Milk production and eating patterns of lactating cows under grazing and indoor feeding conditions in central Thailand

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Abstract

Grazing behaviour, milk production, liveweight change and health status were studied in 2 groups of 6 Friesian-cross cows grazed outdoors on pasture or housed indoors during mid-lactation in central Thailand. Indoor cows were housed in an open-sided barn and fed with cut-and-carried pasture. Outdoor cows were strip-grazed on the same guinea grass pasture without any shade and were brought indoors only for milking. All cows were also fed meal concentrate twice daily at milking according to their level of milk production. Milk production (11.9 *vs* 12.3 kg/d for FCM yield) and composition were similar in both groups. Hoof damage was higher amongst cows housed than in those grazing outdoors. These data suggest that dairy cows will produce satisfactory milk yields when grazed outdoors instead of being housed, as is common in Thailand. This grazing system should result in significant reductions in farm costs.

Introduction

Mean ambient temperatures and humidities of 27.6°C and 79% (Meteorological Department 1998), respectively, in central Thailand would be expected (Johnson 1987) to cause heat stress in dairy cattle during much of the year, and adversely affect milk production. Hence, most Thai dairy farmers adopt a cut-and-carry system of feeding their livestock as they believe that shaded indoor conditions provide a better environment for cows and result in higher milk yields. However, very limited quantitative data are available on this point (Hongyantarachai *et al*. 1989), for cows either grazed continuously or housed indoors. Climatic conditions impact on dairy cows directly through the animals' physiological mechanisms and indirectly through the quality and quantity of forage available (Mawson and White 1971) and the effects of parasites and diseases (Johnson 1981).

This experiment was conducted to examine physiological changes (Prasanpanich *et al*. 2002) as well as the extent and pattern of forage intake, milk production and liveweight change plus the health status of 2 groups of Friesian-cross dairy cows in mid-lactation which were either grazed outdoors on a guinea grass pasture, or fed the same pasture (cut-and-carry) while housed indoors in an open-sided barn, for 3.5 months during the wet season (June–September). Both groups had daily access to an abundant supply (approx. 3 × requirement) of fresh pasture, the aim being to investigate potential milk production under the two feeding systems.

Materials and methods

The experimental site of 2.8 ha of guinea grass pasture (*Panicum maximum*) cv. Purple guinea was located at Muaklek Research Station of the Dairy Farming Promotion Organisation of Thailand, Muaklek, Saraburi, Thailand (14° 50′N, 101° 10′E; elevation 220 m). The soil type was clay loam of moderate fertility (Wang Saphung Series) and the mean annual rainfall was 1192 mm.

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Experimental design and treatments

Two groups of cows were studied, *viz.*:

Group 1 — 6 cows housed, unrestrained, in an open-sided barn fed with pasture cut-and-carried from the pasture area about 300 m distant. The barn was 12 m long × 7 m wide × 3.5 m high. Its long axis was oriented east-west and it had a tiled roof; and

Group 2 — 6 cows strip-grazed continuously on a shadeless pasture, apart from twice-daily milking (in the same barn as Group 1), and rotated daily around the 35 sub-paddocks allocated to them.

The cows were all crossbred animals (>75% Friesian × local *Bos indicus*), all in their 1^{st}–5^{th} lactation and at 30–40 days of lactation when the experiment began. The cows were balanced for these factors across the 2 groups, and account was also taken of their liveweight and previous milk production. A pre-experimental period of 1 week was allowed on similar pasture to the experimental area for the cows to adapt to changed management conditions, and for preliminary milk production data to be collected. The experiment began on June 21, 1999.

During any particular day, Group 2 grazed an area of 0.04 ha. All cows were also individually fed a commercial meal concentrate (92%DM, 16.4%CP, 70%TDN) according to their current milk production (adjusted weekly) at the rate of 1 kg of concentrate per 3 kg of milk, divided between the morning and afternoon milkings. This was fed indoors immediately prior to milking and all meal was consumed.

