863914.6	31640.8	27.30**
Yield, 2nd five cycles	458	1080320.0	34879.2	30.97**
Persistency	458	0.44	0.06	7.12**

[1] Degrees of freedom.

[2] Significant at the 1% probability level.

There was a decrease in estimated efficiency (kg FCM/kg TDN) by supplementation. Cows on maize (T_2), molasses (T_3), and urea-molasses (T_6) were higher in efficiency than those receiving the concentrate supplement (table 2). The fact that efficiency declined with level of supplementation indicates a greater rate of substitution of concentrate energy for energy from PGDM. This finding is also supported by the similarity in level of efficiency between the T_4 and T_7 groups. PGDM played a lesser role in the total DM intake of the cows on high level of supplement; hence, doubling the stocking rate had no detectable influence on the efficiency of the T_7 cows.

PEAK YIELD AND PERSISTENCY

Group effects were significant for 10-day cycles at which the peak yield of lactation was reached, the highest 10-day yield, total production over the first and second 5 cycles following parturition, and persistency of milk yield (table 3). Cows on grazing alone (T_1) peaked earlier in their lactation than the supplemented groups (table 4). There was a tendency for cows receiving higher levels of supplement (T_4, T_7) to peak later than for the lower supplemented groups. Plottings of the average 10-day milk yields (fig. 1) show that cows receiving the concentrates (T_4, T_5, T_7) had a more definite peak than the other groups.

Milk yield for the peak cycle was highest for the concentrate supplemented groups (table 4). There was a linear trend with CP percent of the supplement similar to that for FCM.

Total yield over the first five cycles (1-50 days) followed the same trend as level of production for peak cycle with the exception that the two molasses-supplemented groups (T_3, T_6) did not differ significantly (table 4). Over the second five cycles (51-100 days), the T_6 group averaged higher in yield than the T_3 group. Since the T_3 cows did not differ significantly from groups T_1 and T_2 during this period, there may be an effect of level of CP in the supplement on the ability of cows to maintain persistence following the peak of lactation. From the 61st to 160th day of lactation, milk yield declined by 3.68, 3.56, 2.58, 2.39, 3.31, 3.04, and 2.50% per 10-day cycle for groups T_1 through T_7. The lower rate of decline for

TABLE 4.—*Means, tests of significance, and standard errors for lactation curve statistics by treatment group, Gurabo*

Source	Feeding system						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
	Means and tests of significance[1]						
Number of records	107	74	46	101	92	24	21
Cycle for peak yield	2.6[a]	3.2[b]	3.0[b]	3.6[b]	3.3[b]	3.5[b]	3.8[b]
Yield, peak cycle (kg)	174[a]	177[a]	187[ac]	220[b]	223[b]	197[c]	224[b]
Yield, 1st five cycles (kg)	796[a]	816[ac]	858[ac]	1009[b]	1045[b]	900[c]	1039[b]
Yield, 2nd five cycles (kg)	667[a]	722[a]	733[ac]	941[b]	921[b]	808[c]	977[b]
Persistency (%)	63.9[a]	69.3[bc]	66.5[ab]	69.2[bc]	66.2[a]	66.3[ab]	71.9[c]
	Standard errors of the means						
Cycle for peak yield	0.16	0.21	0.28	0.19	0.17	0.34	0.26
Yield, peak cycle (kg)	3.1	3.1	4.5	5.1	4.1	4.8	10.5
Yield, 1st five cycles (kg)	13.5	15.3	20.9	23.6	19.6	26.4	49.2
Yield, 2nd five cycles (kg)	11.9	14.8	26.1	26.2	10.1	30.2	55.3
Persistency (%)	0.8	0.8	1.1	0.8	0.8	1.9	1.5

[1] Mean values in the same row with one or more letters in common do not differ significantly at the 5% probability level.

T_4 and T_7 shows that decline can be slowed by higher levels of supplementary feeding. The rate of change for T_5 and T_6 cows was faster than expected. There is no clear cause, but the level of CP in the supplements may have promoted higher PGDM intakes, which declined with time. Changes in body weight could also be a factor in that the high CP, moderate rate of feeding, (T_5, T_6) promoted more rapid mobilization of fat reserves in early lactation which would be depleted by 60 days or later in lactation. Finally, it may be that the downward adjustment of rate of

