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Milk yields from feeding maize silage and meat-and-bone meal to Friesian cows grazing a tropical grass and legume pasture

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Summary—Twenty Friesian cows in mid-lactation were used in a 2×2 factorial experiment to determine the responses in milk yield, milk composition and liveweight to maize silage supplement (3 kg dry matter/cow.d, or free access during the day) with or without a meat-and-bone meal supplement (5 silage: 1 meat-and-bone meal, on a dry matter basis). Cows grazed green panic (*Panicum maximum* var. trichoglume) and glycine (*Neonotonia wightii* cv. Tinaroo) mixed pastures at 2.5 cows/ha. Experimental treatments were maintained for eight weeks after which cows grazed as one group on unsupplemented pasture for a further eight weeks.

Milk yields averaged 14.7 and 16.0 kg/cow.d for the low and high silage levels ($P < 0.01$), and 15.8 and 14.8 kg/cow.d with and without meat-and-bone meal ($P < 0.05$). There was a residual effect of 1.2 kg milk/cow.d ($P < 0.05$) for eight weeks after the experimental period from feeding silage at the high level.

Feeding meat-and-bone meal reduced milk fat percentage from 3.61 to 3.30% ($P < 0.05$). Protein yield and the short-chain fatty acid (C4–C16) content of milk fat were increased by increasing the level of intake of silage ($P < 0.01$), while feeding meat-and-bone meal increased protein yield ($P < 0.05$), but decreased the short-chain fatty acid content of milk fat ($P < 0.05$). Cows lost an average of 15.2 kg liveweight at the low silage level and gained 6.7 kg at the high silage level ($P < 0.01$) over the eight weeks of experimental feeding.

The marked seasonality of pasture production in tropical and subtropical environments requires dairy farmers to provide supplemental feed for their cows during winter and spring. Silages are one such form of supplemental feed. Silages made from tropical grass or grass and legume pastures are not able to maintain milk yields of high producing cows because of their low digestible energy content (Esperance and Guerra 1978; Hamilton *et al.* 1978).

The use of forage maize as silage is a popular alternative on farms on the Atherton Tablelands and other dairying areas of Queensland where irrigation of temperate species is not possible. The high dry matter production per unit area of maize and the high digestible energy content of maize silage make it an ideal feed for high producing dairy cows (Phipps *et al.* 1976). Work with stall feeding has shown that diets based on maize silage require additional protein to produce higher milk yields (Huber and Thomas 1971; Phipps and Cramp 1978). Protein supplementation is not widespread for cows grazing tropical pastures because of its high cost and unproven benefits in terms of extra milk yield.

No work could be found reporting the use of maize silage for cows grazing a tropical pasture while information on how any response to maize silage might be varied by a protein supplement such as meat-and-bone meal for a tropical grazing situation, is not available. This experiment was designed to record the immediate and carry over responses in milk yield, milk composition and cow liveweight to two levels of a maize silage supplement and to evaluate the benefits of an additional protein supplement.

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Materials and methods

Location and climate

The experiment was conducted at Kairi Research Station, northern Queensland (17° 14'S, 145° 25'E and altitude 700 m) during the winter and spring of 1979. Average annual rainfall is 1294 mm with 15% falling between May and October. Rainfall (mm) data for the experimental period were:

	1979	*50 year mean*
May	28.0	55.6
June	80.0	40.0
July	32.4	25.2
August	12.5	22.8
September	9.1	18.5

Mean maximum temperatures ranged from 23.5°C in September to 19.9°C in July and minimum temperatures ranged from 15.6°C in July to 9.5°C in August.

Pasture

The experimental area was on a vigorous, weed-free, green panic (*Panicum maximum* var. trichoglume) and glycine (*Neonotonia wightii* cv. Tinaroo) pasture on a fertile krasnozem soil. The pasture had been established 17 years earlier and no fertilizer had been applied in the past ten years. The area was divided into eight paddocks each of one hectare.