Pasture management

Two months prior to the start of the experiment, the selected guinea grass pasture was cut at an average 8 cm (range 5–10 cm; 2–3 nodes remaining) above ground level with a mechanical forage harvester and the material removed. It was then topdressed with 156 kg/ha N:P:K (15:15:15) fertiliser and allowed to regrow until the experiment began.

Based on an intake requirement (3%; DM basis) for bodyweight maintenance and milk production, and proximate analysis of the experimental forage, it was estimated that the available area would provide 35 days' forage for the 12 cows. The area was thus divided into 35 strips, each 5 m wide. Half of each strip was allocated to the grazed cows (Group 2), the other half was cut to a height of 8 cm and the cut material fed to the indoor cows (Group 1). Grazing was controlled by electric fences which were moved daily. After grazing, each strip was again mechanically harvested to a height of 8 cm, and fertilised with 156 kg/ha urea. Sprinkler irrigation was applied when necessary to ensure optimal soil moisture conditions for pasture growth. Drinking water was provided in a trough, which was moved daily to the end of each new forage strip.

Rotational grazing/cutting was practised. During the first grazing/cutting rotation (Cycle 1), cows were offered pasture that varied from 60–95 day growth, and which was classed as mature (Hongyantarachai *et al.* 1989). The average age of regrowth in the second and third rotations (Cycles 2 and 3) was 34 days resulting in a much improved pasture quality. All the pasture available in the sub-paddock allocated to housed cows each day was harvested (mean 8611 kg/haDM × 0.04 ha × 25.1%DM = 1372.2 kg fresh forage in Cycle 1; 737.5 kg fresh in Cycles 2 and 3; Table 1), transported to the barn and thoroughly mixed. To avoid spillage and spoilage, each housed cow was initially fed a random 35 kg of mixed fresh forage at 07.30 h. Feed troughs were topped up with fresh forage throughout the day, to replace materials consumed, and on average cows were thus given access to 78 kg/hd/d fresh forage in Cycle 1 and 65 kg/hd/d in Cycles 2 and 3.

Table 1. Mean pasture composition and yield before feeding in Cycle 1 and Cycles 2 and 3.

	Cycle 1	Cycles 2 and 3
Leaf (%)	36	62
Stem (%)	40	33
Dead material (%)	24	5
Pasture DM concentration (%)	25.1	22.6
Pasture yield (kg/haDM)	8611	4167
IVDMD (%)	40.6	48.6
Sward height (cm)	98.6	70.4

Cycle 3 was undertaken to examine further the downward turn in fat-corrected milk (FCM) recorded during the final week of Cycle 2. The results (Figure 1) recorded by Day 25 of Cycle 3 confirmed this trend, and the experiment was terminated on September 24, 1999 (95 days).

Pasture measurements

The forage available in each paddock before grazing/cutting was estimated by cutting 8 random