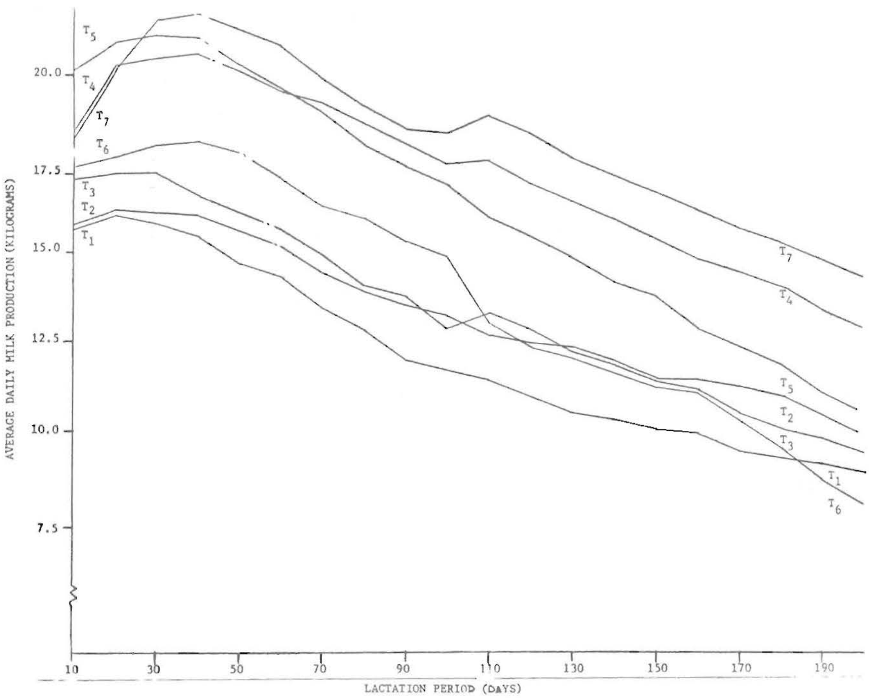

FIG. 1.—Lactation curves, by treatment, Gurabo Substation.

supplement feeding could have depressed CP intake. As milk yield declined from 18 to 12 kg, T_5 and T_6 cows were reduced from 4 to 1 kg of supplement per day. In the same period, the supplement for T_4 and T_7 cows was reduced from 9 to 6 kg per day.

For persistency (P) of milk yield calculated as

[P (%) = (total milk/milk high 10-day cycle) × (DIM/10) × 100], system of feeding effects were significant (table 3). P appears to be associated more with level of supplementation than type of supplement (table 4) and is related to level of peak yield (fig. 1).

BODY WEIGHT

System of feeding effects was significant for body weights and weight gain during lactation (table 5). The average weight loss during the first month of lactation (weight on day of parturition minus 30-day weight) was 35, 32, 32, 33, 29, 39 and 24 kg for groups T_1 through T_7, respectively. Cows in T_6 were heavier at parturition and had the greatest loss. Even so, group differences were small for 30-day weight and in final weight (table 6). Except for the T_4 group the amount of weight gain was low for all groups. Weight gains for all groups were considerably lower than those in similar experiments conducted in temperate areas, where weight gains during lactation exceeded 60 kg (5, 7, 13). The reasons for the modest changes in weight are not clear at this time. It may be that the cows expended more energy than estimated in walking to and from the pastures; hence the level of feeding in relation to total requirements was less than anticipated. Also, it may be that the tropical environment depressed appetite to an extent that the cows did not eat to accumulate fat as they might in a cooler environment (8).

TABLE 5.—*Mean squares and* F *values from analysis of variance and test of significance for bodyweights*

	Error df[1]	Mean squares		*F*
		System[2]	Error	
Weights				
30-day	449	7792.0	2826.0	2.76*[3]
Final	449	16474.7	2842.6	5.81**[4]
Gain	449	7691.3	1267.4	6.28**

[1] Degrees of freedom.
[2] Treatment df = 6.
[3] Significant at the 5% probability level.
[4] Significant at the 1% probability level.

BREEDING EFFICIENCY

System of feeding effects were significant ($P < .01$) for days open, time from first breeding to conception, and calving interval, but not for days from calving to first heat or services per conception (table 7). Cows on grazing alone were slower by 5 to 13 days in returning to normal estrus cycle following parturition (table 8). The cows on high stocking rate (T_7) required the most services and had longest calving interval. In general, the cows on high concentrate feeding required more days and services for conception. Trimberger et al. (22) also found poor breeding efficiency in Holsteins on liberal concentrate feeding because of a high frequency of cystic follicles. Although the sampling variance for almost any measure of breeding efficiency may be high (12), it appears from this study and from data on commercial dairy herds in Puerto Rico (3) that there is an association between breeding efficiency and concentrate feeding in a tropical environment. The cause and effect relationships are not clear, however.

EFFICIENCY OF USE OF SUPPLEMENT

Milk yield from supplement consumed was estimated by 10-day cycles up to 150 days of lactation for groups T_3, T_4, and T_6 (tables 9, 10, 11, 12).

TABLE 6.—*Means, tests of significance and standard errors for bodyweight*

Source	Feeding system						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
			Means and tests of significance[1]				
Number of records	103	70	41	104	94	23	21
Weights (kg)							
30-day	484^{a}	494^{a}	497^{a}	501^{a}	507^{a}	517^{b}	490^{a}
Final	505^{a}	527^{b}	529^{b}	546^{b}	524^{b}	538^{b}	523^{ab}
Gain (kg)	21^{ad}	33^{b}	33^{abc}	45^{c}	18^{d}	22^{abd}	35^{abcd}
			Standard errors of the means				
Weights (kg)							
30-day	5.1	6.9	8.5	5.6	4.4	10.7	13.5
Final	5.2	6.6	8.5	5.2	5.3	10.4	14.2
Gain (kg)	3.6	4.0	5.8	3.6	3.7	6.3	7.7

[1] Mean values in the same row with one or more letters in common do not differ significantly at the 5% probability level.

TABLE 7.—*Mean squares and* F *values from analysis of variance and test of significance for measures of breeding efficiency*

	Error df[1]	Means squares		*F*
		System[2]	Error	
Calving to 1st heat	423	1285.8	1082.7	1.19
Days open	387	10099.2	3505.1	2.88**[3]
1st breeding to conception	394	8506.6	3409.0	2.50**
Services/conception	394	3.3	2.2	1.52
Calving interval	394	405120.0	3363.5	117.80**

[1] Degrees of freedom.
[2] Treatment df = 6.
[3] Significance at the 1% probability level.