Design

Twenty multiparous Friesian cows 7–12 weeks into lactation with an average weight of 503 kg were divided into five groups on the basis of milk yield in the four weeks before feeding, stage of lactation and liveweight, and within groups allocated at random to the four treatment groups. Treatments were as follows:

Silage	*Meat-and-bone meal*
3 kg DM/cow.d	nil (LU)
2.5 kg DM/cow.d	0.5 kg DM/cow.d (LS)
To appetite between 8 a.m. and 3 p.m.	nil (HU)
To appetite between 8 a.m. and 3 p.m.	In the ratio 5:1 (silage to meat-and-bone meal) on a DM basis (HS)

The maize silage was made in May 1979. Maize was cut to 1 cm and stored in above ground silos. No supplements were added to the silage. The meat-and-bone meal was a local preparation (North Queensland Bacon Factory Pty Ltd) commonly referred to as meatmeal.

Management

Cows in the low silage treatments were individually fed the supplement between 8 a.m. and 9 a.m., then returned to their paddocks. Cows in the high silage treatments remained in their stalls with access to supplement and water between 8 a.m. and 3 p.m. and returned to their paddocks at 4 p.m., after milking.

Cows were milked between 6.30 and 7.30 a.m. and 3.30 and 4.00 p.m. each day. Animals were stocked at 2.5 cows/ha and grazed through two pasture replications on a one week grazing, one week spelling rotation. A supplement containing salt and phosphorus was available to cows at the dairy, and drinking water was available both in the paddocks and at the dairy.

Cows entered the experimental area on May 8, 1979 and were adjusted to the supplements over 9 d. Experimental measurements were for eight weeks, from May 17 to July 10, after which the cows were returned to the main station herd and grazed without supplement and as one group on tropical grass and legume pastures at 2.0 cows/ha for a further eight weeks. The experiment finished on September 5, 1979.

Measurements

The milk yields of individual cows were recorded at each milking. A composite sample of afternoon and morning milk was taken once each week and analysed for butterfat (Milkotester MkII) and solids-not-fat (SNF) (hydrometric) each week, and total protein content once a fortnight (Pro-Milk MkII). A sample of milk from each cow was analysed for triglyceride fatty acid composition by the method of Aston (1977) in week one (May 22) and week eight (July 11). Cows were weighed once a fortnight after morning milking.

Pasture on offer in each paddock was sampled twice (May 15 and July 5) for dry matter yield and botanical and chemical composition. Eight 0.40 m^2 quadrats of pasture were cut in each paddock with hand shears to 3 cm above ground level. After the fresh samples were weighed, two subsamples were taken, one for dry matter determination and one for sorting into grass, legume, dead, and weed components. Samples were dried in a forced draught oven at 80°C for 24 h. Dried grass and legume samples were hammermilled through a 1 mm screen and analysed for crude protein content (Kjeldahl) and *in vitro* dry matter digestibility (Minson and McLeod 1972).

The botanical and chemical compositions of the cows' diet were determined on July 6 from four cows with oesophageal fistulas. Each paddock was sampled with two cows and the samples from these two cows were bulked. The samples were squeezed through muslin and a subsample dried at 70°C for 24 h, hammermilled and analysed for nitrogen and *in vitro* dry matter digestibility. Another subsample was separated into botanical components according to the technique of Chacon *et al.* (1977).

Samples of silage and meat-and-bone meal offered to cows were taken twice a week for dry matter determination (400 g at 80°C for 48 h). Feed refusals were weighted daily and dry matter determinations made once a week. Samples of both supplements were bulked during June and July for chemical analysis. The silage had 7.4% crude protein, a pH of 3.8 and 26.4% dry matter. The meat-and-bone meal averaged 51.1% crude protein with 5.8% phosphorus. Rumen degradability of nitrogen in the meat-and-bone meal was measured according to the technique of Mehrez and Orskov (1977) and showed that 34.2% of the total nitrogen was rumen soluble, with the remainder degrading at 0.72%/h.

