Feeding of Fodder-Sugarcane Silage to Holstein Cows

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Abstract

To provide relevant information on utilizing fodder-sugarcane for dairy cows, we investigated the chemical composition, and long-term effect of fodder-sugarcane feeding on physiological aspects in non-lactating cows and milk production in lactating cows. The CP content of fodder-sugarcane silage (KRFo93-1; harvested 4 months after regrowth) was at the lowest level, whereas NDFom content peaked in roughage fed to lactating cows on conventional dairy farms. When 6 non-lactating Holstein cows were fed fodder-sugarcane silage with soybean meal and steam-rolled corn or sudangrass hay for 106 days, there were few changes in BW, hematological parameters, and blood metabolites throughout the experimental period. Seven lactating Holstein cows were fed TMR (TDN, 69%DM; CP, 15%DM) containing 0, 3, 5, 10, 15, or 20% fodder-sugarcane silage along with commercial concentrate (1.8 kg DM/cow/day). Milk yield and milk composition were unaffected by the proportion of fodder-sugarcane silage in the TMR. Conversely, the percentage of large particles (>19 mm) in TMR and in orts rose with an increasing proportion of fodder-sugarcane silage in TMR. The BUN concentration increased when cows were fed TMR containing over 15% fodder-sugarcane silage. These results suggest that fodder-sugarcane can be fed to cows without adversely affecting their physiological condition. However, for practical feeding to lactating cows, it is necessary to observe sorting against fodder-sugarcane silage.

Discipline: Animal industry
Additional key words: chemical composition, lactating cows, milk production, non-lactating cows

Introduction

   One of the factors restricting the expansion and development of livestock farming on the Nansei Islands, an archipelago of southwest Japan between Kyushu and Taiwan, is the limited area of cultivatable fields. In response, fodder-sugarcane KRFo93-1 was developed by cross breeding NCo310 with Glagah Kloet (*Saccharum spontaneum*). This is the first sugarcane breed specialized for animal feed in Japan, which is characterized by its high yield, high drought resistance, and lodging resistance in a typhoon[20]. It is known that KRFo93-1 has higher fiber content and dry matter (DM) yield as well as containing less sucrose than common sugarcane bred for sugar production[17]. It is also known that the fiber content of KRFo93-1 increase with advancing maturity, while crude protein (CP) decrease[19]. To replace conventional feeds with fodder-sugarcane silage and ensure its effective utilization, the nutritional characteristics of fodder-sugarcane silage and the current feeds used in Nansei Island must be known. Information on the physiological condition and productivity of livestock fed fodder-sugarcane silage is also necessary. Sakaigaichi & Terajima[16] reported that fodder-sugarcane silage showed low pH (3.5) and high fermentation quality. Feeding of sugarcane bred for sugar production to beef cattle[14] and lactating cows[6] and feeding KRFo93-1 to Japanese Black steers during rearing has been reported[5]. However, the information on feeding of

fodder-sugarcane to dairy cows remained limited.

The objective of this study was therefore to evaluate the nutritional characteristics of KRFo93-1 compared with the roughage used in some conventional dairy farms on the Nansei Islands, and investigate its long-term effect on body weight (BW), hematological parameters and blood metabolites in non-lactating Holstein cows and on milk production in lactating Holstein cows.

Materials and methods

The feeding trials in this study were conducted in accordance with the protocol approved by the Guide for the Care and Use of Experimental Animals [Animal Care Committee, NARO Kyushu Okinawa Agricultural Research Center (KARC)].

1. Feed collection on practical dairy farms

Samples of roughage were collected on two dairy farms on Tanegashima Island, located at the northern end of the Nansei Islands, every 4 months from July 2007 (total of 6 sample collections). Those collected roughage were produced on the island and fed to lactating cows . The chopped roughage samples were dried at 55 °C for 48 h and then ground (pore size, 1 mm; P-15, FRITSCH, Idar-Oberstein, Germany) for chemical analysis.

2. Preparation of fodder-sugarcane silage

Fodder-sugarcane (KRFo93-1) was harvested around 4 months after regrowth using a sugarcane harvester (MCH-15; Matsumoto Kiko Co., Kagoshima, Japan) at the sugarcane experimental station, KARC on Tanegashima Island (30°74'N, 131°06'E). The cultivation management followed the recommendation[17] to harvest twice yearly (on early June and late September). The harvested fodder-sugarcane was chopped to a theoretical cutting length of 9 mm using a corn harvester (MCH2830; IHI STAR Machinery Corporation, Hokkaido, Japan) and this chopped fodder-sugarcane was ensiled using a round baler for chopped material (TSB1000; IHI STAR Machinery Corporation) and a wrapping machine (MWM1060W; IHI Star Machinery Corporation). A silage sample was dried at 55 °C for 48 h and then ground (pore size, 1 mm; P-15, FRITSCH) for chemical analysis. A filtered extract of fodder-sugarcane silage was prepared from a mixture of fodder-sugarcane silage (25 g) and distilled water (100 mL) that was stored at 5°C overnight. The extract was kept at −20°C until the fermentation quality had been analyzed.