For these estimates, the net energy for lactation (NE_L) of ground maize was assumed as 2.03 Mcal/kg DM, and the corresponding value for molasses as 1.64 Mcal/kg DM (16). The NE_L content of the commercial concentrate was estimated as 1.49 Mcal/kg DM from the equation of Moe and Tyrell (14): $NE_L = -0.12 + 2.45$ (% TDN). The milk production from supplement was estimated by dividing total NE fed as supplement by fat percentage, and subtracting from this the adjusted requirement for

NE_L per kg of milk (16). Energy supplied by body weight loss during the first 30 days of lactation was ignored since type of supplement appeared more important than level of supplement.

The additive model for milk yield assumes that the estimated milk derived from supplement should add directly to the milk produced by T_1 cows from consumption of PGDM without supplement as follows:

Milk potential = milk supplement + milk PGDM (T_1).

Actual average daily milk divided by the potential provides an estimate of the degree of conformity to the additive model. Supplemental energy which did not result in additional milk was assumed to have substituted for PGDM in providing for maintenance and weight gains. Differences in

TABLE 8.—*Means, tests of significance, and standard errors for reproductive statistics by treatment group, Gurabo*

Source	Feeding system						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
	Means and tests of significance[1]						
Number of records	90	61	41	90	87	18	21
Calving to 1st heat (days)	65.3	60.1	52.5	60.5	55.4	54.2	59.7
Days open	126.4[a]	112.3[a]	111.3[a]	134.2[ac]	127.6[a]	97.4[b]	158.3[c]
1st breeding to conception (days)	45.1[a]	29.3[b]	35.6[a]	53.4[a]	48.3[a]	21.2[b]	72.3[c]
Services/conception	2.2	2.0	2.1	2.4	2.2	1.5	2.6
Calving interval (days)	406[a]	392[a]	391[a]	414[b]	408[b]	377[a]	438[b]
	Standard errors of the means						
Calving to 1st heat (days)	3.4	4.5	3.4	3.7	3.6	3.9	6.8
Days open	6.0	6.2	7.4	6.7	7.4	10.4	19.4
1st breeding to conception (days)	5.3	5.1	9.7	6.9	7.0	10.9	17.3
Services/conception	0.15	0.25	0.26	0.17	0.15	0.24	0.45
Calving interval (days)	6.0	6.2	7.4	7.0	7.0	10.4	19.4

[1] Mean values in the same row with one or more letters in common do not differ significantly at the 5% probability level.

body weight and possible depression in digestibility with higher levels of intake were ignored in the analysis. Differences in CP content of the supplements were also ignored since it was assumed not be a major factor limiting milk production, although this assumption may not be entirely valid for T_2 cows consuming maize.

Groups T_3 and T_6 were similar in average percent of expected milk yield for all 15 cycles (tables 9, 10). Cows in T_3 showed an increase from cycle 1 to 14 in the conformity measure (percentage of expected yield) while T_6 cows dropped abruptly in expected milk yield by cycle 11 when supplementary feeding ceased following a decline in milk below 10 kg per day. In the same cycle, fat percent declined approximately 50%. These changes by the T_6 group in performance were more rapid than anticipated.

The T_5 group averaged 83.4% of expected milk yield (table 11). Unlike the T_6 group (table 10), the T_5 cows did not show a rapid decline in relation to projected milk yield when supplement level was low or no supplement was fed. During cycles 14 and 15, when supplement averaged less than 1 kg per day, the T_5 cows actually exceeded expected production. To do so, these cows had either to increase PGDM intake and/or utilization relative to T_1 cows or to mobilize body tissue. Since weight gains for T_5 cows were low (table 6), body tissue mobilization was unlikely.

T_4 cows averaged lowest in milk yield in comparison to expected

TABLE 9.—*Estimated milk yield from supplement and expected milk yield under the additive model for T_3 cows in the first 15 cycles*

Cycle	Average daily milk	Fat	Supplement		Milk yield		
			Consumed	Milk	T_1	T_3 Expected	Expected
	kg	%		*kg*			%
1	17.4	2.9	4.5	12.9	16.0	28.9	60.2
2	17.6	3.0	3.7	10.5	16.4	26.9	65.4
3	17.9	3.0	3.8	10.8	16.2	27.0	66.3
4	17.3	2.8	3.5	10.2	15.8	26.0	66.5
5	16.8	2.9	3.7	10.6	15.1	25.7	65.4
6	16.3	3.1	3.4	9.5	14.9	24.4	66.8
7	15.8	3.1	3.2	8.9	13.8	22.7	69.6
8	15.0	3.1	2.9	8.1	13.3	21.4	70.0
9	14.7	3.1	2.5	7.0	12.5	19.5	75.4
10	13.9	3.0	2.4	6.8	12.2	19.0	73.2
11	13.2	2.9	2.0	5.8	10.3	16.1	82.0
12	12.8	3.0	1.6	4.5	9.9	14.4	88.9
13	12.2	2.9	1.4	4.1	9.6	13.6	89.7
14	11.9	2.9	1.1	3.2	9.3	12.5	95.2
15	11.3	2.9	1.5	4.3	9.2	13.5	83.7
Average							74.6

average milk yield (51.6%), table 12. Deviation from expected milk yield declined rapidly after cycle 1. Despite showing higher persistency in milk yield relative to that of T_5 cows (69.2 vs 66.2%) (table 4), and a slower rate of decline (−2.39 vs −3.31% per 10 days) from 61 to 160 days of lactation, the T_4 cows either converted a greater proportion of supplemental energy to body weight gain or decreased PGDM intake to a greater degree as lactation progressed. The T_4 cows gained much more weight than T_5 cows; thus there is more evidence for the latter hypothesis.

