Effects of Natural Grass Forage to Concentrate Ratios and Feeding Principles on Milk Production and Performance of Crossbred Lactating Cows

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ABSTRACT : Two experiments were conducted to evaluate the effects of forage:concentrate ratios and feeding principles on milk yield, milk composition, body weight change, postpartum oestrus and feed cost. A total of 36 crossbred F1 cows (Holstein Friesian× Local Yellow) in the 8th week of lactation were used. In each experiment, animals were divided into three groups using a randomized block design according to the milk yield of the previous eight weeks. Cows were fed 30, 50 and 70% concentrate in the diet based on DM. In experiment 1 (Fc), cows were given the same amount of DM with constant ratios of forage and concentrate within treatments. In experiment 2 (Fa), cows were given the same constant amounts of concentrate as in experiment 1 and *ad libitum* forage. The forage consisted of a natural grass mixture based on 5 species of grasses with high nutritive values. There was no difference in total DM intake between treatments within experiments. However, cows fed forage *ad libitum* had higher DM intakes compared to cows fed constant forage (1.6, 4.5 and 9.5% for cows fed 70, 50 and 30% forage, respectively). Daily milk yield of cows fed forage *ad libitum* was higher than that of cows fed constant forage:concentrate ratio. Within experiment, milk yield was highest for cows fed 30% DM forage, followed by cows fed 50% and then cows fed 70% forage (11.17, 10.98 and 10.71 for the 30Fc, 50Fc and 70Fc cows; 11.73, 11.16 and 10.81 kg for the 30Fa, 50Fa and 70Fa cows, respectively). Decreased forage ratio in the diets resulted in decreased milk fat content and tended to increase milk protein. Increased concentrate ratio in the diet and feeding forage *ad libitum* increased body weight gain. The effect of forage:concentrate ratio on postpartum oestrus was not significant. The feed cost per kg milk produced was lowest for the cows fed 70% forage. It is concluded that increased ratio of concentrate resulted in increased body weight gain, milk yield, milk protein, and decreased milk fat. Feeding forage *ad libitum* increased feed intake, milk yield and body weight gain. The ratio of 50% forage is more suitable for milk production and animal condition, but in terms of feed cost and under the conditions of small dairy farmers, the 70% *ad libitum* forage feeding is recommended. ***(Asian-Aust. J. Anim. Sci. 2002. Vol 15, No. 5 : 650-657)***

Key Words : Crossbred Cows, Natural Grass, Forage:Concentrate Ratio, Milk Production, Postpartum Oestrus, Body Weight Change

INTRODUCTION

In many regions of the tropics and sub-tropics, feeds for ruminants are primarily based on natural pasture resources and/or crop residues. Because attempts to improve the quality or quantity of nutrient supplies through grass and legume cultivation are constrained by variable rainfall and several other factors, the emphasis of research strategies in such circumstances has generally been directed at improvement of efficiency in milk production by genetic improvement of cows rather than nutritional means (Cronje, 2000). However, due to harsh environments and disease problems, most of the tropical dairy cows are crossbred, with about 50% dairy breed, and thus have not been selected for high milk production. The genetic potential is around 10 to 15 kg milk per day at peak production or up to 3,000 kg per lactation (Cunningham and Syrstad, 1987).

Feeds and ration formulation are important factors affecting milk yield and milk composition of dairy cows. The feeds often constitute about 70% of the total cost of milk production. Therefore it is important in ruminant nutrition to minimize the cost of a diet by including cheap but often fibrous materials, while ensuring an adequate supply of digestible nutrients. We need to know more about how ruminants trade off the various factors tending to stimulate or inhibit feeding, especially the balance between nutrients and fibre (Forbes and Provenza, 2000). Nutrient levels of tropical pastures are below the requirements for optimum milk production (Butterworth, 1967). Increasing the concentrate ratio in the diet results in increased energy intake, but will lead to decreased forage intake if energy intake is to meet animal requirements.

Several studies on feeds and ration formulation for high yielding cows have shown positive relationships between increased ratio of concentrate and feed intake, milk yield and body weight gain. In some of the studies, negative relationships have been found between ratio of concentrate:roughage and milk fat content (Oldham and Sutton, 1979; Sporndly, 1986). These relations have been well documented by Macleod et al. (1983) in their studies of forage:concentrates ratios from 80:20 to 35:65. They found that as the proportion of concentrate increased, daily DM intake increased linearly, and milk yield, milk protein content and body weight increased, while milk fat content decreased. Changes towards lower forage:concentrate ratios

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in total mixed rations fed *ad libitum* to dairy cows also resulted in higher total intake of DM and energy as well as milk yield (Moseley et al., 1976). In tropical environments, Mahal et al. (1997) found that daily DM intake differed (10.4, 10.2 and 9.9 kg) between groups fed roughage and concentrates in the ratios 50:50, 60:40 and 70:30, respectively. Tuan (2000) also showed that when increasing the concentrate ratio in the diet from 30 to 45 percent the digestibility of organic matter and crude protein were improved and the milk yield increased, but there was no effect on milk composition.