Grazing time at pasture was measured between May 31 and June 14 with vibracorders (Stobbs 1970). Two cows from each treatment were recorded for 3 d on each pasture replication—a total of four cows per treatment.

Statistical analysis

Animal data were analysed by analysis of variance to isolate the effects of silage, meat-and-bone meal, and their interaction. The error term was estimated from animal to animal variation after an allowance was made for treatments and blocks. Milk yield, butterfat, SNF and milk protein were analysed with the corresponding measurements from April 17–May 8 as covariates.

Results

Milk yield

More milk was produced from the high levels of both silage ($P < 0.01$) and meat-and-bone meal ($P < 0.05$) during the experimental period (table 1). There was evidence of an interaction in milk yield ($P > 0.05$) between level of silage and provision of meat-and-bone meal (figure 1). Milk yield of cows supplemented with meat-and-bone meal was increased ($P < 0.05$) by 4% at the low level of silage and by 8.5% at the high level of silage. In week eight the difference in milk yield between the groups with and without meat-and-bone meal was 1.0 and 1.6 kg milk/cow.d ($P > 0.05$) for the low and high silage levels, respectively (figure 1).

Linear regression coefficients for the change in milk yield (kg/cow.week) from week one to eight were significant ($P < 0.05$) for both level of silage and level of meat-and-bone meal with values of -0.37, -0.32, -0.31 and -0.11 for LU, LS, HU and HS, respectively. After the experimental period cows that had received the high level of silage continued to produce more milk than those that had received the low level of silage ($P < 0.01$; table 1). There was no residual effect on milk yield for cows fed meat-and-bone meal ($P > 0.05$).

Milk composition and liveweight

Butterfat percentage was decreased by feeding meat-and-bone meal ($P < 0.05$) but was not changed by the level of silage (table 1). Feeding a high level of silage increased both SNF percentage ($P < 0.05$) and SNF yield ($P < 0.01$); whereas feeding meat-and-bone meal only increased SNF yield ($P < 0.05$; table 1). Milk protein percentage was not changed by either the level of silage or the provision of meat-and-bone meal. However protein yield was increased by both the increased level of silage ($P < 0.01$) and meat-and-bone meal ($P < 0.01$; table 1).

Cow liveweight was increased ($P < 0.01$) by feeding silage at the high level, but not by feeding meat-and-bone meal (table 1). Further evidence of an interaction between levels of silage and meat-and-bone meal was the negligible difference in weight loss between LU and LS and the 9.4 kg increase from HU to HS ($P > 0.05$).

Intake of supplement and grazing time

The total intake of supplement averaged over eight weeks was 7.9 and 7.0 kg DM/cow.d for cows in HS and HU, respectively ($P > 0.05$). Intakes ranged from 3.8–12.7 and 2.5–10.0 kg DM/cow.d for individual cows in HS and HU. Supplement intakes in weeks six–eight were higher and showed a smaller difference between HU and HS with levels of 8.5 and 8.7 kg DM/cow.d, respectively. There was no feed refusal by cows given the low levels of silage.

Cows given the low level of silage spent more time grazing ($P < 0.05$) at pasture than cows given the high level. Cows in HU spent 46 min more time grazing than cows in HS ($P > 0.05$; table 1).

Pasture composition and diet selectivity

Pasture yields were similar for all treatments at the start of the experiment (table 2). By week eight there was an

TABLE 1

Milk yield and composition, milk fatty acids, liveweight change and grazing time of cows during and after the experimental period.