On the basis of actual yields of milk, fat and FCM and efficiency, T_5 cows, which were fed at approximately the same level of supplement as groups T_2, T_3 and T_6, responded as did the T_4 and T_7 cows which were also fed commercial concentrate. This fact suggests that the formula of the concentrate provided some factor or factors essential to higher production not available from grazing. Since the response of T_3 cows, fed molasses only, and T_6 cows, which were receiving urea-molasses, was similar for all factors, except milk and fat yields. CP does not appear as the major limiting factor. This assumption is supported by the high levels of CP in plucked samples from the pastures (11, 24). However, as the additional CP in the supplement for T_6 cows was non-protein-nitrogen (NPN) in the form of urea, the response of T_5 cows may have been to preform and by-pass CP in the commercial concentrate (6). Heavily fertilized tropical grass pastures are known to have high levels of NPN in the form of nitrates (1, 4), and selection of a diet high in leaf provides more NPN in the form of amino acids (23). While these forms of NPN are converted to microbial protein in the rumen, given adequate availability of energy, there may be a ceiling on the amount of NPN which can be used (18). The concentrate may have contained ingredients, such as soybean meal or cottonseed meal, which provided for a greater yield of microbial protein or possibly for some by-pass protein utilized directly by the cows through post-ruminal digestion.

TABLE 10.—*Estimated milk yield from supplement and expected milk yield under the additive model for T_6 cows in the first 15 cycles*

Cycle	Average daily milk	Fat	Supplement		Milk yield		
			Consumed	Milk	T_1	T_6 Expected	Expected
	kg	%		*kg*			%
1	17.2	2.7	4.5	9.1	16.0	25.1	68.5
2	17.7	2.8	3.6	7.1	16.4	23.5	75.3
3	18.0	2.8	3.9	7.7	16.2	23.9	75.3
4	18.2	2.9	4.0	7.8	15.8	23.6	77.1
5	17.4	3.2	4.1	7.7	15.1	22.8	76.3
6	16.7	3.1	3.7	7.0	14.9	21.9	76.3
7	16.2	3.0	3.9	7.5	13.8	21.3	76.1
8	15.8	3.0	3.1	6.0	13.3	19.3	81.9
9	15.2	2.9	2.9	5.7	12.5	18.2	83.5
10	14.8	3.0	2.6	5.0	12.2	17.2	86.0
11	6.5	1.5	2.4	6.0	10.3	16.3	39.9
12	6.4	1.5	0.0	0.0	9.9	9.9	64.6
13	6.1	1.6	0.0	0.0	9.6	9.6	63.5
14	5.9	1.6	0.0	0.0	9.3	9.3	63.4
15	5.7	1.5	0.0	0.0	9.2	9.2	62.0
Average							71.3

The additive models (tables 9, 10, 11) indicate that on medium levels of supplement the utilization of supplement in milk production is efficient but not so when the level of supplement is high (table 12). There are also indications that a "balanced supplement" is better utilized (table 11) than either maize (table 9) or molasses with urea (table 10).

PASTURE GRASS DRY MATTER INTAKE

In tables 13-17 are estimates of average daily consumption of kg of PGDM for groups T_1, T_3, T_4, T_5, and T_6 over the first 150 days of lactation. Maintenance requirements in Mcal NE_L were estimated as 0.80 Mcal per unit metabolic size ($W^{.75}$) with an additional 3% for walking to and from pasture (17) and 10% for grazing (16). The NE_L content of PGDM was estimated as 1.35 Mcal per kg on the basis of an assumed 60% TDN for heavily fertilized improved pastures selectively grazed at a stocking rate of 2.5 cows per hectare. Equation 8 of Moe and Tyrell (14) was used to convert the estimated TDN content of PGDM to NE_L. Each kg of body weight loss was assumed to supply 4.92 Mcal NE_L (15). The Mcal from weight changes were converted to PGDM and subtracted from daily total intake. The NE_L equivalent of average daily gain (ADG) was estimated as 5.12 Mcal per kg (16). Average daily PGDM intake was computed as the sum of daily intake necessary to satisfy maintenance, the observed milk yield and ADG.

TABLE 11.—*Estimated milk yield from supplement and expected milk yield under the additive model for T_5 cows in first 15 cycles*

Cycle	Average daily milk	Fat	Supplement		Milk yield		
			Consumed	Milk	T_1	T_5 Expected	Expected
	kg	%		*kg*			%
1	20.5	2.7	4.5	11.0	16.0	27.0	75.9
2	21.3	2.9	5.3	12.4	16.4	28.8	74.0
3	21.4	2.8	5.7	13.7	16.2	29.9	71.6
4	21.3	2.7	5.7	13.9	15.8	29.7	71.7
5	20.5	2.7	5.7	13.9	15.1	29.0	70.7
6	19.9	2.7	5.3	12.9	14.9	27.8	71.6
7	19.3	2.8	4.7	11.3	13.8	25.1	76.9
8	18.4	2.9	4.2	9.8	13.3	23.1	79.7
9	17.8	2.9	3.9	9.1	12.5	21.6	82.4
10	17.3	2.9	3.7	8.6	12.2	20.8	83.2
11	12.4	2.2	1.2	3.2	10.3	13.5	91.9
12	12.0	2.1	1.0	2.7	9.9	12.6	95.2
13	11.6	2.1	0.8	2.2	9.6	11.8	98.3
14	11.0	2.1	0.5	1.3	9.3	10.6	103.8
15	10.7	2.1	0.4	1.1	9.2	10.3	103.9
Average							83.4