In the North of Vietnam, which has a tropical climate, dairy cows are traditionally kept in semi-intensive systems and are fed mainly natural grasses, crop residues and by-products from processing industries with a small amount of concentrate. There have been only a few experiments on crossbred lactating cows reported where the effects of forage:concentrate ratios based on natural grass species and mainly crop by-products as concentrates have been studied. The present studies aimed to investigate the effects of different ratios of natural grasses and concentrates on milk production and performance of lactating cows, fed according to two principles of forage supply, either *ad libitum* forage with different amounts of concentrates, or at constant forage/concentrate ratios.

MATERIALS AND METHODS

Experimental design and ratio of forage to concentrate

A total of 36 crossbred F1 cows (Holstein Friesian×Vietnamese Local Yellow) in the 8th week of lactation, with a body weight of about 400 kg and lactation number from three to five, were divided into two experiments with three groups in each, with a randomized block design according to the milk yield of the previous eight weeks. The entire experimental period was 16 weeks, from week 9 to week 24 of lactation.

Feeding standards were based on the National Research Council, USA, recommendations (NRC, 1988): for maintenance: 0.56 MJ metabolisable energy (ME) and 3.5 g crude protein (CP) per 1 kg $BW^{0.75}$ and 16 g Ca, 11 g P for a 400 kg cow; for milk production: 5.19 MJ ME, 90 g CP, 3.21 g Ca and 1.98 g P per 1 kg fat corrected milk (FCM) produced; for weight gain: 35.77 MJ ME and 320 g CP per 1 kg weight gain, for weight loss: -34.52 MJ ME and -320 g CP per 1 kg weight loss.

The ration was formulated based on body weight and daily milk yield at the beginning of the experiment (8th week of lactation). The cows in the two experiments were given different ratios of forage (F) to concentrates (C) with 70F:30C (70F), 50F:50C (50F) and 30F:70C (30F) based on dry matter (DM). In experiment 1, all cows were given a constant amount of DM throughout the entire experiment with the three constant ratios of concentrates and forage. In experiment 2, the cows were given constant amounts of concentrate at three levels as in experiment 1 and forage *ad libitum*. The condition for *ad libitum* was that the residues should never be less than 10%. The experimental schedules are shown in table 1.

Feeds and feeding

The concentrates included compound feed and brewers' grains. The compound feed, which was mixed every two weeks, consisted of rice bran (50%), cassava meal (20%), maize bran (15%) and groundnut cake (15%). A mineral premix was added at a level of 1%. Brewers' grains was supplied daily by a local beer factory. The natural grasses consisted mainly of Wire grass *(Cynodon dactylon (L.) Pers)*, Goose grass *(Eleusine indica (L.) Gaertn)*, Creeping panic grass *(Panicum repens L.)*, Honey grass *(Melinis minutiflora SW.)* and Green grass *(Paspanum conjugatum Berg)*. The grasses were cut every morning and supplied to the barn once daily. At cutting about 10 cm stubbles or 25-35% of the forage height was left. The chemical composition and nutritive value of the feeds are shown in table 2.

The total digestible nutrients (TDN), digestible energy (DE) and metabolisable energy (ME) of the feeds were calculated by the models used and cited in the "Composition and Nutritive Value of Animal Feeds in

Table 1. The ratio (%) of forage (F) and concentrate (C) in the two experiments

Group of animals	Number of animals	Ratio of forage	Ratio of concentrate	Treatments
Experiment 1	18	Constant	Constant	
Group 1	6	70	30	70Fc
Group 2	6	50	50	50Fc
Group 3	6	30	70	30Fc
Experiment 2	18	*ad lib.*	Constant	
Group 1	6	*ad lib.*	30	70Fa
Group 2	6	*ad lib.*	50	50Fa
Group 3	6	*ad lib.*	70	30Fa

Fc: constant forage. Fa: *ad libitum* forage.

Table 2. Chemical composition and nutritive values of feed used in the two experiments. Mean values and standard deviation (n=8)

Item	Natural grasses	Brewers' grains	Compound feed
DM (%)	20.4 (±0.8)	22.4 (±0.5)	89.3 (±0.9)
CP (g/kg DM)	121.9 (±19.0)	313.5 (±17.2)	149.4 (±5.8)
EE (g/kg DM)	24.1 (±6.9)	82.2 (±6.7)	33.9 (±4.0)
CF (g/kg DM)	269.5 (±25.3)	141.7 (±19.3)	84.0 (±7.0)
NFE (g/kg DM)	508.3 (±41.5)	400.9 (±48.5)	650.7 (±13.9)
Ca (g/kg DM)	5.3 (±1.0)	3.0 (±1.0)	16.6 (±4.4)
P (g/kg DM)	2.1 (±1.2)	6.1 (±0.9)	8.8 (±0.8)
ME (MJ/kg DM)	9.7 (±0.3)	11.5 (±0.4)	11.1 (±0.1)