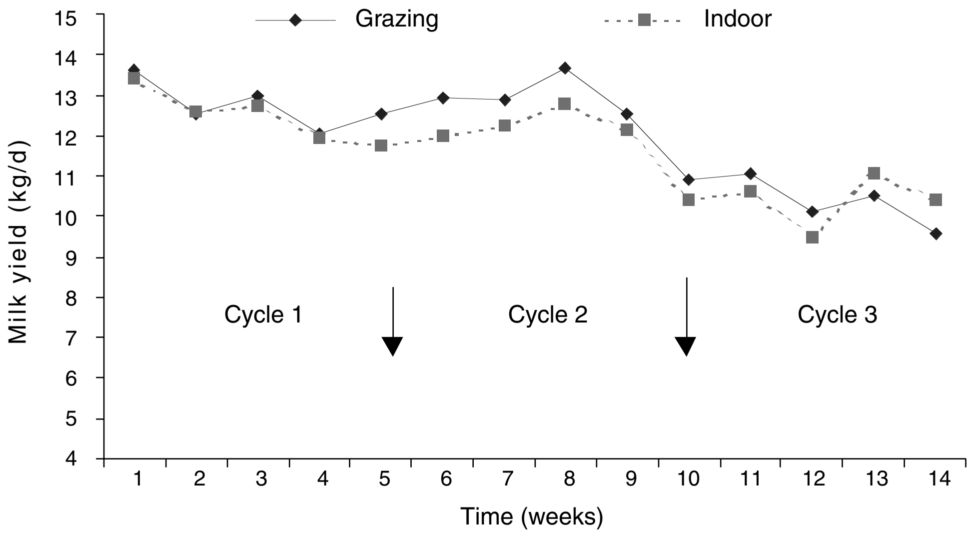

Figure 1. 4% FCM yield per cow for grazed and housed groups during the study.

quadrats (each 0.25 m^2) with hand shears to a height of 8 cm. The material from each quadrat in the pregrazing measurement was separated into green leaf, stem and dead material. This operation was always performed by the same operator to minimise the variability associated with the technique (Thompson 1986). After each grazing, a post-grazing estimate was immediately made using the same techniques.

Mean pasture intake of the grazed cows was estimated as the difference between the daily pre- and post-grazing pasture estimates of forage availability, and that of the indoor cows as the difference between the daily herbage offered and the residual uneaten herbage.

Pasture samples were analysed for DM content, Kjeldahl nitrogen (Tecator system 1002), neutral and acid detergent fibre (NDF and ADF; van Soest 1967) by the VELP Scientifica (Type FIWE, Fibre Tech, Italy) and DM digestibility by the *in vitro* method (IVDMD; Clarke *et al*. 1982).

Animal measurements

Milk yield was recorded for each cow at each milking and a composite sample of morning and afternoon milk for each cow was analysed at weekly intervals for fat, protein, lactose and solids-non-fat (SNF) using the Milkoscan Tester. Yield of 4% FCM was calculated by the formula of Walker *et al*. (2001) which was modified from Overman and Gaines (1948) as follows:

$$\text{FCM (kg/cow/d)} = \text{milk yield (kg/cow/d)} \times [0.4 + 0.015 \times \text{fat content (g/kg)}]$$

Liveweight was recorded before the experiment began and at fortnightly intervals thereafter. Individual cows were examined daily for clinical signs of mastitis and hoof problems.

A technique (Blowey *et al*. 1973) to assess the nutritional status of dairy cows in relation to production was applied on August 9, 1999. To accommodate that technique, morning supplementation was delayed until after milking on that day only. Individual jugular venous blood samples (Vacutainer) were collected at 07.30 h immediately after the morning milking but before supplementation, and again before the afternoon milking (5 hours after morning supplementation). Heparinised samples were centrifuged and stored at –20°C before being analysed for plasma urea nitrogen (BUN; Tiffany *et al*. 1972) and plasma glucose (Slein 1963).

Observations on grazing/eating behaviour and climate

An attempt was made to record behavioural patterns of the total number of cows in each activity. The numbers of cows in each group that were grazing/eating, ruminating or idling and the incidence of thermal panting, were recorded hourly for 24 consecutive hours on August 7, 14 and 28 and September 4, 1999. The observations were totaled at hourly intervals for each 24 h period apart from milking times and expressed as a percentage of cows involved in each activity at each hour throughout the day.

Dry- and wet-bulb temperatures (DB and WB; by dry- and wet-bulb thermometer), black-globe temperature (BG; by Vernon globe), relative humidity (RH; by the conversion of DB and WB temperatures) and wind speed were recorded at 08.00 h and 14.00 h each day, in a Stephenson screen located in the grazing area (for Group 2), and at cow level in the barn (for Group 1). Temperature-humidity indices (THI) were then calculated using the equation for lactating dairy cows from McDowell (1972):

$$THI = 0.72\ (DB + WB) + 40.6$$

On-farm meteorological data from June–September 1999 are presented in Table 2.

Statistical analyses of milk production, blood metabolites, grazing pattern and liveweight changes were carried out using a t-test with animals as the experimental unit (SAS 1985).