Over the 15 cycles, cows on grazing alone (T_1) consumed 14.26 kg per day of PGDM which was equivalent to 2.9% of body weight (table 13). Groups receiving low levels consumed about 10 kg of supplement (T_3, T_5,

T_6) and had similar average PGDM intakes (tables 14, 15, 16). However, these groups averaged 28.9, 26.0 and 23.8% lower in intake than T_1 cows. The near identical intakes of groups T_3, T_5, and T_6 indicate that type of supplement (low or high CP) had little influence on PGDM intake, given the validity of the assumptions used in the estimates. T_6 cows had above average intake for cycles 4–10, but for some unidentified reason, PGDM intake declined rapidly in cycle 11 when supplement feeding ceased. The continuation of an intake of 10 or more kg of PGDM by the T_3 and T_5 cows, even after supplement was reduced to less than 3 kg per day (table 14, 15), suggests that a change in the feeding systems to which the cows were accustomed affected PGDM intake.

TABLE 12.—*Estimated milk yield from supplement and expected milk yield under the additive model for T_4 cows in first 15 cycles*

Cycle	Average daily milk	Fat	Supplement		Milk yield		
			Consumed	Milk	T_1	T_4 Expected	Expected
	kg	%		*kg*			%
1	18.6	2.8	4.5	10.8	16.0	26.8	69.4
2	20.4	2.8	9.3	22.4	16.4	38.8	52.6
3	20.7	2.9	10.2	24.2	16.2	40.4	51.2
4	20.9	2.9	10.4	24.6	15.8	40.4	51.7
5	20.4	2.8	10.5	25.2	15.1	40.3	50.6
6	19.9	2.8	10.2	24.5	14.9	39.4	50.5
7	19.5	2.7	10.0	24.4	13.8	37.2	52.4
8	19.0	2.8	9.8	23.5	13.3	36.8	51.6
9	18.4	2.7	9.5	23.3	12.5	35.8	51.4
10	17.8	2.7	9.2	22.5	12.2	34.7	51.3
11	14.7	2.3	8.9	23.3	10.3	33.6	43.8
12	14.2	2.4	7.4	18.9	9.9	28.8	49.3
13	13.7	2.4	7.1	18.2	9.6	27.8	49.3
14	13.4	2.4	6.9	17.7	9.3	27.0	49.6
15	13.0	2.5	6.7	16.9	9.2	26.1	49.8
Average							51.6

Feeding supplement at a high level (T_4) reduced average daily intake (table 17) about 50% of that for the low supplement groups and nearly 60% below the T_1 group. With the exception of cycle 1, when only 4.5 kg of supplement was fed to the T_4 cows, high feeding resulted in much of the energy being utilized for body maintenance as shown by the negative values for PGDM in table 17. The estimates indicate T_4 cows used no PGDM for milk yield, except perhaps during the first 10 days of lactation.

When PGDM intake is reduced 50 to 60% by high supplement feeding, doubling the stocking rate to 5.0 cows per ha should result in intakes equivalent to that for cows on grazing alone. That T_7 cows exceeded T_4 cows in milk, fat, and FCM yields (table 2) shows that the energy which

T_7 cows consumed from pasture was higher than that for T_4 cows. The higher stocking rate could have increased pressure on the grasses to maintain them in a better vegetative state than when grazed with only 2.5 cows per ha. Subsequent experiments with 2.5, 5.0, and 7.5 cows/ha are under way at the Gurabo Substation to test further the influence of grazing pressure on forage yield and vegetative characteristics of tropical grasses.

The intake of metabolizable energy from PGDM for T_1 cows was estimated as 2.04 multiples of maintenance. McDowell et al. (11) stated that when intake of TDN is less than twice maintenance needs, no more than 40% of the total energy consumed is available for milk production

TABLE 13.—*Estimated pasture grass dry matter intake for T_1 cows*

Cycle	BW[1]	Milk attributable		ADG	Average daily PGDM intake				BW
		Supplement	PGDM		M	Milk	ADG	Total	
				kg					%
1	519		16.0	(−1.16)	7.29	7.45	(−4.22)	10.52	2.0
2	519		16.4	(−1.16)	7.29	10.48	(−4.22)	13.55	2.6
3	519		16.2	(−1.16)	7.29	10.35	(−4.22)	13.42	2.6
4	484		15.8	0.08	6.92	9.94	0.30	17.16	3.6
5	484		15.1	↓	6.92	9.65	0.30	16.84	3.5
6	484		14.9		6.92	9.38	0.30	16.60	3.4
7	481		13.8		6.90	8.55	0.30	15.75	3.3
8	481		13.3		6.90	8.55	0.30	15.75	3.3
9	481		12.5		6.90	7.63	0.30	14.83	3.1
10	481		12.2		6.89	7.68	0.30	14.87	3.1
11	481		10.3		6.89	6.09	0.30	13.28	2.8
12	481		9.9		6.89	5.85	0.30	13.04	2.7
13	481		9.6		6.89	5.67	0.30	12.86	2.7
14	481		9.3		6.89	5.59	0.30	12.78	2.7
15	481		9.2	0.08	6.89	5.53	0.30	12.72	2.7
Average					6.98	7.89	−0.60	14.26	2.9

[1] BW, body weight; PGDM, pasture grass dry matter; ADG, average daily gain; M, maintenance.

and gross efficiency (kg FCM/kg TDN) is low. When the TDN percent of PGDM is at 60%, as used in the current estimates, the same can be said for PGDM intake. Only in cycles 4–10 did PGDM intake for T_1 cows exceed 2.0 multiples of maintenance. Values ranged from a low of 1.44 multiples in cycle 1, where weight loss was estimated to reduce PGDM intake, to a high of 2.48 multiples of maintenance in cycle 4, where maintenance requirements had declined by 0.37 kg PGDM and requirements for ADG increased the intake estimate by 0.30 kg.