3. Feeding trial in non-lactating cows (Exp. 1)

A feeding trial with 6 non-lactating Holstein cows was conducted in a paddock at KARC (32°88'N, 130°74'E) from 29 May, 2009 to 8 October, 2009. The cows averaged 742±112 kg of BW (mean±SD) and 66±25 month of age at the start of the feeding trial. The cows had free access to the round-baled sugarcane silage (mean weight on as-fed basis: 315 kg) in a round bale rack and were fed 1.7 kg DM/cow/day of steam-rolled corn and 0.7 kg DM/cow/day of soybean meal during days 0 to 14 (period 1), 0.6 kg DM/cow/day of soybean meal and 2.8 kg DM/cow/day of oats hay from days 15 to 41 (period 2), and 0.8 kg DM/cow/day of soybean meal from days 42 to 105 (period 3). The amount and type of the supplemental feeds were designed according to BW change and the Japanese Feeding Standard for dairy cattle[12]. The supplemental feed was provided once daily at 16:00. A mineral block (E100TZ; Nippon Zenyaku Kogyo Co. Ltd., Fukushima, Japan) and water were freely accessed. Blood was collected from the jugular vein into heparinized sealed tubes on days 0, 6, 27, 63, 91, and 105 of the experiment, whereupon hematological testing was performed immediately using a hematology analyzer (KX-21NV; SYMEX Corporation, Hyogo, Japan) following blood collection. The plasma was separated at 3000 rpm for 15 min at 4 °C and stored in a freezer at −20 °C.

4. Feeding trial in lactating cows (Exp. 2)

Seven lactating Holstein cows were used in this trial conducted at KARC from 27 December, 2009. The cows averaged 120±24 days in milk (DIM; mean±SD) and 569±46 kg of BW at the start of the feeding trial. The cows had free access to total mixed ration (TMR), water, and a mineral block (E100TZ; Nippon Zenyaku Kogyo Co. Ltd.) in the feeding barn and were milked at 8:30 and 17:30 daily. The individual milk yield was measured daily. The cows were fed 0.9 kg DM/cow of commercial concentrate (Kumaraku P&F74C; Kumamoto Dairy cooperative, Kumamoto, Japan) during every milking session. TMR was prepared and provided twice daily at 9:30 and 16:00. The roughage to concentrate ratio in TMR remained constant at 6:4 throughout the trial, whereas Italian ryegrass was gradually replaced with sugarcane silage from 0 to 20% of TMR on a DM basis (Table 2). This feeding trial comprised 6 experimental periods: TMR containing 0, 3, 5, 10, 15, and 20% fodder-sugarcane silage was fed to lactating cows in each period on days 0 to 21, 22 to 36, 37 to 64, 65 to 77, 78 to 91, and 92 to 106, respectively. To retain 69.0% of total digestible nutrients (TDN) and 15.0% of CP content in TMR throughout the trial, the ratios of commercial concentrate (Kumaraku P&C75; Kumamoto Dairy cooperative), soybean meal, and steam-rolled corn were adjusted. Blood samples were collected from the jugular vein into heparinized sealed tubes, following morning milking on days 16, 30, 58, 72, 87 and 100, whereupon hematological testing was conducted immediately using a hematology analyzer (KX-21NV; SYMEX Co. Ltd.). The plasma was separated at 3000 rpm for 15 min at 4 °C and stored in a freezer at −20

°C. Samples of TMR and orts in the feed bank were collected 3 times during each blood sampling period, while milk samples on consecutive 2 days were collected on days 16, 30, 44, 58, 72, 87 and 100. Part of the TMR sample was dried at 55 °C for 48 h before being ground (pore size, 1 mm; P-15, FRITSCH) for chemical analysis, while the remaining TMR and orts samples were used for particle size analysis.

Data on the milk yield and milk component of 5 cows during the winter season of the previous year (22 December, 2008 to 7 April, 2009) were prepared as a control. The control cows, averaging 120±23 DIM at the start of the data collection, were selected from the same herd and under the same management with experimental cows. The control cows were fed TMR containing constant feed material (corn silage, Italian ryegrass silage, commercial concentrate, soybean meal, steam rolled corn, and minerals and vitamin supplements) throughout the period of data collection. The chemical composition of the TMR also remained constant throughout the period (TDN, 71.5% DM; CP, 14.5% DM). Additionally, the cows were fed 0.9 kg DM of the commercial concentrate (Kumaraku P&C75; Kumamoto Dairy cooperative) at milking as well as the present study (Exp. 2). The individual milk yield was recorded daily. For milk fat, milk protein and milk lactose analysis, milk samples on consecutive 2 days were collected on days 1, 26, 39, 53, 67, 78, 92 and 106 from the start of the data collection.

5. Feed, blood, and milk analyses

The chemical composition of the feed samples collected from dairy farms, fodder-sugarcane silage, and TMR were determined, while the DM content was determined after drying at 135 °C for 2 h. The crude ash, ether extract, and CP content were measured according to AOAC[1]. The neutral detergent fiber exclusive of residual ash and without the inclusion of sodium sulfite[21] (NDFom), acid detergent fiber excluding residual ash[15] (ADFom), and acid detergent lignin[15] (ADL) were also determined. The non-fiber carbohydrate was estimated by subtracting the moisture, CP, NDFom, EE, and crude ash from 100, while the neutral detergent-insoluble and acid detergent-insoluble nitrogen content were respectively determined according to Licitra et al.[9] TDN content was calculated according to the equation by NRC[13]. The digested fodder-sugarcane silage in nitric-perchlonic acid was prepared to analyze phosphorous (P), calcium (Ca), potassium (K) and magnesium (Mg). The P content was determined by the colorimetric method of Gomori and Ill[3]. The Ca, K and Mg contents were determined by atomic absorption spectrophotometry (SOLAAR M6, Nippon Jarrell-Ash Co., Ltd, Kyoto, Japan).