Results

Meteorological data

Mean maximum and minimum outdoor temperatures, rainfall and mean wind velocity throughout the experimental period (Table 2) were representative of the hot humid months of the year (Meteorological Department 1998). Monthly means for temperature, RH and THI at 14.00 h at both the outdoor and indoor sites are presented in Table 3. The outdoor group experienced significantly higher BG temperatures at 14.00 h than the indoor group, and relative humidity was lower for the housed cows than for the grazed group in August–September.

Milk production and blood metabolites

In the pre-experimental period, values for FCM, SNF, lactose, fat and protein did not differ significantly between groups and averaged 13.8 *vs* 13.6 kg/d; 8.9 *vs* 8.8%; 5.3 *vs* 5.1%; 4.1 *vs* 3.8%;

Table 2. Average on-farm meteorological data throughout the experiment at the Stephenson screen.

Time period	Overall mean				Daily mean at 08.00 h		
	Air temp		Rainfall	Wind	Air temp	RH[1]	THI[2]
	Max	Min					
	(°C)		(mm)	(m/s)	(°C)	(%)	
Jun 21–30	31.0	23.4	25.7	1.80	27.3	81.6	78.1
Jul 1–31	31.0	23.7	108.4	3.54	27.3	73.9	77.5
Aug 1–31	30.2	22.5	211.1	1.68	25.9	82.1	76.0
Sep 1–24	30.5	22.0	134.1	1.56	26.7	80.4	77.0

[1] Relative humidity.
[2] Temperature-humidity index.

Table 3. Mean climatological data collected at 14.00 h from the outdoor grazing site and indoor housing.

Time period	Outdoor grazing				Indoor housing			
	Air temp	BG[1]	RH[2]	THI[3]	Air temp	BG	RH	THI
	(°C)	(°C)	(%)		(°C)	(°C)	(%)	
Jun 21–30	27.6	32.4	82.0	78.9	27.5	29.4	81.7	78.7
Jul 1–31	29.2	34.7	74.1	77.8	28.6	27.9	73.5	76.9
Aug 1–31	29.8	37.8	76.9	80.9	30.3	30.3	66.2	80.9
Sep 1–24	30.9	40.3	73.1	78.9	30.2	30.3	66.5	76.7

[1] Black-globe temperature.
[2] Relative humidity.
[3] Temperature-humidity index.

and 3.2 *vs* 2.9%, respectively. FCM yields for the grazed and housed groups did not differ significantly throughout the experimental period with means of 12.3 and 11.9 kg/d, respectively. This represented a decline from about 13.5 kg/d at the start to about 10 kg/d at the end of the study in both groups (Figure 1). Any differences in milk composition were small, as indicated in Figure 2.

BUN and blood glucose concentrations for the 2 groups are shown in Table 4. Mean BUN levels at the AM feeding in the grazed group were significantly higher ($P<0.05$) than those in the indoor group. Glucose levels, however, did not differ significantly between the 2 groups.

Table 4. Mean plasma urea nitrogen (BUN) and blood glucose concentrations in cows either grazing or fed indoors.

		Grazing	Indoors	SEM	Level of significance
		(mg/100ml)			
BUN	AM feeding	24.1	21.8	0.92	*
	PM feeding	24.9	23.9	1.833	ns
Glucose	AM feeding	53.8	54.3	2.639	ns
	PM feeding	58.2	57.7	1.484	ns

Liveweight change and animal health

Cows in Groups 1 and 2 averaged 410 and 397 kg liveweight at the start of the experiment and gained 17.8 and 11.7 kg, respectively, during the study.

Only 1 cow in the housed group and 2 in the grazed group showed signs of mastitis. Other health disorders (hoof and teat injuries) were higher in the housed group (3 housed cows with hoof injuries and 1 cow with teat injury; no such injuries in the grazed cows).