The estimates for daily PGDM intake by T_1 cows ranged from a low of 10.52 kg in cycle 1 to 17.16 kg in cycle 4 (table 13). With an assumed DM percent of 20%, the range in intake of green grass as a percent of body weight would range from 10.1 in cycle 1 to 17.7 during cycle 4. The latter value is higher than an earlier estimate for T_1 cows of 12.2% by McDowell et al. (11). On the basis of sampling of pastures before grazing over an 18-month period, McDowell et al. (11) found that DM content ranged from 17.2 to 27.6%, average 21.6%. From samplings following grazing, DM averaged 24.1% but ranged from 18.1 to 32.5%

CONCLUSIONS

The merits of using fertilized improved varieties of tropical grasses as the sole source for feeding cows with a high potential for milk yield versus grazing with supplement remains subject to conjecture. On the plus side,

TABLE 14.—*Estimated pasture grass dry matter intake for T_3 cows*

Cycle	BW[1]	Milk attributable		ADG	Average daily PGDM intake				BW
		Supplement	PGDM		M	Milk	ADG	Total	
				kg					%
1	530	12.9	4.5	(−1.07)	7.40	2.10	(−3.89)	5.61	1.1
2	530	10.5	7.1	(−1.07)	7.40	3.36	(−3.89)	6.87	1.3
3	530	10.8	7.1	(−1.07)	7.40	3.36	(−3.89)	6.87	1.3
4	498	10.2	7.1	0.12	7.06	3.26	0.61	10.93	2.2
5	498	10.6	6.2		7.06	2.89	0.61	10.56	2.1
6	498	9.5	6.8		7.06	3.27	0.61	10.94	2.2
7	487	8.9	6.9		6.94	3.32	0.61	10.87	2.2
8	487	8.1	6.9		6.94	3.32	0.61	10.87	2.2
9	487	7.0	7.7		6.94	3.70	0.61	11.25	2.3
10	486	6.8	7.1		6.93	3.36	0.61	10.90	2.2
11	486	5.8	7.4		6.93	3.45	0.61	10.99	2.3
12	486	4.5	8.3		6.93	3.93	0.61	11.47	2.4
13	492	4.1	8.1		7.00	3.77	0.61	11.38	2.3
14	492	3.2	8.7	↓	7.00	4.05	0.61	11.66	2.4
15	492	4.3	7.0	0.12	7.00	3.26	0.61	10.87	2.2
Average					7.07	3.36	(−0.29)	10.14	2.0

[1] BW, body weight; PGDM, pasture grass dry matter; ADG, average daily gain; M, maintenance.

a herd of high grade Holsteins or dairy breed crosses, grazing at the rate of 2.5 cows per ha, can average 3,000 kg or more of milk per lactation. With a calving interval of 400 days, the cows will average about 2,750 kg per year. These facts suggest that the level of feeding could provide sufficient nutrients for cows native to tropical areas and improved dairy breed-native crossbred cows to produce up to near their genetic potential.

As shown in this study, cows on grazing alone have a considerably higher PGDM intake than when supplement is fed. The fat content of milk produced from grazing will easily meet acceptable market standards; reasonably satisfactory breeding efficiency can be expected; and no problems of nutritional deficiencies or toxicities are likely to occur. The use of grazing generally requires less capital investment per cow and lower labor needs than for the preparation and storage of forages such as hay or silage. This is especially the case in areas of steep slopes or where the terrain is irregular as it is in many areas of Puerto Rico. Rainfall patterns, characteristic of the humid tropics, generally inhibit making either hay or silage sufficient in quantity for the 3,000 kg level of milk yield (21).

In some situations a unit of metabolizable energy for a cow from grazing may have a lower unit cost than for a supplement. When the costs of CP supplements are high, relying solely on grazing may be more practical

TABLE 15.—*Estimated pasture grass dry matter intake for T_5 cows*

Cycle	BW[1]	Milk attributable		ADG	Average daily PGDM intake				BW
		Supplement	PGDM		M	Milk	ADG	Total	
				kg					%
1	538	11.0	9.5	(−1.00)	7.48	4.29	(−3.64)	8.13	1.5
2	538	12.4	8.9	(−1.00)	7.48	4.21	(−3.64)	8.05	1.5
3	538	13.7	7.7	(−1.00)	7.48	3.54	(−3.64)	7.38	1.4
4	508	13.9	7.4	0.07	7.17	3.34	0.36	10.87	2.1
5	508	13.9	6.6		7.17	2.98	0.36	10.51	2.1
6	508	12.9	7.0		7.17	3.16	0.36	10.69	2.1
7	503	11.3	8.0		7.12	3.67	0.36	11.15	2.2
8	503	9.8	8.6		7.12	4.07	0.36	11.55	2.3
9	503	9.1	8.7		7.12	4.12	0.36	11.60	2.3
10	504	8.6	8.7		7.12	4.12	0.36	11.60	2.3
11	504	3.2	9.2		7.12	3.83	0.36	11.31	2.2
12	504	2.7	9.3		7.12	3.77	0.36	11.25	2.2
13	508	2.2	9.4		7.17	3.85	0.36	11.38	2.2
14	508	1.3	9.7	↓	7.17	3.97	0.36	11.50	2.3
15	508	1.3	9.6	0.07	7.17	3.93	0.36	11.46	2.3
Average					7.21	3.79	(−0.44)	10.56	2.1

[1] BW, body weight; PGDM, pasture grass dry matter; ADG, average daily gain; M, maintenance.

than using products low in CP, such as molasses or cassava (11, 24).