The pH and organic acid composition of fodder-sugarcane silage extract were measured using a glass-electrode pH meter (PH82; Yokogawa Electric Co., Tokyo, Japan)

and HPLC (LC-20000; JASCO Co., Tokyo, Japan), respectively. The fermentation quality of the silage was evaluated by Flieg's scoring[11], which was based on the proportions of lactic, acetic, propionic, and butyric acids and ranged from 0 to 100.

The particle size distribution of TMR, the feeds in TMR, and orts were determined using a Penn State Particle Separator (PSPS) consisting of 3 stacked sieves (pore size: 19.00, 8.00, and 1.18 mm) and a pan. The PSPS was shaken horizontally, after the samples had been placed on the top sieve[8]. The remaining particles on each sieve and the pan were weighed, and particle size distribution was calculated on an as-fed basis.

The hematological parameters determined during the feeding trial in non-lactating and lactating cows were as follows: white blood cells (WBC), red blood cells (RBC), hemoglobin (HGB), hematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and platelets (PLT). Albumin (ALB), blood urea nitrogen (BUN), ammonia, Ca, inorganic phosphorous (IP), and Mg concentration in plasma for non-lactating cows, and ALB, BUN, Ca, IP, and Mg concentration in plasma for lactating cows, were determined using a FUJI DRI–CHEM (3500V; FUJIFILM Co., Tokyo, Japan). Milk fat, milk protein, and milk lactose contents of samples from experimental and control cows were determined using a MILKO-SCAN 133B (Foss Electric, Hillerød, Denmark).

6. Statistical analysis

Data were analyzed using the MIXED procedure of SAS[18], while statistical significance among mean values was assessed by Tukey's test. The linear regression analysis between daily milk yield and experimental day, and between concentrates of respective milk components and experimental day were performed by the REG procedure in SAS[18]. Data were considered to differ statistically for $P < 0.05$.

Results and discussion

1. Chemical composition and TDN content of fodder-sugarcane silage and roughage in dairy farms

The following roughage was fed to lactating cows on the two dairy farms: Bahia grass, Italian ryegrass, sorghum, sorghum with corn, and Sudan grass as silage, and Guinea grass, Italian ryegrass, Napier grass, oats, Rhodes grass, sugarcane tops as fresh forage, and rice straw. Additionally, imported oats hay, timothy hay, and alfalfa hay had been fed to lactating cows but were excluded from the samples.

The pH and lactic acid, acetic acid, propionic acid, and butyric acid content of the fodder-sugarcane silage were 3.6 and 2.63, 0.33, 0.00, and 0.00% (on an as-fed basis), respectively. Fliegs' score was consequently 100, indicating the

Table 1. Feed formula, chemical composition, and total digestible nutrients (TDN) in total mixed ration (TMR) containing 0, 3, 5, 10, 15, and 20% of fodder-sugarcane silage (Exp. 2)

	Proportion of fodder-sugarcane silage[1]					
	0%	3%	5%	10%	15%	20%
Feed Formula (% DM basis)						
Fodder-sugarcane silage	-	3.0	4.9	9.9	14.8	19.7
Corn silage	30.6	30.6	30.6	30.6	30.6	30.6
Italian ryegrass silage	29.8	26.6	24.7	19.7	14.8	9.9
Commercial concentrate	16.9	15.8	14.8	10.9	8.9	5.9
Soybean meal	5.6	6.9	7.9	9.9	11.8	12.8
Steam-rolled corn	-	-	15.8	17.8	17.8	19.7
Minerals and vitamins	1.3	1.3	1.3	1.3	1.3	1.3
Chemical composition (%DM)						
EE	3.7	3.6	3.5	3.4	3.2	3.1
CP	14.2	14.3	14.4	14.4	14.5	14.1
NDFom	35.7	36.0	36.3	36.8	37.5	38.1
ADFom	20.6	21.0	21.3	22.0	22.8	23.5
TDN (%DM)	70.0	69.0	69.0	69.0	68.9	68.9

DM, dry matter; EE, ether extract; CP, crude protein; NDFom, ash-free neutral detergent fiber; ADFom, ash-free acid detergent fiber; TDN, total digestible nutrients.
[1] The proportion in TMR based on DM.

highest fermentation quality. The crude ash, CP, and TDN content of fodder-sugarcane silage were lower than those of the mean roughage values on the dairy farms, whereas NDFom, ADFom, and ADL content were higher for fodder-sugarcane silage compared with roughage on the dairy farms (Table 1). The CP content of fodder-sugarcane silage was close to rice straw (3.61 %DM). The TDN content of fodder-sugarcane silage was below the mean value, but within the mean±SD range. From a chemical composition perspective, the roughage used for lactating cows in Tanegashima could be replaced with fodder-sugarcane silage, but a supplemental source of CP would be necessary. These findings are similar to the report on fodder-sugarcane as fresh forage by Suzuki et al.[19]

2. Feeding non-lactating cows (Exp. 1)

Soybean meal was provided throughout the experimental periods to ensure an adequate protein source, while steam-rolled corn was also provided in period 1, due to the uncertain intake of fodder-sugarcane silage. The steam-rolled corn was replaced with oats hay in period 2, whereupon only soybean meal was provided as supplementary protein and an energy source in period 3. Because the roll-baled silage of sugarcane was consumed in almost 2 days, silage was provided on alternate days. Therefore, it is considered that daily DM consumption of fodder-sugarcane silage was around 5.5 kg per cow throughout the experimental period.