Pasture quality and intake

Due to the extended growth period (60–95 d) before grazing commenced, pasture on offer in Cycle 1 was relatively high in DM percentage, pasture yield and sward height, but had low IVDMD% and low leaf percentage (Table 1). However, with the inter-grazing intervals of 35 d in the study, pasture on offer contained more leaf and was more digestible in Cycles 2 and 3. This was associated with much less dead material

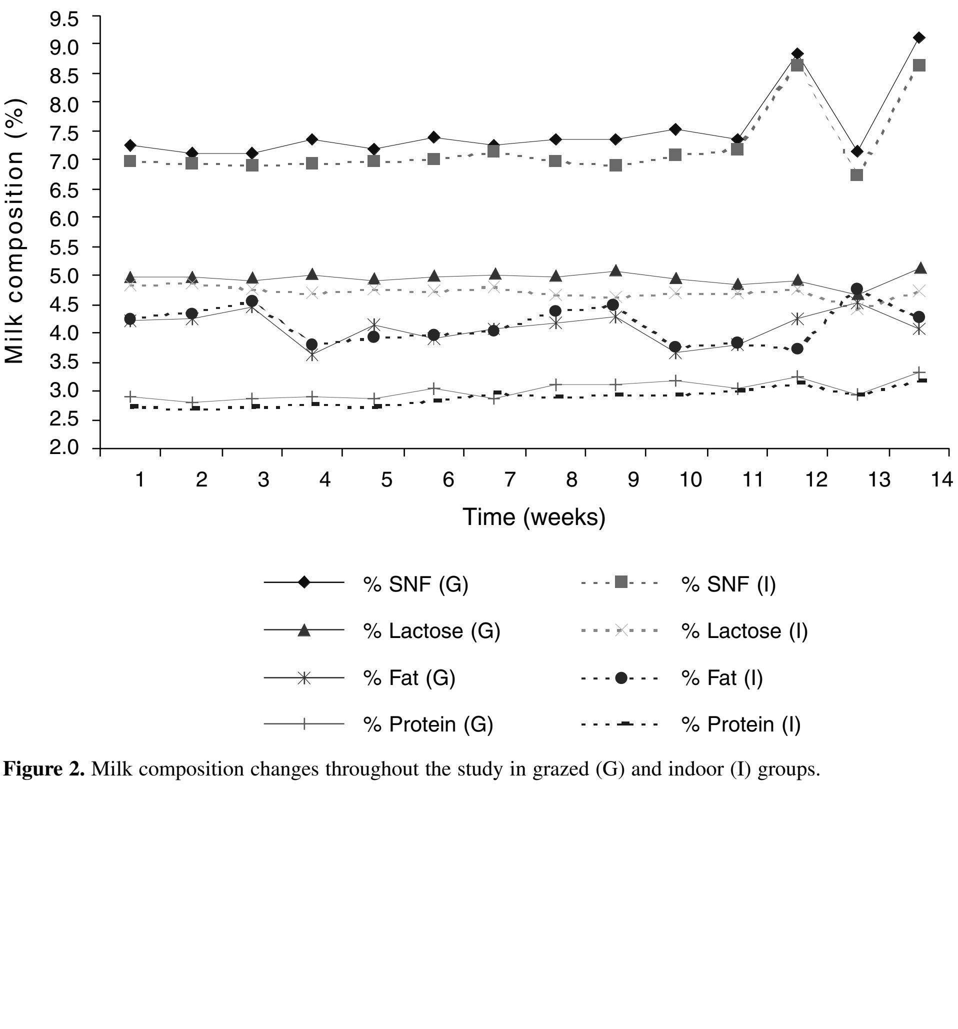

Figure 2. Milk composition changes throughout the study in grazed (G) and indoor (I) groups.

together with lower dry matter percentage and pasture yield.

Estimated daily pasture DM intakes were 7.1 and 8.2 kg/cow for grazed and housed groups, respectively, in Cycle 1, and 10.1 and 12.4 kg/cow in Cycles 2 and 3.