Vietnam" (National Institute of Animal Husbandry, 1995):

TDN grass = -21.7656 + 1.4284 CP + 1.0277 NFE + 1.2321 EE + 0.4867 CF

TDN compound feed = 40.2625 + 0.1969 CP + 0.4228 NFE + 1.1903 EE - 0.1379 CF

TDN brewers' grains = 40.3227 + 0.5398 CP + 0.4448 NFE + 1.4218 EE - 0.7007 CF

Where CP is crude protein, NFE is nitrogen free extractives, EE is ether extract and CF is crude fiber of feed on a dry matter basis (calculated by percent).

DE (Mcal/kg DM) = 0.04409 TDN

ME (Mcal/kg DM) = 0.82 DE

Natural grasses were given 3 times daily at 09:00, 13:00 and 19:00 h, while concentrates were given twice daily during milking. Water was available at all times in a water trough, which was cleaned every day.

Environmental conditions and animal management

The research farm is situated inside the boundary of Hanoi City, Vietnam, in an area where the average temperature is 23.5°C (16.4-28.9°C), relative humidity is 84% (81-89%) and mean rainfall is 1,680 mm per year. The cows were kept in a concrete barn and separated from their calves. They were tied up and fed individually indoors with daily exercise in a small area for a few hours during cleaning time. They were milked twice daily by hand at 04:00-06:00 and 16:00-18:00 h.

Data collection and sample analysis

Milk yield was recorded at every milking and milk composition was analyzed every 2 weeks. Cow body weight was taken every 4 weeks in the morning before feeding. Postpartum oestrus was checked daily by visual observation and recorded. Data for individual animals on daily milk yield, daily feed intake, milk composition, body weight and postpartum interval to first oestrus were collected. Feed conversions, rate of yield decrease and feed costs were calculated.

The feeds were weighed at every feeding and feed refusals were weighed daily in the morning before the next feed was given. Grasses, compound feed and brewers' grains composition was analyzed every 2 weeks.

Chemical analysis

Proximate parameters were analyzed by standard methods of the Association of Official Analytical Chemists (AOAC, 1990). Dry matter (DM) was determined by oven drying at 100-105°C for 6-8 h, total nitrogen (N) by the Kjeldahl method and crude protein (CP) calculated from N (CP=N×6.25 for feed and CP=N×6.38 for milk), ether extract (EE) by the Soxhlet system, crude fiber (CF) by the Weende method, and calcium (Ca) and phosphorus (P) by procedures of the AOAC. Milk fat was analyzed by the Gerber method.

Statistical analysis

The data was analyzed by using the General Linear Model in MINITAB program release 12.21 (1998). Analysis of variance was done for all parameters. For milk yield, an adjustment was made using each cow's daily milk yield for the previous week as covariate.

The mathematical model used was: $Y_{ij}=\mu+b_i+f_j+\varepsilon_{ij}$

Where μ is overall mean, b_i is effect of i_{th} block, f_j is effect of ratio of forage to concentrate and ε_{ij} are errors.

RESULTS

Daily feed intake

There was no difference in total daily DM intake, but, as planned, there were differences in natural grass DM and compound feed intake among the treatments in the two experiments (table 3). In the constant forage feeding experiment (Exp. 1) where both the amount and ratios of forage and concentrate were constant within treatments, the feed intake during the experiment were almost kept at the planned levels due to small amounts of residues. In the *ad libitum* feeding experiment (Exp. 2), the forage intake was only slightly below the planned level for the cows on treatment 70Fa, but increased above the planned levels for the cows on 50Fa and 30Fa, reducing the ratios of concentrate to 47.2 and 63.3% and thus increasing the ratios of forage to 52.8 and 36.7%, respectively. As a consequence of the increased concentrate ratios, the total ME and CP intake increased in both experiments. The increase was even more pronounced in cows fed *ad libitum* forage compared to cows fed a constant forage ratio. Compared to the 70Fc cows, the ME intakes of the 50Fc and 30Fc cows were greater by 2.8% and 5.0% respectively; at *ad libitum* forage feeding, the ME intake of the 50Fa and 30Fa cows increased by 5.6% and 12.3%, respectively, compared to the