BW remained stable throughout the experiment excepting the BW on day 0, which was the highest in the measurements (Fig. 1). The standard BW of the cows on day 0,
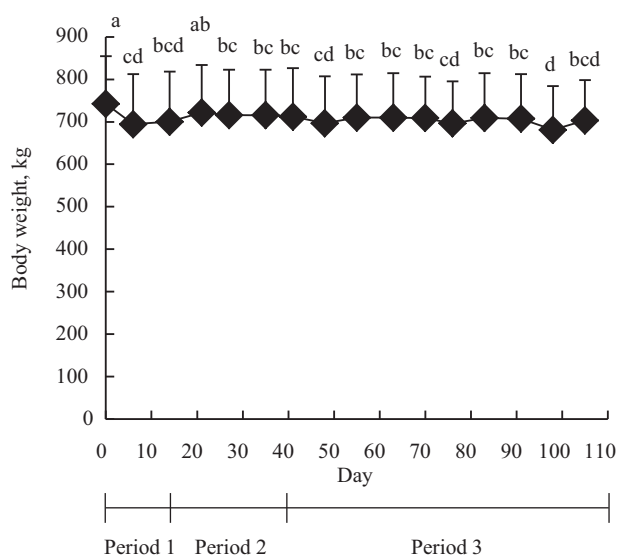
Fig. 1. Changes in the body weight of non-lactating cows (n=6; mean±SD) fed fodder-sugarcane silage with corn and soybean meal (period 1), with oats hay and soybean meal (period 2), or with soybean meal (period 3) (Exp. 1)
[abcd]Values with different letters differ among measurements ($P < 0.05$).

calculated using the growth curve for Holstein cows[12], is 675 kg, which is lower than actual BW on day 0 (742 kg) as well as the actual BW throughout the experimental period excepting day 0 (mean BW, 704 kg). Therefore, it is considered that the nutritional intake was sufficient to maintain their BW throughout the experiment, whereas the cows on day 0 were considered obese.
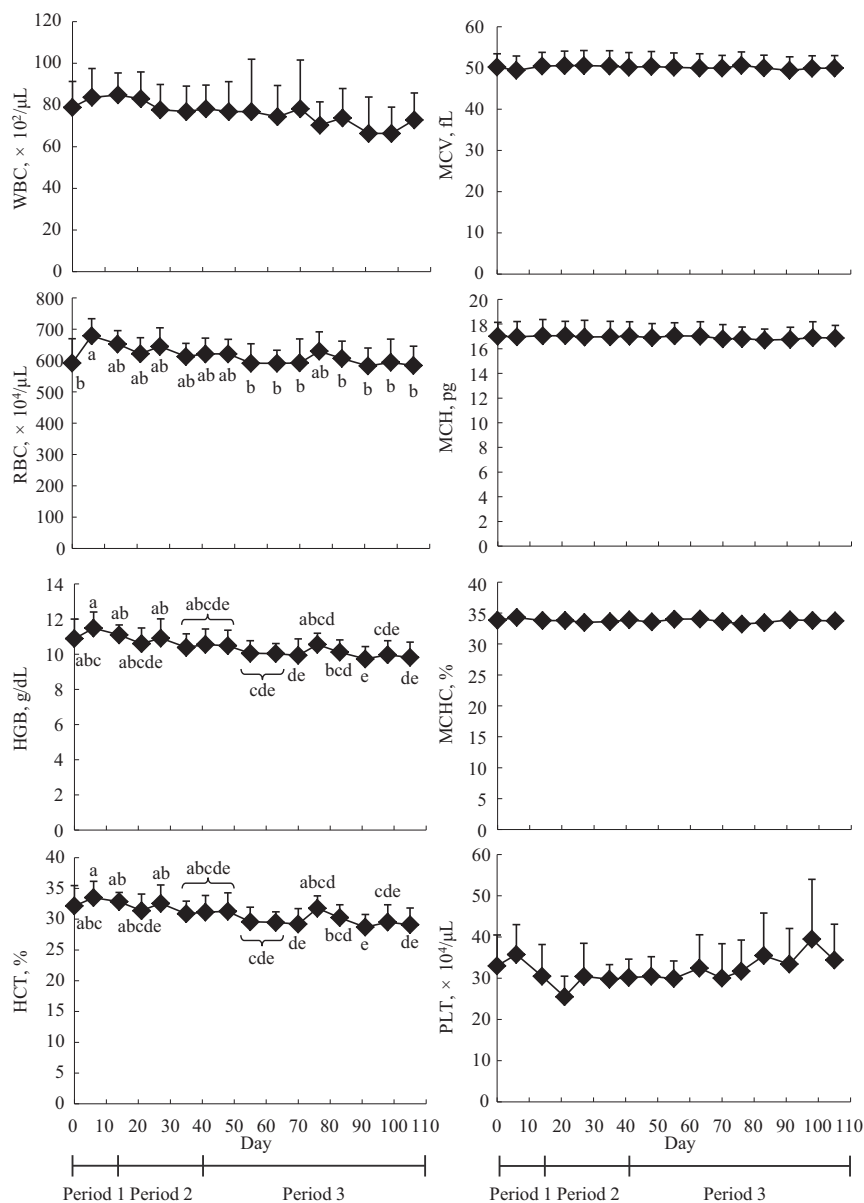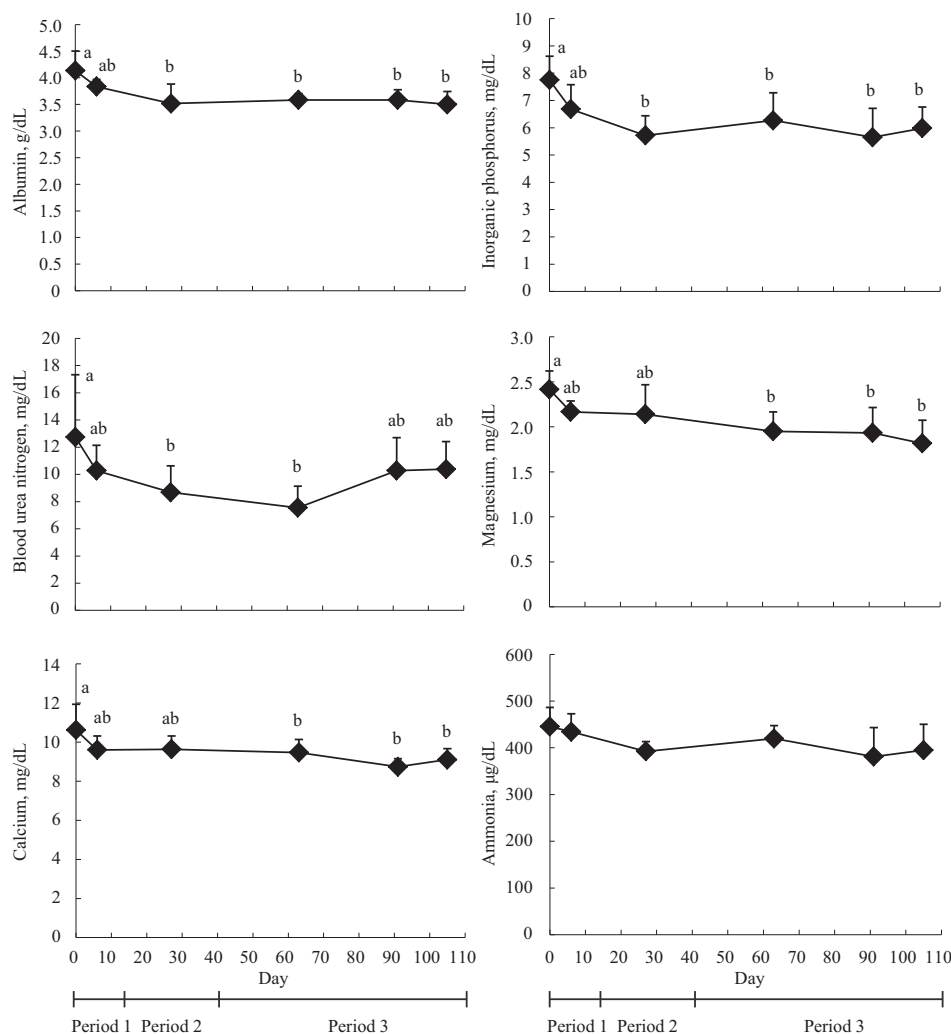
Fig. 2. Changes in hematological parameters of non-lactating cows (n=6; mean±SD) fed fodder-sugarcane silage with corn and soybean meal (period 1), with oats hay and soybean meal (period 2), or with soybean meal (period 3) (Exp. 1)
[abcde]Values with different letters differ among sampling days (P < 0.05). WBC, white blood cell; RBC, red blood cell; HGB, hemoglobin; HCT, hematocrit; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; PLT, platelet.