Grazing/eating behaviour

Two peaks of grazing or eating were observed each day (Figure 3c) immediately after each milking in both groups. The morning peak from 09.00 h to 11.00 h was significantly shorter ($P < 0.01$) in grazed animals than in housed animals, but by 11.00 h eating had virtually ceased in both groups. There were no significant differences between groups in the afternoon period, but at 21.00 h there was a significant ($P < 0.01$) but minor peak of eating in the housed animals. The opportunity for night-time compensation for morning grazing became essential for the grazed group from 22.00 h to 04.00 h next morning. However, there were no significant differences between groups.

Ruminating activity was inversely related to eating behaviour, with daily peaks between 11.00 h and 14.00 h, and again between 19.00 h and 05.00 h next morning (Figure 3b).

Quite large differences in the incidence of idling were observed between groups (Figure 3a), with levels being significantly higher ($P < 0.05$) under grazing conditions (Group 2) during the middle of the day. Panting accompanied idling in the grazed animals from mid-morning till late afternoon.

Discussion

Under the conditions of this study, there was no significant difference in yield and composition of milk of cows grazed outdoors and cows fed indoors supporting the findings of Hongyantarachai *et al.* (1989). This finding brings into question the claims made and the practice adopted by most Thai dairy farmers that it is essential to keep milking cows indoors under shade in order to achieve maximum milk yields.

When one examines the climatological data for possible effects on the animal, it is clear that air temperatures at both the indoor and outdoor sites exceeded the acknowledged upper critical temperature of 26°C for Friesian cattle (Johnson *et al.* 1961). Also, the THI values derived for Groups 1 and 2 exceeded the critical value of 72 for Friesian cows beyond which heat stress occurs and production is likely to fall (Johnson 1987) by 5–9 units (Table 3). The mean wind speed recorded of 2.1 m/s corresponds to a gentle breeze (McDowell 1972), and the results of Ittner *et al.* (1954) suggest that such a breeze is likely to reduce heat stress. Unfortunately, wind speed was not measured indoors, and it is thus not possible to draw conclusions as to its importance in the present experiment. S. Chakriyarat (personal communication) has calculated the critical THI for heat stress in genotypes similar to those used in the current experiment to be 78. Whichever of these THI values is most appropriate, it is apparent from Table 3 that both groups of cows in our study were subjected to similar levels of heat stress and that reductions in milk production due to heat stress were likely in both groups.

Even though grazed cows panted for considerable periods, indicating higher heat stress than in the housed cows, this did not significantly affect production. Both groups of cows tended to avoid activity during the hotter part of the day by concentrating their grazing/eating during relatively cooler periods, immediately after milking, *i.e.* in the early morning and late afternoon extending into the cool of the evening. During the heat of the day, they spent their time idling and panting, which occurred to a much greater extent outdoors than indoors.

The overall pattern of eating activity recorded was similar to the general pattern recorded in dairy cows under a variety of conditions (Winter *et al.* 1980). We consider that the rising temperature and humidity (Tables 2 and 3) experienced by both groups contributed to the decline in eating activity observed between 09.00 h and 11.00 h, and that increasing solar radiation as indicated by increasing BG temperatures forced the early cessation of grazing in the grazed group (Cowan *et al.* 1993).

Ruminating activity observed was similar to the general pattern recorded under tropical conditions by Winter *et al.* (1980). The occurrence of panting and open-mouthed breathing during periods of idling activity among the grazed cows is a general pattern observed by Lampkin and Quarterman (1962) and Winter *et al.* (1980). Thermal panting in cattle is a mechanism for coping with heat stress and generally rises as deep body temperature rises (Findlay 1957). In