Table 3. Daily feed intake, least square means and SEM

Item	Experiment 1				Experiment 2			
	70Fc	50Fc	30Fc	SEM	70Fa	50Fa	30Fa	SEM
No. of cows	6	6	6		6	6	6	
DM feed intake (kg)	10.74	10.76	10.69	0.29	10.91	11.25	11.71	0.42
DM natural grasses (kg)	7.41[a]	5.45[b]	3.28[c]	0.15	7.53[a]	5.92[b]	4.26[c]	0.21
DM brewers' grains (kg)	2.24	2.24	2.24	0	2.24	2.24	2.24	0
DM compound feed (kg)	1.08[a]	3.07[b]	5.17[c]	0.17	1.15[a]	3.09[b]	5.21[c]	0.35
Ratio of concentrate (%)	31.0[a]	49.4[b]	69.3[c]	0.3	31.1[a]	47.2[b]	63.3[c]	1.5
Ratio of forage (%)	69.0[a]	50.6[b]	30.7[c]	0.3	68.9[a]	52.8[b]	36.7[c]	1.5
ME (MJ)	109.5	112.6	115.0	3.1	111.2	117.4	124.9	4.5
CP (kg)	1.77	1.82	1.87	0.04	1.79	1.88	2.00	0.06
CF in diet (%)	22.4[a]	18.9[b]	15.3[c]	0.1	22.4[a]	19.3[b]	15.5[c]	0.1
Ca (g)	7.4[a]	10.1[b]	12.9[c]	0.3	7.5[a]	10.4[b]	13.5[c]	0.7
P (g)	4.5[a]	5.9[b]	7.4[c]	0.2	4.6[a]	6.1[b]	7.7[c]	0.3
ME/kg DM (MJ)	10.2	10.5	10.8	0.3	10.2	10.4	10.7	0.4
CP/kg DM (g)	165	169	175	4	164	167	171	5
DM intake/body weight (%)	2.8	2.7	2.8	0.1	2.7	2.8	2.9	0.1

Fc and Fa are ratios of forage with constant and *ad libitum* amounts, respectively (see table 1).
[a,b,c] Means in the same row and same experiment with different superscripts differ at $p<0.05$.

70Fa cows. The CP intakes also increased following the increase of concentrate ratio. The DM intake of the 70Fa, 50Fa and 30Fa cows increased by 1.6, 4.5 and 9.5%, respectively, causing increased ME intakes of 1.6, 4.3 and 8.6% compared to the 70Fc, 50Fc and 30Fc cows, respectively.

Milk yield and milk composition

Milk yield and milk composition are shown in table 4. In the constant forage feeding experiment, the milk yield was significantly higher on treatment 30Fc than on 70Fc ($p<0.05$). In the *ad libitum* feeding experiment, there were differences in milk yield among the three treatments ($p<0.05$). The milk yield of the 30Fa cows was 5.1 and 8.5% higher than that of the 50Fa and 70Fa cows, respectively. Milk yield of the 70Fa, 50Fa and 30Fa cows increased by additional 1.0, 1.6 and 5% compared to the 70Fc, 50Fc and 30Fc cows, respectively. The rate of decrease was lower for the cows fed *ad libitum* forage than that for cows fed constant forage, and was highest for the cows fed 70% forage, followed by the 50F and then the 30F cows. There was no significant difference in the rate of decrease for cows fed constant forage (2.3, 2.0 and 1.8% weekly), but the difference was significant ($p<0.05$) for cows fed *ad libitum* forage (2.1, 1.8 and 1.4% weekly). The protein content of the milk did not differ, although it tended to increase following increasing ratios of concentrate. The fat content increased with higher forage ratio in both experiments; the difference was significant ($p<0.05$) between the cows fed 70% forage and cows fed 30% forage (4.30 vs. 4.09% in experiment 1 and 4.31 vs. 4.15% in experiment 2, respectively).

Body weight change and postpartum oestrus

No difference in body weight gain was observed between the cows fed 30% and 50% forage, while it was significantly lower in the cows fed 70% forage ($p<0.05$) in both experiments. The cows fed *ad libitum* forage had

Table 4. Milk yield, milk composition and rate of decrease, Least square means and SEM

Item	Experiment 1				Experiment 2			
	70Fc	50Fc	30Fc	SEM	70Fa	50Fa	30Fa	SEM
No. of cows	6	6	6		6	6	6	
Daily milk yield (kg)	10.71[a]	10.98[ab]	11.17[b]	0.51	10.81[a]	11.16[b]	11.73[c]	0.8
Rate of decrease (%/week)	2.3	2.0	1.8	0.1	2.1[a]	1.8[b]	1.4[c]	0.1
Milk protein (%)	3.46	3.51	3.50	0.05	3.33	3.43	3.45	0.05
Milk fat (%)	4.30[a]	4.17[b]	4.09[b]	0.04	4.31[a]	4.20[b]	4.15[b]	0.03
Daily FCM (kg)	11.17	11.29	11.33	0.57	11.19	11.54	12.02	1.44
Daily milk fat (g)	459.9	458.9	457.6	23.5	461.8	472.3	487.9	5.9

Fc and Fa are ratios of forage with constant and *ad libitum* amounts, respectively (see table 1).
[a,b,c] Means in the same row and same experiment with different superscripts differ at $p<0.05$.

higher body weight gain compared to the cows fed constant forage (16.7, 28.7 and 32.8 kg compared to 7.8, 19.7 and 16.8 kg for the 70F, 50F and 30F cows, respectively).