Changes in hematological parameters are shown in Fig. 2. The HGB and HCT decreased over the experimental period, but remained within a normal range[10] (8 to 15 g/dL and 24 to 46%, respectively). It is considered that the increase in water intake, which is related to elevated ambient temperature, resulted in this declining trend, because the experiment started at the beginning of summer. The other hematological parameters showed few constant changes as the experimental period progressed and were within the normal range[10].

Changes in plasma metabolite concentrations are shown in Fig. 3. The ammonia concentration remained similar throughout the experimental period, as did other plasma metabolite concentrations, except for day 0. One of the factors affecting these higher concentrations on day 0 was the excess nutrition preceding the experiment. The P, Mg, Ca, and K content of the provided fodder-sugarcane silage were 0.171, 0.095, 0.244, and 3.48% of DM, respectively. It is known that a high level of K and low level of Mg in the feed leads to a lack of Mg uptake called grass tetany[12]. The tetany ratio [K/(Ca+Mg) on an equivalent weight basis] of the fodder-sugarcane silage in the present study

Fig. 3. Changes in plasma metabolites of non-lactating cows (n=6; mean±SD) fed fodder-sugarcane silage with corn and soybean meal (period 1), with oats hay and soybean meal (period 2), or with soybean meal (period 3) (Exp. 1)
[ab]Values with different letters differ among sampling days (P < 0.05).

was 4.4, indicating that silage is considered tetany-prone feed[12] (>2.2). However, the plasma Mg concentrations of the cows in the present study remained normal throughout the experimental period (normal range[10], 1.8 to 3.2 mg/dL of serum). Meanwhile, for the cows in transition or in the early lactation stage, which were most susceptible to grass tetany or Mg deficiency[12], the K and Mg levels of the fodder-sugarcane silage have to be assessed.

3. Feeding lactating cows (Exp. 2)

The particle size distribution of TMR and orts is shown in Table 4. The ratio of TMR on the 19.0-mm sieve rose with increasing sugarcane proportion in TMR, whereas that on the 8.0-mm sieve decreased. These results were due to the replacement of Italian ryegrass with fodder-sugarcane silage. The fodder-sugarcane silage contained more particles retained on the 19.0-mm sieve compared with Italian ryegrass silage (73.8 vs. 12.0%), but fewer particles on the

8.0-mm sieve (21.2 vs. 62.5%; Table 3). The results in orts were similar to those in TMR: The proportion of orts on the 19.0-mm sieve rose with increasing sugarcane proportion in TMR, whereas that on the 8.0-mm sieve decreased. Increasing the fodder-sugarcane silage in TMR is considered to have facilitated sorting of the large particles. Bhandari et al.[2] and Kononoff et al.[8] also found that sorting against large particles retained on the 19.0-mm sieve was greater for TMR containing longer rather than shorter roughage.