Attribute	Low silage		High silage		Main effects		SE of
	U†	S	U	S	L vs H	U vs S	mean
Milk yield (kg/cow.d)							
Weeks 1–8	14.3	15.0	15.3	16.6	**	*	0.4
Weeks 9–16‡	13.6	14.0	15.0	15.0	**	NS	0.3
Fat (%)	3.66	3.38	3.56	3.23	NS	*	0.14
Fat yield (kg/cow.d)	0.51	0.51	0.55	0.54	NS	NS	0.02
Solids-not-fat (%)	8.38	8.42	8.54	8.49	*	NS	0.04
Solids-not-fat yield (kg/cow.d)	1.19	1.26	1.31	1.41	**	*	0.03
Protein (%)	2.86	2.86	2.85	2.77	NS	NS	0.04
Protein yield (kg/cow.d)	0.40	0.41	0.44	0.48	**	*	0.01
Milk fatty acids (Molar % C4–C16)							
Week 1	53.8	57.3	57.1	57.1	NS	NS	2.1
Week 8	54.6	51.5	61.5	56.6	**	*	1.5
Liveweight change (kg)							
Week 1–8	−15.0	−15.4	2.0	11.4	**	NS	6.5
Grazing time (min/24 h)	497	505	343	293	*	NS	78.1

† U, nil meat-and-bone meal; S, meat-and-bone meal provided in the ratio 5 : 1 (silage to meat-and-bone meal) on a dry matter basis.

‡ Covariance was not significant. Unadjusted means presented.

* $P<0.05$; ** $P<0.01$; NS $P>0.05$.

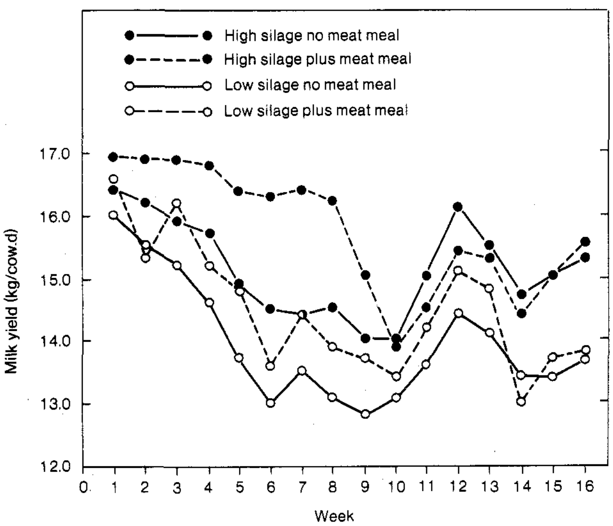

Figure 1 —Changes in covariate adjusted milk yield during the experimental period (weeks 1–8) and unadjusted milk yield after the experimental (weeks 9–16) period for each of the four supplement treatments.

extra 671 kg DM/ha ($P > 0.05$) in the paddocks grazed by cows fed the high level of silage, compared with the paddocks grazed by cows fed the low level. Legume content of pasture increased and grass content declined over the experimental period. This is consistent with the seasonal pattern of growth found in this environment.

The crude protein content of grass increased from 10.0% in week one to 11.6% in week eight while crude protein content of legume rose from 15.9% to 17.3% over the same period. *In vitro* DM digestibility also increased with time from 49.3% to 54.8% for grass and 59.5% to 62.5% for legume from week one to week eight.

The botanical compositions of the diet of cows in week eight for each treatment are presented in table 2. Cows given the low level of silage had a dietary crude protein content of 13.6%, compared with 17.7% for cows given the high level of silage. *In vitro* DM digestibility of the diet averaged 52.5% and 62.5% for low and high silage treatments, respectively.

TABLE 2

Pasture yield and botanical composition in week one and week eight of the experiment and diet composition in week eight.