The number of days to first oestrus was similar in the two experiments. However, the cows in both experiments fed 70% forage had the longest interval compared to the cows in the other groups. All the cows showed oestrus before 4 months after calving (table 5).

Total feed intake and feed conversion

The total feed intake and feed conversion are shown in table 6. The ME conversion per kg milk produced after correction for body weight gain did not differ ($p>0.05$) in both experiments (5.51, 5.10 and 5.48 MJ for the 70Fc, 50Fc and 30Fc cows and 5.20, 5.11 and 5.38 MJ for the 70Fa, 50Fa and 30Fa cows, respectively).

Feed cost for milk production

If applying actual feed costs at the time of the experiments, no difference in total feed cost could be found between the two experiments, but within each experiment the differences between the treatments were significant ($p<0.05$) (table 7). The feed cost per kg milk produced was lowest for the cows fed 70% forage, followed by the cows fed 50% forage and then the cows fed 30% forage. The feed cost, including body weight change, was 1,430, 1,730 and 2,030 VND for the 70Fc, 50Fc and 30Fc, and 1,400, 1,740 and 2,000 VND for the 70Fa, 50Fa and 30Fa cows, respectively.

DISCUSSION

The forage used in these experiments was a mixture of different species of natural grasses. These grasses did not contain any thick, fibrous stems like elephant grass, and had higher crude protein and lower crude fibre content compared to crop residues or even to planted grasses such as elephant grass. The five main species made up more than 90% of the total DM. They are known to have high nutritive content as expressed in "Composition and Nutritive Value of Animal Feed in Vietnam" (National Institute of Animal Husbandry, 1995), with a range of 9.1 to 9.7 MJ ME and 108 to 129 g CP per kg DM. In the countryside, natural grasses grow easily in areas where people cannot cultivate crops. They are available around the year and farmers can collect them in the field, along the roads or river dykes. In small dairy farms, natural grasses are an important source of available fodder for animals.

Increased concentrate ratio of the rations resulted in higher milk yield in both experiments, reflecting the positive effects of higher concentration per kg DM of ME and CP, which often also results in higher feed intake at *ad libitum* feeding of forage. The increase in total feed DM intake at *ad libitum* forage and increasing amounts of concentrate was, however, not statistically significant. The substitution rate of the natural grasses was 0.8 kg DM per 1.0 kg DM increase of concentrates both in the interval 70Fa to 50Fa and 50Fa to 30Fa (table 3). These substitution rates are comparatively high, particularly at the lower concentrate levels, but frequently reported in other studies with large amounts of concentrates (Faverdin et al., 1995).

Several authors have shown positive relationships between ratio of concentrate and dairy cow performance. These are related to high ratio of concentrate in the diet, resulting in increased digestibility of DM and OM, and higher energy and CP content (Castro et al., 1991; Gonda et al., 1996). Most of the studies have been carried out with temperate feeds and cows yielding above 20 kg milk/day. From studies by Macleod et al. (1983), Raab (1994) and Okine et al. (1997) it can be concluded that within the range of forage:concentrate ratios of 80:20 to 35:65, total feed intake and milk yield were increased. Macleod et al. (1983) stated that the DM intake increased until the hay ratio was reduced to about 58% of the diet. In the quoted studies milk yield increased by 10-15%. In tropical areas, Singh et al. (1972) and Tuan (2000) found a significant increase in milk yield with increased amounts of concentrate. In addition, Tuan (2000) showed that increased concentrate ratio

Table 5. Body weight (BW) change and the first observed postpartum oestrus, Least square means and SEM

Item	Experiment 1				Experiment 2			
	70Fc	50Fc	30Fc	SEM	70Fa	50Fa	30Fa	SEM
Number of cows	6	6	6		6	6	6	
Initial BW (kg)	381	396	378	11	398	403	392	15
BW after 4 weeks (kg)	382	399	380	11	398	406	397	15
BW after 8 weeks (kg)	384	402	385	11	402	411	406	15
BW after 12 weeks (kg)	388	409	393	11	407	420	415	15
BW after 16 weeks (kg)	389	416	395	11	415	432	425	15
Total gain (kg)	7.8^{a}	19.7^{b}	16.8^{b}	1.1	16.7^{a}	28.7^{b}	32.8^{b}	1.8
Postpartum oestrus (days)	108	98	102	7	112	103	100	8

Fc and Fa are ratios of forage with constant and *ad libitum* amounts, respectively (see table 1).
^{a,b} Means in the same row and same experiment with different superscripts differ at $p<0.05$.