Changes in the hematological parameters of lactating cows are shown in Fig. 4. Although significant differences emerged in WBC, HGB, and HCT among experimental periods, no specific relationships between the proportion of fodder-sugarcane silage and these parameters were found. Additionally, the values of WBC, HGB, and HCT were within the normal range[10] (40 to 120×10²/μL, 8 to 15 g/dL, and 24 to 46%, respectively). There were no significant dif-

Table 2. Chemical composition and total digestible nutrients (TDN) of fodder-sugarcane silage and roughage collected from 2 dairy farms on Tanegashima Island

	Fodder-sugarcane silage	Roughage collected from dairy farms			
		Mean	SD	Min.	Max.
DM (%, as fed)	21.3	-	-	-	-
Chemical composition (% DM)					
Crude ash	7.3	11.3	3.4	6.9	20.6
EE	1.7	1.9	0.7	1.1	3.7
CP	3.6	8.7	3.3	3.6	20.0
NFC	13.4	12.1	4.5	24.7	5.8
NDFom	71.8	66.0	6.3	47.5	77.9
ADFom	44.5	39.0	3.2	29.8	44.6
ADL	5.8	5.0	1.3	2.2	7.0
TDN (% DM)	51.1	53.2	3.3	47.1	59.5

DM, dry matter; EE, ether extract; CP, crude protein; NFC, non-fiber carbohydrates; NDFom, ash-free neutral detergent fiber; ADFom, ash-free acid detergent fiber; ADL, acid detergent lignin.

Table 3. Particle size distribution[1] of total mixed ration (TMR) containing 0, 3, 5, 10, 15, or 20% of fodder-sugarcane silage and orts (Exp. 2)

	Proportion of fodder-sugarcane silage[2]						SEM	P
	0%	3%	5%	10%	15%	20%		
TMR (% retained, as-fed basis)								
19.0 mm	10.6[d]	15.5[cd]	14.9[cd]	19.9[bc]	23.5[b]	30.4[a]	1.5	<0.001
8.0 mm	57.7[a]	54.0[ab]	52.1[abc]	46.6[c]	48.8[bc]	36.3[d]	1.3	<0.001
1.18 mm	27.8	26.3	28.1	28.4	23.9	27.5	1.2	0.241
Pan	3.9	4.3	4.9	5.0	3.8	5.8	1.0	0.609
Orts (% retained, as-fed basis)								
19.0 mm	24.3[c]	27.3[c]	29.0[c]	48.7[b]	46.6[b]	72.7[a]	2.8	<0.001
8.0 mm	48.5[a]	45.8[a]	43.5[a]	30.5[b]	31.6[b]	15.0[c]	1.2	<0.001
1.18 mm	23.2[a]	23.1[a]	23.2[a]	17.8[a]	18.8[a]	10.8[b]	1.3	<0.001
Pan	4.0[a]	3.8[ab]	4.2[a]	3.0[ab]	3.0[ab]	1.4[b]	0.5	0.031

SEM, standard error of the mean
[1] Determined using the Penn State Particle Size Separator (Kononoff et al., 2003).
[2] The proportion in TMR based on DM.
[abcd] Values with different letters differ in the same row (P < 0.05).

Table 4. Particle size distribution[1] of roughages and concentrates used for materials of total mixed ration (Exp. 2)

	Fodder-sugarcane silage	Corn silage	Italian ryegrass silage	Commercial concentrate	Soybean meal	Steam rolled Corn
% retained, as-fed basis						
19.0 mm	73.8	6.6	12.0	0.0	0.0	0.0
8.0 mm	21.2	80.9	62.5	69.9	3.1	37.6
1.18 mm	4.9	12.5	24.6	29.9	83.0	52.2
Pan	0.0	0.0	1.0	0.2	13.9	10.2

[1] Determined using the Penn State Particle Size Separator (Kononoff et al., 2003).

ferences among the experimental periods in RBC, MCHC, and PLT. The MCV and MCH throughout these periods were within the normal range[10] (40 to 60 fL and 11 to 17 pg, respectively), whereas the MCV and MCH peaked when cows were fed 20% fodder-sugarcane silage in TMR.