When the genetic potential for milk yield of cows exceeds 3,000 kg, the results from the Gurabo Substation experiments show that increased yields obtained with supplements are economically feasible. Even though the pastures received heavy applications of nitrogen, there was a linear response to level of CP supplement. Supplementary feeding increased days in milk, peak yield during lactation, and persistency of milk yield but decreased fat percent. Supplement feeding at low levels increased breeding efficiency, but at high levels it decreased breeding efficiency.

Where high levels of milk yield and a uniform day to day output from a herd is the goal, pastures are unreliable. In this study, estimated intake from pasture ranged from 1.44 multiples of maintenance to 2.48. A similar range has been reported previously (11).

McDowell et al. (9) showed that when lactating cows were exposed for more than 6 hours per day to temperatures above 27°C, there was a significantly lower feed consumption compared to that on days when maximum daily temperature did not exceed 20°C. They also found that when lactating cows were fed a complete ration of 60% roughage and 40% concentrate, intake declined 8% from that at 17–20° C when the cows were exposed to 6 hours or more of 27° C heat. Rate of intake decreased to 17% when the daily temperature exceeded 30° C for 6 hours per day.

TABLE 16.—*Estimated pasture grass dry matter intake for T_6 cows*

Cycle	BW[1]	Milk attributable		ADG	Average daily PGDM intake				BW
		Supplement	PGDM		M	Milk	ADG	Total	
				kg					%
1	556	9.1	8.1	(−1.30)	7.67	3.66	(−4.74)	6.59	1.2
2	556	7.6	10.1	(−1.30)	7.67	4.64	(−4.74)	7.57	1.4
3	556	7.9	10.1	(−1.30)	7.67	6.26	(−4.74)	9.19	1.7
4	517	8.0	10.2	0.08	7.26	6.42	0.41	14.09	2.7
5	517	6.9	10.5	↓	7.26	6.91	0.41	14.58	2.8
6	517	7.4	9.3		7.26	4.47	0.41	12.14	2.4
7	508	6.0	10.2		7.17	4.83	0.41	12.41	2.4
8	508	5.6	10.2		7.17	4.83	0.41	12.41	2.4
9	508	5.1	10.1		7.17	4.71	0.41	12.29	2.4
10	511	4.6	10.2		7.20	4.83	0.41	12.44	2.4
11	511	0.0	6.5		7.20	2.38	0.41	9.99	2.0
12	511	0.0	6.4		7.20	2.35	0.41	9.96	2.0
13	511	0.0	6.1		7.20	2.28	0.41	9.89	1.9
14	511	0.0	5.9		7.20	2.21	0.41	9.82	1.9
15	511	0.0	5.7	0.08	7.20	2.09	0.41	9.70	1.9
Average					7.30	4.19	(−0.62)	10.87	2.1

[1] BW, body weight; PGDM, pasture grass dry matter; ADG, average daily gain; M, maintenance.

On grazing, the decline in intake was more dramatic: 12% at 27° C, and more than 50% when the maximum temperature exceeded 30° C for 6 or more hours per day. These authors concluded that supplementation with concentrate reduced the rate of decline in total energy intake under thermal stress. This conclusion suggests that supplementary feeding may decrease total heat production in the cow's body and thereby permit cows to perform more efficiently in a tropical environment.

The attractiveness of supplementary feeding is reduced by the following factors: the decline in PGDM intake by growing heifers at the Corozal Substation by 57 to 65% when fed 1.4 kg of maize per day as a supplement (24); the lowering of intake of lactating cows by 28–30% on a low level of supplement (groups T_3, T_5, T_6); and the even further lowering of intake by cows on high supplement (T_4). St. Louis et al. (20, 21) also found that supplementing cows and heifers on grazing with Stargrass hay or pellets made from maize plants brought about a marked decrease in PGDM intake. The lowering of PGDM intake, irrespective of type or level of supplement, indicates a strong substitution effect for cattle grazing tropical grass pastures. Yazman (24) showed that 300-kg heifers on heavily fertilized grass pastures, as the sole source of feed, consumed only 4 to 9% of the available PGDM. If utilization of total PGDM available is assumed to be this low, supplementary feeding will further lower the utilization, particularly if there is not a careful adjustment in stocking rate.