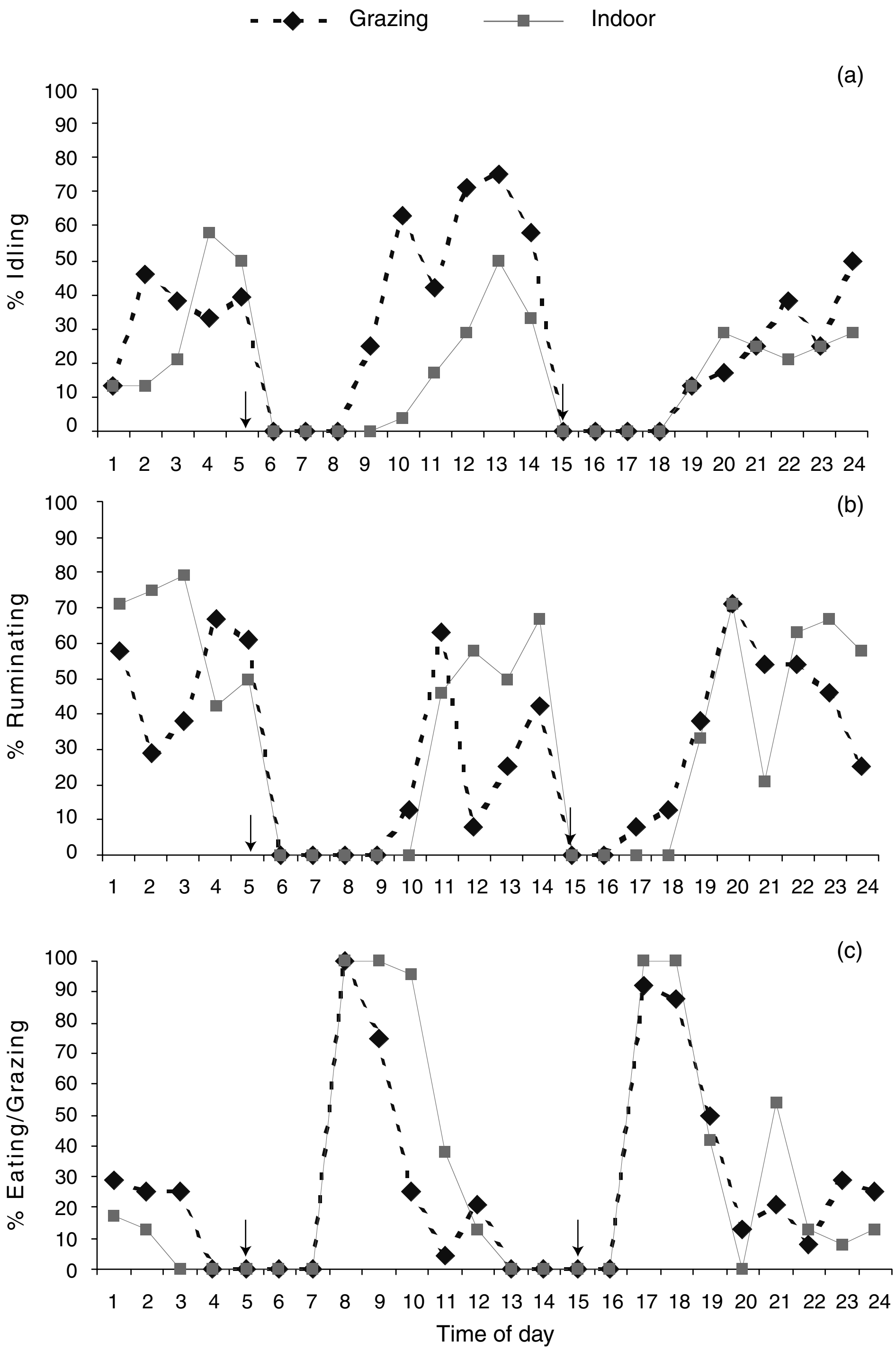

Figure 3. Grazing/eating patterns of animals either grazed or fed indoors: (a) idling; (b) ruminating; and (c) eating/grazing. Milking times are indicated by arrows.

the current work, respiratory rates and rectal temperatures averaged 87.9 breaths/min and 40.4°C in the outdoor and 62.9 breaths/min and 39.0°C in the indoor groups, respectively (Prasanpanich *et al*. 2002).

BUN concentrations were above the normal range of 12.3–17.8 mg% (Rowlands *et al.* 1977) for both groups at both the AM and PM feedings, with the outdoor cows displaying significantly higher ($P < 0.05$) concentrations at the AM feeding than the indoor cows. Figure 3c indicates that outdoor cows showed higher eating activity than their housed counterparts early in the morning, which would be expected to elevate blood urea levels.