Changes in the plasma metabolites of lactating cows are shown in Fig. 5. There were no significant differences in the experimental periods in Ca and ALB concentrations. IP and Mg concentrations showed significant differences among experimental periods, but no constant changes with the increasing proportion of fodder-sugarcane silage. The BUN concentrations at TMR, including 15 and 20% fodder-
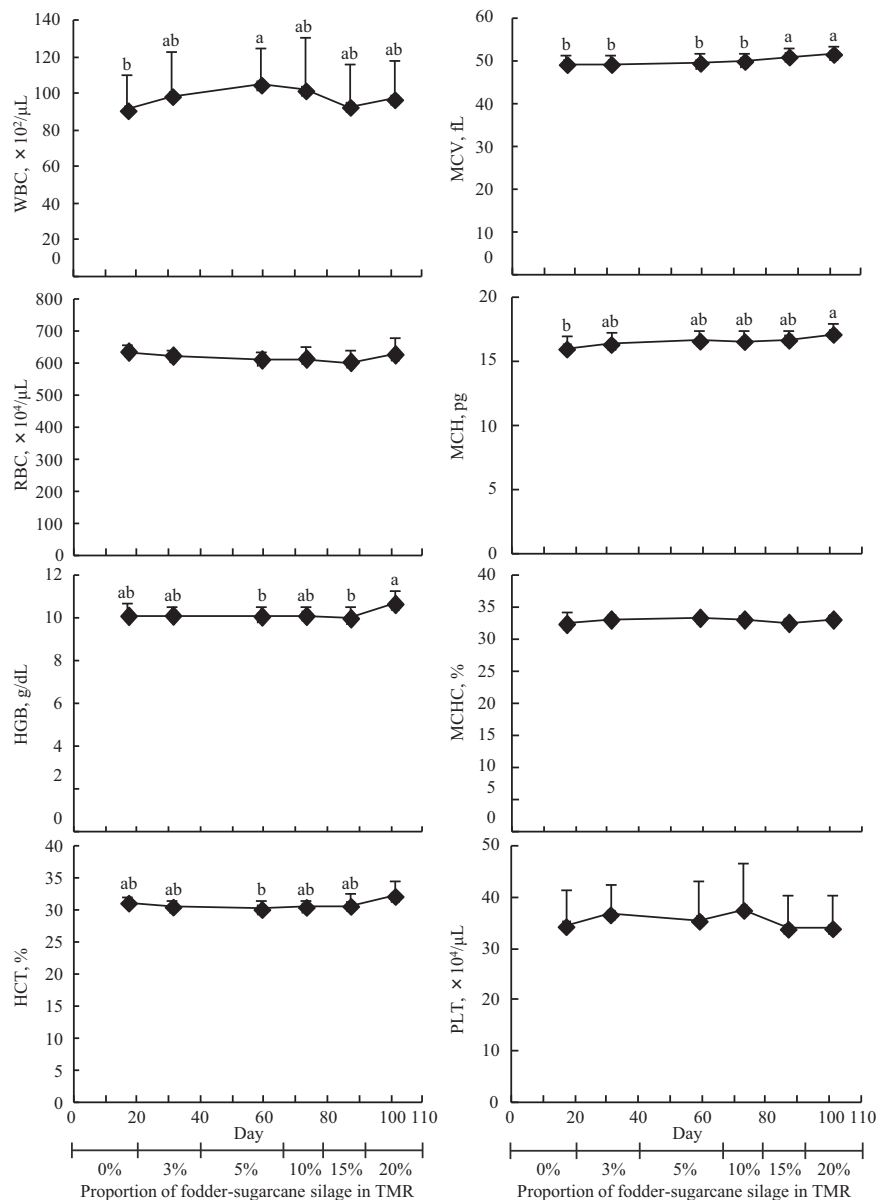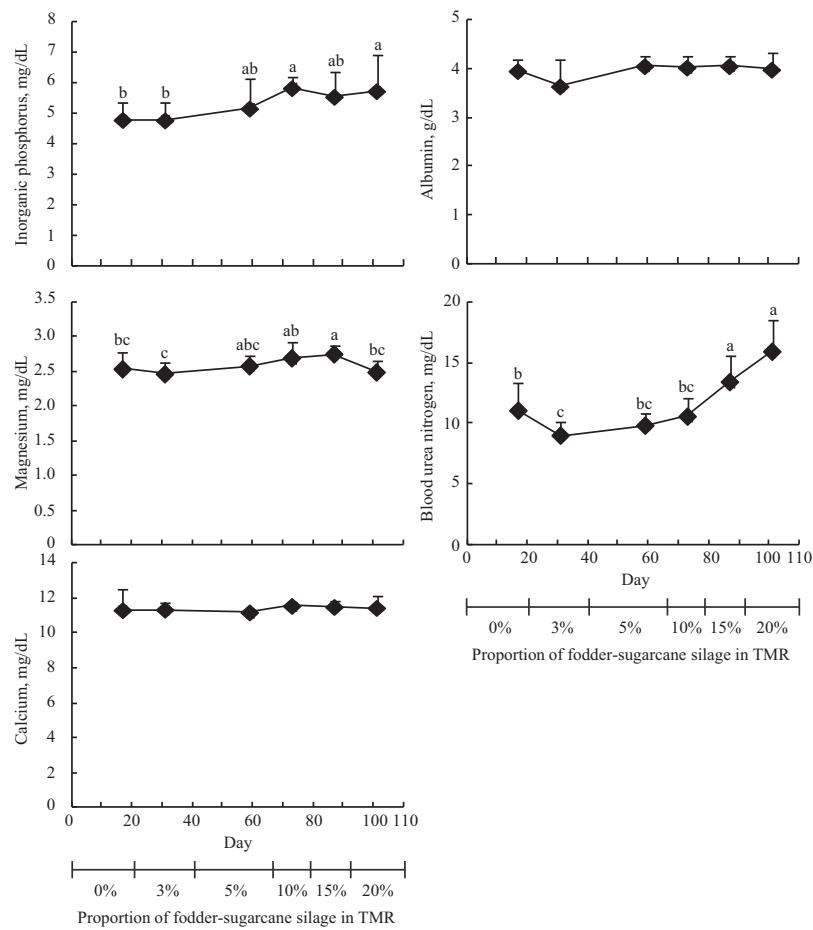
Fig. 4. Changes in hematological parameters of lactating cows (n=7; mean±SD) with increasing of fodder-sugarcane silage in total mixed ration (TMR) from 0 to 20% on a dry matter basis (Exp. 2)
[ab]Values with different letters differ among sampling days (P < 0.05). WBC, white blood cell; RBC, red blood cell; HGB, hemoglobin; HCT, hematocrit; MCV, mean corpuscular volume; MCH, Mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; PLT, platelet.