Table 6. Total feed intake, milk yield, body weight gain and calculated feed conversion in the whole experimental period, Least square means and SEM

Item	Experiment 1				Experiment 2			
	70Fc	50Fc	30Fc	SEM	70Fa	50Fa	30Fa	SEM
No. of cows	6	6	6		6	6	6	
Total DM intake (kg)	1,202	1,205	1,197	33	1,221[a]	1,260[b]	1,311[c]	47
Total ME intake (MJ)	12,262	12,609	12,876	345	12,458	13,148	13,987	507
Total CP intake (kg)	198,0	204,4	209,9	4,5	200.5	211.2	223.9	6.7
Total milk produced (kg)	1,197[a]	1,233[ab]	1,251[b]	60	1,209[a]	1,249[b]	1,313[c]	87
Body weight gain (kg)	7.8[a]	19.7[b]	16.8[b]	1.1	16.7[a]	28.7[b]	32.8[b]	1.3
ME for weight change (MJ)	280[a]	703[b]	602[b]	44	596[a]	1,025[b]	1,174[b]	67
CP for weight change (kg)	2.5[a]	6.3[b]	5.4[b]	0.4	5.3[a]	9.2[b]	10.5[b]	0.6
ME for maintenance (MJ)	5,361	5,609	5,377	151	5,609	5,712	5,665	143
CP for maintenance (kg)	33.5	35.1	33.6	0.9	35.1	35.7	35.4	0.8
ME for milk production (MJ)	6,621	6,296	6,896	427	6,252	6,410	7,146	517
CP for milk production (kg)	162.0	163.1	170.9	4.9	160.1	166.3	178.0	6.7
ME/kg milk (MJ)	5.51	5.10	5.48	0.13	5.20	5.11	5.38	0.11
CP/kg milk (g)	137	133	137	9	131	133	135	7

Fc and Fa are ratios of forage with constant and *ad libitum* amounts, respectively (see table 1).
[a,b,c] Means in the same row and same experiment with different superscripts differ at $p<0.05$.

Table 7. Daily feed cost per head and per kg milk produced, least square means and SEM

Item	Experiment 1				Experiment 2			
	70Fc	50Fc	30Fc	SEM	70Fa	50Fa	30Fa	SEM
Number of cows	6	6	6		6	6	6	
Natural grasses (kg/day)	36.3[a]	26.7[b]	16.1[c]	0.8	36.8[a]	28.9[b]	19.4[c]	1.2
Brewers' grains (kg/day)	10	10	10		10	10	10	0
Compound feed (kg/day)	1.2[a]	3.4[b]	5.7[c]	0.2	1.3[a]	3.5[b]	5.8[c]	0.3
Cost of grass (VND)	7,250[a]	5,340[b]	3,210[c]	153	7,360[a]	5,790[b]	3,880[c]	224
Cost of brewers' grains (VND)	5,000	5,000	5,000	0	5,000	5,000	5,000	0
Cost of compound feed (VND)	3,000[a]	8,580[b]	14,460[c]	466	3,210[a]	8,670[b]	14,580[c]	999
Total daily feed cost (VND)	15,250[a]	18,920[b]	22,670[c]	580	15,570[a]	19,460[b]	23,460[c]	976
Feed cost per kg milk (VND)	1,430[a]	1,730[b]	2,030[c]	41	1,400[a]	1,740[b]	2,,000[c]	75

Fc and Fa are ratios of forage with constant and *ad libitum* amounts, respectively (see table 1).
[a,b,c] Means in the same row and same experiment with different superscripts differ at $p<0.05$.
Feed costs: fresh natural grasses 200 VND/kg; wet brewers' grains 500 VND/kg and compound feed 2,500 VND/kg.
Exchange rate 1 USD=14,000 VND (Vietnam Dong).

improved the degradability of feed OM and CP, while the CF digestibility decreased.

In the present study, the milk protein content was not significantly different, but showed a slight increase following the increase of the concentrate ratio in the two experiments. The opposite was observed for the milk fat content, which decreased as a result of the increased concentrate ratio. There are several studies which are in agreement with these results. Macleod et al. (1983) found that protein content increased from 3.11 to 3.26% and milk fat content decreased from 3.83 to 3.33% when reducing the ratios of forage:concentrates from 80:20 to 35:65. Gruber et al. (1991) reported a milk protein concentration of 3.0, 3.2 and 3.4% and milk fat concentration of 4.3, 4.2 and 4.1% at 0, 25 and 50% concentrate in the diets, respectively. Emery (1978) stated that milk CP can increase as the dietary CP increases, and feeding lactating cows with less fibre will result in increasing milk protein due to increased propionate relative to acetate. Bartsch et al. (1979) reported that the content of milk protein was higher when the diet had a greater proportion of concentrate, but milk fat content was similar for all ratios.