TABLE 17.—*Estimated pasture grass dry matter intake for T_4 cows*

Cycle	BW[1]	Milk attributable		ADG	Average daily PGDM intake				BW
		Supplement	PGDM		M	Milk	ADG	Total	
				kg					%
1	534	10.8	7.8	(−1.10)	7.44	9.32	(−4.01)	12.75	2.4
2	534	22.4	(−2.0)	(−1.10)	7.44	(−0.92)	(−4.01)	2.51	0.5
3	534	24.2	(−3.5)	(−1.10)	7.44	(−1.63)	(−4.01)	1.80	0.3
4	501	24.6	(−3.7)	0.17	7.09	(−1.73)	0.87	6.23	1.2
5	501	25.2	(−4.8)		7.09	(−2.20)	0.87	5.76	1.2
6	501	24.5	(−4.6)		7.09	(−2.11)	0.87	5.85	1.2
7	503	24.4	(−4.9)		7.11	(−2.21)	0.87	5.77	1.2
8	503	23.5	(−4.5)		7.11	(−2.07)	0.87	5.91	1.2
9	503	23.3	(−4.9)		7.11	(−2.21)	0.87	5.77	1.2
10	506	22.5	(−4.7)		7.15	(−2.12)	0.87	5.90	1.2
11	506	23.3	(−8.6)		7.15	(−3.64)	0.87	4.38	0.9
12	506	18.9	(−4.7)		7.15	(−2.02)	0.87	6.00	1.2
13	509	18.2	(−4.5)		7.18	(−1.94)	0.87	6.11	1.2
14	509	17.7	(−4.3)		7.18	(−1.85)	0.87	6.20	1.2
15	509	16.9	(−3.9)	0.17	7.18	(−1.71)	0.87	6.34	1.3
Average					7.19	(−1.26)	(−0.11)	5.82	1.2

[1] BW, body weight; PGDM, pasture grass dry matter; ADG, average daily gain; M, maintenance.

Perhaps the characteristics of grasses in a tropical environment lead to low intakes and high rate of substitution. High ambient temperature brings about rapid rate of maturity and increased cell wall content (CWC) in the grasses. This increase occurs in both temperate and tropical grasses but the change is more pronounced in tropical grasses. Average CWC for temperate grasses is about 35% at 20° C and increases to about 45% at 27° C. At corresponding temperatures the values are 53 and 63% for tropical grasses. As CWC increases, intake is lowered, rumination time is increased, and digestibility of CWC declines (9). Another consequence of high CWC is a decline in NE. When the CWC exceeds 50%, the NE per unit of TDN is only 78% of that for CWC of 35%. These observations pertaining to the influence of both CWC and heat stress on intake show that there are serious inhibitors to tropical grasses which will not likely be overcome entirely by grazing alone or with supplement. Because of the interaction effects of climatic conditions on forages and the cows, it is difficult at this time to provide guidelines on how best to utilize tropical grasses for feeding dairy cows with high potential for milk yield.

The present study, as well as others (9, 10, 20, 21, 24, 25), indicates a significant effect of stocking rate on tropical grass pasture quality which needs further investigation. The considerably higher milk yield with 5.0 cows per ha (T_7) supports this hypothesis. Also, the high yields of cows on limited concentrate supplement (T_5) suggest that the best forms and types of supplement are not as yet understood.

RESUMEN

Los registros de producción de leche, porcentaje de grasa láctea, peso del animal, reproducción y salud de 362 vacas en 506 partos se utilizaron para estimar la eficiencia de utilización de los pastos tropicales por vacas lactantes pastando exclusivamente o pastando con suplementación. Se evaluaron 7 sistemas de alimentación: pasto exclusivamente (T_1); pasto más suplementación con maíz molido (T_2); con melaza (T_3); con alimento concentrado (T_5) o con urea-melaza (T_6); a razón de 1.0 kg por cada 2.0 kg de leche en exceso de 10 kg de leche por día; o pasto más alimento concentrado a razón de 1.0 kg por cada 2.0 kg de leche, independientemente de la producción de leche, al usar una densidad de pastoreo de 2.5 (T_4) ó 5.0 (T_7) vacas por ha. Todos los sistemas de suplementación arrojaron producciones significativamente mayores de leche, grasa, y leche corregida para contenido de grasa, que las en el sistema de pasto exclusivamente (T_1). El contenido de grasa parece depender del consumo de los pastos. La suplementación también extendió el período de producción lechera. Se obtuvieron diferencias significativas entre los efectos de los sistemas de alimentación en cuanto a la ganancia de peso, el tiempo que tomó alcanzar la máxima producción de leche, el nivel de la producción máxima, la persistencia en la producción de leche, el intervalo entre el parto y la concepción subsiguiente, el tiempo desde el primer cruzamiento hasta la concepción y el intervalo entre partos. Los elevados niveles de suplementacción (T_4, T_7), aumentaron la ganancia de peso, la persistencia productiva y el tiempo necesario para alcanzar la producción máxima, pero disminuyó la eficiencia reproductiva. En los niveles medianos de suplementación (T_3, T_5, T_6), la eficiencia (Mcal/kg materia seca) de la utilización del suplemento para la producción de leche fue satisfactoria. Sin embargo, no occurrió lo mismo en los niveles elevados de suplementación (T_4, T_7). Los suplementos (concentrados) tan o más ricos en nitrógeno no pro-

teínico o proteína bruta que el maíz o la melaza, proveyeron una mejor eficiencia de utilización. Durante los primeros 150 días de lactancia (T_1), las vacas consumieron una media de 14.3 kg de materia seca del pasto por día, ó 2.9% del peso corporal. Las vacas en suplementación baja (T_2, T_3, T_5, T_6) arrojaron de 24 a 29% menos, y las que recibieron suplementación alta casi el 60% menos de consumo. El tipo de suplementación influyó limitadamente el consumo de la materia seca del pasto. Cuando el potencial genético para producir leche sobrepasó los 3000 kg, la alimentación suplementaria pareció económicamente factible. Aun con fertilización intensiva, se obtuvo una respuesta lineal con el nivel de suplementación proteínica. La alimentación suplementaria causó una alta tasa de sustitución en los pastos tropicales. Por esta razón, se reduce la eficiencia en el uso de la materia seca del pasto a menos que la densidad de pastoreo sea cuidadosamente ajustada.

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