Blood glucose concentrations at the AM and PM feedings were slightly above the normal range of 42.5–45.4 mg% (Payne *et al.* 1974), indicating an adequate energy supply to all cows (Rook and Line 1961).

Little importance can be attached to the data relating to animal health as animal numbers were low. However, the level of hoof damage recorded in the indoor animals compared with the absence of damage in the grazing animals, reflects the commonly reported problems associated with housing animals on concrete (Albright and Alliston 1971).

In terms of the pasture parameters recorded, it was clear that the greater leafiness and higher crude protein concentration in the pasture offered during the second and third cycles of grazing accounted for the noticeable increase in forage intake at that time. Workers such as Chacon and Stobbs (1976) have shown that increased leafiness and crude protein level of pasture have a marked and beneficial effect on animal intake.

As mentioned, the current aim was to investigate potential milk production under indoor and outdoor feeding conditions. Abundant forage was thus provided to all cows, and feed refusals (an average of 3.9, 1.7 and 1.7 tonnes/d in Cycles 1 to 3 indoors, and 4.0, 1.8 and 1.8 tonnes/d, respectively, outdoors) were much higher than a commercial farmer could tolerate. Time did not allow refusals in the current work to be separated into leaf, stem and dead material, but observations made by the senior author every second day suggest that the outdoor cows consumed relatively more leaf than the indoor ones, which appeared not to have accessed all their forage. If total forage offered was restricted to the cows' requirement (*i.e.* to commercial practice), we could expect FCM to decline both indoors and outdoors because of a reduced opportunity for selective grazing.

While the data suggest that housed cows consumed more forage than the grazed group, it is probable that the before-and-after-grazing method was not sufficiently accurate to allow such small differences to be established. While the method was affected by the concentrate intake of the cows, as the indigestible marker technique would have been (Corbett 1978), it provided only a mean intake value for the grazed group and thus did not allow statistical analyses to be performed.

Finally, the lack of any clear advantage in production of one pasture management system over the other means that the farmer must use other criteria to decide which system he will adopt. For example, under a cut-and-carry system, there is the potential for a substantial loss of excreted nutrients from the system, as the urine which contains most of the excreted N and K, is generally lost in the drainage and the dung is seldom returned on a regular basis to the pasture. This can lead to a marked decline in soil fertility and subsequent pasture productivity, unless the nutrients are replaced by expensive fertiliser. By comparison, the grazing system ensures a natural and substantial return of dung and urine to the pasture and a maintenance of soil fertility (Goodall 1951). However, under a grazing system, pugging or compaction may adversely affect pasture productivity, although Campbell (1966) found little evidence of real treading damage even under high stocking rates.

A further important consideration in farmers' deliberations is obviously the relative labour and capital costs of the two systems. The grazing system entails considerable capital expenditure in fencing but allows the animal to harvest its own forage while the cut-and-carry system requires little or no fencing but demands much more labour and/or mechanical harvesting equipment. The relative costs of such variables will affect decision making and the proportions of farmers adopting the grazing or the cut-and-carry system on their dairying enterprises.

Acknowledgements

The authors gratefully acknowledge the support of the Dairy Farming Promotion Organisation of Thailand (DPO) and Tabkwang Artificial Insemination Centre, Department of Livestock Development who provided the experimental site and the

Milkoscan Tester, respectively. Special thanks are also extended to the Royal Golden Jubilee Scholarship, the Thailand Research Fund, for financial support. The authors also appreciated the genuine interest and effort made by the DPO Director and farm staff, Messrs S. Siwichai, S. Ruangsri, R. Jamsasuk and P. Duansawang, for their on-farm assistance and fencing establishment throughout the experiment. In particular, the graphical assistance from Mr S. Chumnanwach is also acknowledged.

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(Received for publication January 22, 2001; accepted April 25, 2002)