Forage diets high in cellulose give rise to acetic acid, while concentrate diets give rise to propionic acid, and the proportion of acetic acid falls (McDonald et al., 1995). High levels of concentrate are conducive to production of propionic acid in the rumen, which in turn promotes partition of energy towards synthesis of body fat instead of milk fat synthesis, resulting in a decrease in milk fat content (Randby, 1996). Fiber content has been considered to be an

indicator of low nutritive value of feeds, but the unlignified hemicelluloses and celluloses are important nutritive sources for dairy cows, since the products of their fermentation in the rumen are mostly short chain volatile fatty acids and microbial cells that can be utilized by the host animal for milk production.

In the present study, the 30F and 50F cows had higher body weight gain than that of the 70F cows. This can be due to both the higher ME and CP intake as well as a possible increase in the production of propionic acid when feeding more concentrate with lower fibre content. Some authors have also reported a positive correlation between weight gain and ratio of concentrate in the diets. Sporndly (1986) concluded that changing the ratio of roughage to concentrate from 62:38 to 50:50 significantly increased both fat corrected milk yield and live weight gain, while Mahal et al. (1997) reported no differences in live weight changes at forage:concentrates ratios of 50:50, 60:40 and 70:30.

The interval from calving to first oestrus of all experimental cows was less than 4 months. No significant differences between ratios of concentrate for the length of the postpartum period before the first oestrus were observed in the two experiments of this study although cows on 70F had the longest interval. They had also on average no or very small body weight gains during the first week of the experiments. The reason for non-significance was probably that the experiments were conducted with a small number of animals, which made the detection of a significant difference more difficult. Lap (1996) and Dat (1998) reported a similar average calving interval of crossbred F1 cows as in the present study, of 440-450 days, which is considerably longer than the potential interval of these cows.

Due to the difference of feeding principles, the DM, ME and CP intakes of the 70Fa, 50Fa and 30Fa cows were higher compared to the 70Fc, 50Fc and 30Fc cows, resulting in higher milk yield and body weight gain. These differences were particularly pronounced for the 50F and 30F treatments.

In this study, there were no significant differences in feed conversion between groups in terms of ME and CP intake per kg milk produced. Similarly, Ty and Ly (1981) and Anh et al. (1983) also showed an energy conversion per kg milk produced of crossbred F1 (Holstein Friesian× Local) cows of 1,250-1,500 kcal (equal to 5-6.5 MJ). Lap (1996) reported that feed conversion per kg milk produced was 1.261, 1.303 and 1.394 Mcal (equal to 5.276, 5.452 and 5.832 MJ) for crossbred F1 cows given 110%, 100% and 95% of the NRC standard requirements, respectively. Dat (1998) found ME conversion for 1 kg milk produced to be 5.5 MJ. In temperate conditions and with high yielding cows, Lindell (1982) also indicated that ME for milk production should be 5.0 MJ ME/kg FCM.

When the grass was bought, the feed cost per kg milk produced was lowest for the 70F ratio. This can be explained by the low cost of grasses compared to compound feed. In terms of economic efficiency, the ratio 70% forage was the best and the significantly higher milk yield at higher concentrate rates could not compensate at the present production levels and feed prices. If using family labor without alternative paid activities for collecting, the forage feed cost would be reduced much more, particularly at high forage feeding levels.

IMPLICATIONS

Decreased ratios of forage to concentrates resulted in increased milk yield and body weight gain of the cows and a tendency to higher milk protein content, but lowered milk fat content. There was no significant effect on postpartum oestrus. Feed conversion was not different between ratios but feed cost per kg milk produced was lowest for cows given 70% forage. The ration with 50% forage is optimum in terms of milk yield, body weight gain, and feed conversion, but in terms of feed cost, the ratio of 70% forage is the best. The *ad libitum* forage feeding system increased feed intake and milk yield. Natural grasses grow easily around the year and are an important source of available fodder for small dairy farmers in North Vietnam. On small dairy farms, the ratio of 30% concentrate and 70% forage fed *ad libitum* can be recommended.

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REFERENCES

Anh, L. V., L. T. At, N. Loi and N. H. Ninh. 1983. Dairy cattle. Agricultural Publishing House, Hanoi.

AOAC. 1990. Official Methods of Analysis. 15th Ed. Association of Official Analytical Chemists, Arlington, Virginia 22201 USA.

Bartsch, B. D., E. R. B. Graham and D. M. McLean. 1979. Protein and fat composition and some manufacturing properties of milk from dairy cows fed on hay and concentrate in various ratios. Aust. J. Agric. Res. 30:191-199.

Butterworth, M. H. 1967. The digestibility of tropical grasses. Nut. Abstr. Rev. 37:349-368.

Castro, T., F. F. Bermudez and R. Sanz Arias. 1991. Effect of forage to concentrate ratio of diet on digestibility of dry matter and cell-wall constituents. Archivos de Zootecnia. 40:85-90.

Cronje, P. B. 2000. Nutrient-Gene interactions: Future potential and applications. In: Ruminant Physiology. Digestion,

Metabolism, Growth and Reproduction. (Ed. P. B. Cronje). CAB International, pp. 409-422.