Attribute	Low silage		High silage		LSD
	U†	S	U	S	(P = 0.05)
Pasture yields and composition					
May 15					
Total yield (kg DM/ha)	3559	3324	3458	3585	1326.4
Grass (%)	28.1	31.1	44.5	30.3	72.2
Legume (%)	44.5	44.7	43.5	55.3	61.6
Dead (%)	27.2	23.5	11.0	14.2	24.3
Weed (%)	0.3	0.8	1.1	0.4	2.3
July 5					
Total yield (kg DM/ha)	2192	2181	2733	2981	540.1
Grass (%)	9.9	17.7	27.8	21.5	52.2
Legume (%)	71.1	60.6	59.5	65.6	71.6
Dead (%)	19.0	21.7	12.7	12.9	21.0
Weed (%)	0.0	0.0	0.0	0.0	—
Composition of diet (July 6)					
Grass leaf (%)	21.5	24.0	27.2	28.6	69.7
Grass stem (%)	18.1	25.0	20.0	20.3	26.1
Legume (%)	34.9	38.8	40.4	40.1	115.1
Dead (%)	25.6	12.4	12.5	11.2	31.1

† U, nil meat-and-bone meal; S, meat-and-bone meal provided in the ratio 5 : 1 (silage to meat-and-bone meal) on a dry matter basis.

Discussion

Our experiment has shown that a protein supplement would be needed to produce maximum milk yields when fed in combination with maize silage to cows grazing a tropical grass and legume pasture and that the response to the protein supplement will increase with increasing level of silage. From the crude protein content of samples of maize silage and meat-and-bone meal as well as those obtained through the oesophageal fistulas and the known supplement intakes, it is possible to estimate dietary protein intakes. Total intakes were assumed at 12.7 kg DM or 2.53% of body weight (National Research Council 1978) for high silage cows and 11 kg DM for low silage cows (Cowan *et al.* 1977). These calculations give daily crude protein intakes of 1.3 kg (11.9%), 1.5 kg (13.9%), 1.5 kg (12.0%) and 2.0 kg (15.8%) for LU, LS, HU and HS, respectively. Milk yields increased linearly with increasing crude protein intake consistent with the review by Cowan (1980) who showed that cows in mid-lactation respond linearly in milk yield up to 2.5 kg crude protein/day.

Both this experiment and that of Minson (1980) on unprotected casein, showed that total grazing time was reduced by approximately 40 min for each kilogram of supplement fed. If it is assumed that intake of pasture is directly proportional to grazing time (Minson 1980) and the value of 11 kg DM for pasture intake by unsupplemented cows in mid-lactation on grass and legume pasture in this environment is used (Cowan *et al.* 1977) then the National Research Council (1978) value of 12.7 kg DM/d for intake of the high silage cows can be checked. Under our assumptions pasture intakes for HU and HS would be 5.5 and 4.7 kg DM/cow.d or total intakes of 12.5 and 12.6 kg DM/cow.d when supplement intakes are added.

In this study cows grazing grass and legume pasture with only silage as a supplement appeared to be deficient in amino acids since meat-and-bone meal increased milk yield by 4% at the low silage level and by 8.5% at the high level. Work by Stobbs *et al.* (1977) and Flores *et al.* (1979) on tropical grass pastures demonstrated milk yield responses from 5 to 20% with formaldehyde-treated casein as a supplement. Meat-and-bone meal supplementation in this study produced almost exactly the same patterns in milk yield and composition as for protected or post-ruminally administered casein in that it increased milk yield, produced milk with a lower fat percentage, similar fat yield and high protein yield than cows not fed meat-and-bone meal (Clark 1975). While it is accepted that a protein supplement of low solubility such as meat-and-bone meal will lead to an increase in the supply of duodenal protein and increased nitrogen retention (Derrig *et al.* 1974; Clark 1975; Majdoub *et al.* 1978) the exact mechanism for increased milk production has yet to be established. Glucose yields, amino acids and hormone secretion or a combination of these factors have been implicated in the improved performance (Machlin 1973; Clark 1975).

The high level of silage feeding demonstrated the strong response in milk yield that occurs with tropical pastures, when high energy supplements are fed. Higher levels of C4–C16 milk fatty acids, SNF percentage and liveweight change clearly indicated that cows on high silage treatments were consuming a more digestible energy intake than cows on low silage (Rook and Line 1961; Stobbs and Brett 1974). The levels of milk fatty acid, SNF percentage and liveweight change also show that while cows in HU and LS had similar milk yields, LS cows were depleting body reserves to maintain this milk yield. If LS cows continued to maintain this level of production for an extended period, then milk yield in a subsequent lactation would be decreased due to reduced body condition (Broster 1974).

The question of obtaining maximum milk yields and economic milk yields from each treatment are compared in table 3. As there was no divergence in milk yield after week five (figure 1) similar to our experience with grain supplementation (Cowan *et al.* 1977), milk yields between weeks six and eight were used. The margin of milk income over feed costs show that the most profitable treatment was LS with both HU and HS more profitable than LU. As the dry matter content of maize silage is increased to 30%, the level at or above which silage is made commercially (J. Harris, personal communication), there is no difference in profitability between LS, HU and HS. Further increases in dry matter content make HU and HS more profitable (table 3). These comparisons refer only to immediate milk yields for cows in mid-lactation and do not take account of carry over responses in milk yield recorded for cows in HU and HS. As in other experiments it would be expected that cows in early lactation would show greater responses to the same level of energy and protein supplements applied here (Gordon 1977).

TABLE 3

Margin of milk income over silage and meat-and-bone meal costs at three dry matter levels of silage, according to milk yield and supplement intakes from weeks 6–8 of the experiment for low and high silage levels, with and without meat-and-bone meal.

Attribute	Low silage		High silage	
	U†	S	U	S
Milk yield (kg/cow.d)	12.9	13.9	14.6	16.4
Milk income‡ (c/cow.d)	271	292	307	344
Cost (c/cow.d)				
Silage A§	17	14	49	41
Silage B	15	13	43	36
Silage C	13	11	37	31
Meat-and-bone meal	0	15	0	44
Margin (c/cow.d)				
Milk over feed costs with silage A	254	263	258	259
Milk over feed costs with silage B	256	264	264	264
Milk over feed costs with silage C	258	266	270	269

† U, nil meat-and-bone meal; S, meat-and-bone meal provided in the ratio 5:1 (silage to meat-and-bone meal) on a dry matter basis.

‡ Based on a milk price of 21c/kg.

§ Silage A, 26.4% DM, grown and fed at 5.7c/kg.
Silage B, 30.0% DM, grown and fed at 5.0c/kg.
Silage C, 35.0% DM, grown and fed at 4.3c/kg.
Meat-and-bone at 30c/kg.

The carry over effect on milk yield from feeding a high level of silage in mid-lactation is in contrast to the work of Broster *et al.* (1969) where milk yield and liveweight of cows increased during the period of extra concentrate supplementation, in weeks 10–18 of lactation, with no residual effect on milk yield. In our experiment pasture on offer declined from week 9 to 16, largely as a result of moisture stress, and the carry over effect observed highlights the importance of body reserves in determining milk yield from cows grazing tropical pastures in late winter and spring (Cowan *et al.* 1975). The carry over effect on milk yield in weeks 9–16 also has important economic implications for the feeding of maize silage. If maize silage costs 1.5c/kg fresh silage grown and fed (P. Hardman, personal communication) the extra silage eaten by the high silage cows during weeks 1 to 8 cost $11.20 for a return in milk (21c/kg) of an extra $14.11 in weeks 9–16. There was no carry over effect on milk yield by cows fed meat-and-bone meal. This was shown in the sudden drop in milk yield in weeks 9–10 of cows previously fed meat-and-bone meal and reflects the inability of cows to store large reserves of labile protein (Paquay *et al.* 1972).

This experiment has produced one of the highest daily milk yields for cows grazing a supplemented tropical pasture (Stobbs 1976) and shown that milk yield responses occurred to both energy and protein supplementation. Further work needs to be done to define responses to maize silage with different levels and sources of protein supplementation for cows in early and late lactation. How such responses vary with different allocations of pasture and silage are the questions to which applied research need address itself.

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