Cunningham, E. P. and O. Syrstad. 1987. Crossbreeding *Bos indicus* and *Bos taurus* for milk production in the tropics. Food and Agriculture Organization of the United Nations, Rome, 1987.

Dat, N. Q. 1998. Some breeding characteristics of crossbred dairy cattle (Holstein Friesian×Local Yellow) raised in Ho Chi Minh City. Ph.D. Thesis. Institute of Agricultural Science and Technology, Hanoi, Vietnam.

Emery, R. S. 1978. Feeding for increased milk protein. J. Dairy Sci. 61:825-828.

Faverdin, P., R. Baumont and K. L. Ingvartsen. 1995. Control and prediction of feed intake in ruminants. In: Recent Developments in the Nutrition of Herbivores (M. Journet, E. Grenet, M-H. Farce, M. Theriez and C. Demarquilly). Proceedings of the IVth International Symposium on the Nutrition of Herbivores, Clermont-Ferrand (France), pp. 114-120.

Forbes, J. M. and F. D. Provenza. 2000. Integration of learning and metabolic signals into a theory of dietary choice and feed intake. In: Ruminant Physiology. Digestion, Metabolism, Growth and Reproduction. (Ed. P. B. Cronje). CAB International, pp. 3-19.

Gonda, H. L., M. Emanuelson and M. Murphy. 1996. The effect of forage to concentrate ratio in the diet on nitrogen and purine metabolism in dairy cows. Anim. Feed Sci. Technol. 64:27-42.

Gruber, L., R. Steinwender, K. Krimberger and J. Solkner. 1991. Forage intake of Simmental Brown Swiss and Holstein Friesian cows fed rations with 0, 25 and 50% concentrates. Livest. Prod. Sci. 27:123-136.

Lap, L. T. 1996. Study on nutrient requirements of crossbred (Holstein Friesian×Local) dairy cows. PhD Thesis. National Institute of Animal Husbandry, Hanoi, Vietnam.

Lindell, L. 1982. Effects of different levels of protein to dairy cows. Swe. J. Agric. Res. 13:47-59.

Macleod, G. K., D. G. Grieve and I. McMillan. 1983. Performance of first lactation dairy cows fed complete rations of several ratios of forage to concentrate. J. Dairy Sci. 66:1668-1674.

Mahal, G. S., S. S. Randhawa, Balwant Singh and B. Singh. 1997. Effect of feeding different forage to concentrate ratios on nutrient utilization and productive performance of crossbred cows. Indian J. Anim. Prod. and Management 13:93-97.

McDonald, P., R. A. Edwards, J. F. D. Greenhalgh and C. A. Morgan. 1995. Animal Nutrition. Fifth edition. Longman Scientific and Technical. Produced by Longman Singapore Publishers (Pte) Ltd. Printed in Singapore.

MINITAB for Windows. 1998. MINITAB release 12.21, Minitab Inc., 3081 Enterprise Drive, State College, PA 16801-3008, 814-238-3280, USA.

Moseley, J. E., C. E. Coppock and G. B. Lake. 1976. Abrupt changes in forage-concentrate ratios of complete feeds fed *ad libitum* to dairy cows. J. Dairy Sci. 59:1471-1483.

National Institute of Animal Husbandry. 1995. Composition and Nutritive Value of Animal Feeds in Vietnam. Agricultural Publishing House, Hanoi.

National Research Council. 1988. Nutrient Requirements of Dairy Cattle. Sixth Revised Ed. National Academy Press, Washington, DC.

Okine, E. K., G. R. Khorasani and J. J. Kennelly. 1997. Effects of source of forage and level of concentrate on chewing activity and milk production response in late lactation cows. Can. J. Anim. Sci. 77:253-258.

Oldham, J. D. and J. D. Sutton. 1979. Milk composition and the high yielding cow. In: Feeding Strategy for the High Yielding Dairy Cow. Granada Publishing, pp. 114-147.

Raab, L. 1994. High energy supply ensures low forage replacement. Neue Landwirtschaft 3:56-58.

Randby, A. T. 1996. Nutritional effects of increased use of concentrate in dairy cows. Norsk Landbruksforsking 10:59-74.

Singh, M., I. Saran and M. C. Jackson. 1972. Value of concentrate supplements to sorghum forage for milk production and growth in cows and buffaloes. Indian J. Anim. Sci. 42:16-21.

Sporndly, R. 1986. Intake and production response of dairy cows to a fixed ratio of silage to cereals, fed as separate feeds, blended or ensiled together. In: Ensiling of blended grass and grain and its utilization by dairy cows. Report 155. Dept. of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Tuan, B. Q. 2000. Effects of Protein and concentrate levels on rumen digestion and milk production of crossbed dairy cattle in Hanoi. PhD Thesis. University of Agriculture, Hanoi, Vietnam.

Ty, V. N. and L. V. Ly. 1981. Dairy cattle. Agricultural Publishing House, Hanoi.