sugarcane silage, exceeded those at TMR, including 0, 3, 5, and 10% fodder-sugarcane silage. It is considered that this increase in BUN was unaffected by advancing DIM, because BUN concentration during the mid- to late lactation period decreases moderately with advancing DIM[7]. The proportion of large particles (>19 mm), which originated mainly from the sugarcane stem, rose with increasing proportion of fodder-sugarcane (Table 4). The CP content of fodder-sugarcane silage was lower than the roughage sources of TMR in this experiment: CP contents of Italian ryegrass and corn silage were 9.3% DM and 8.2% DM, respectively. Therefore, it can be considered that the CP

content of TMR actually fed to the cows rose with increasing proportion of fodder-sugarcane silage (i.e. increasing sorting), consequently increased BUN concentration. Heinrichs and Kononoff[4] recommended that the proportion of particle weight (as-fed basis) retained on a 19.0-mm sieve be 3 to 8% for corn silage and 2 to 8% for TMR. We chopped the sugarcane to 9-mm, which is the shortest theoretical cutting length for our chopping machine, but the proportion of particles on the 19.0-mm sieve in this study was 74% for fodder-sugarcane silage and over 15% for TMR, including fodder-sugarcane silage (Tables 3 & 4). Therefore, to reduce sorting against long particles, the mix-

Fig. 5. Changes in plasma metabolites of lactating cows (n=7; mean±SD) with increasing of fodder-sugarcane silage in total mixed ration (TMR) from 0 to 20% on a dry matter basis (Exp. 2)
[abc]Values with different letters differ among sampling days (P < 0.05).

ing percentage of fodder-sugarcane silage in TMR should be reduced or sugarcane should be chopped as short as possible.

The relationships between experimental days and concentrations of milk fat, milk protein and milk lactose are shown in Fig. 6. Mean milk fat, protein and lactose concentrations throughout the collection days were 4.36, 3.39 and 4.59%, respectively, for control cows, and 3.65, 3.20 and 4.51%, respectively, for experimental cows. Higher mean milk fat concentrations in control cows rather than experimental cows were due to the higher TDN content in provided TMR (71.5 vs. 69.0% DM). Meanwhile, there were no correlations between the data collection day and concentrations of milk fat, protein or lactose for control cows, indicating few changes in milk components with advancing DIM. For experimental cows, no correlations between experimental days and concentrations of those milk components were found either. These results indicate that advancing DIM and increasing the proportion of sugarcane did not affect concentrations of milk fat, protein and lactose in experimental cows.

The daily milk yields of control and experimental cows over 107 days, from a mean DIM of 120, are shown in Fig. 7. There were negative correlation between daily milk yield and day in both control cows (r= -0.422; P<0.001) and experimental cows (r= -0.554; P<0.001). The linear slope of the correlation in control cows was -0.029, indicating a decrease in milk yield caused by advancing DIM. The slope -0.032 in the experimental cows was very similar to that in control cows. The declining milk yield of experimental cows was thus mainly attributed to the advancing lactation stage, but not the increased proportion of fodder-sugarcane silage.

Conclusion

When the chemical composition of the fodder-sugarcane silage was compared with that of roughage provided to lactating cows while dairy farming on Tanegashima Island, the CP content of fodder-sugarcane silage was at the lowest level, whereas the NDFom content of the same was high. Feeding fodder-sugarcane silage as the main forage source
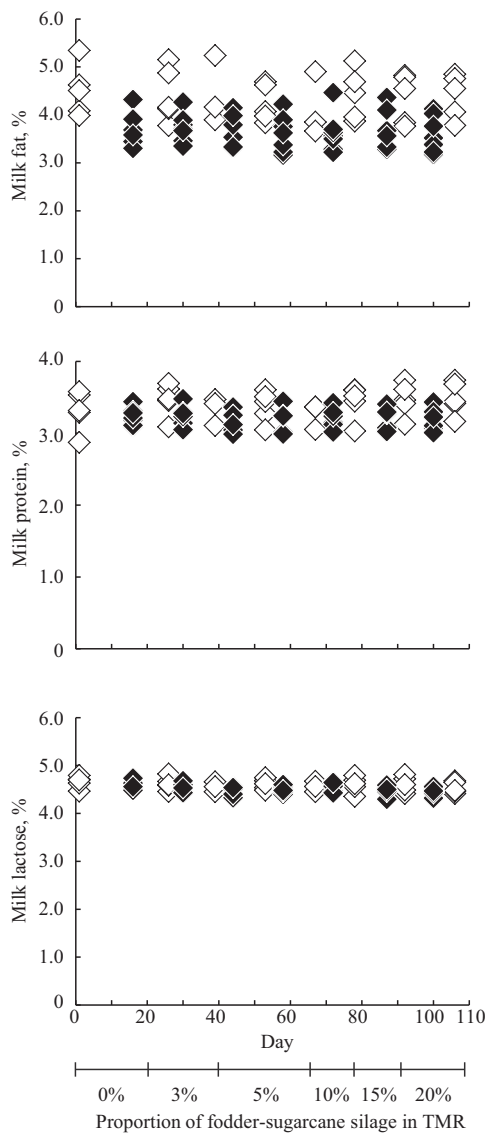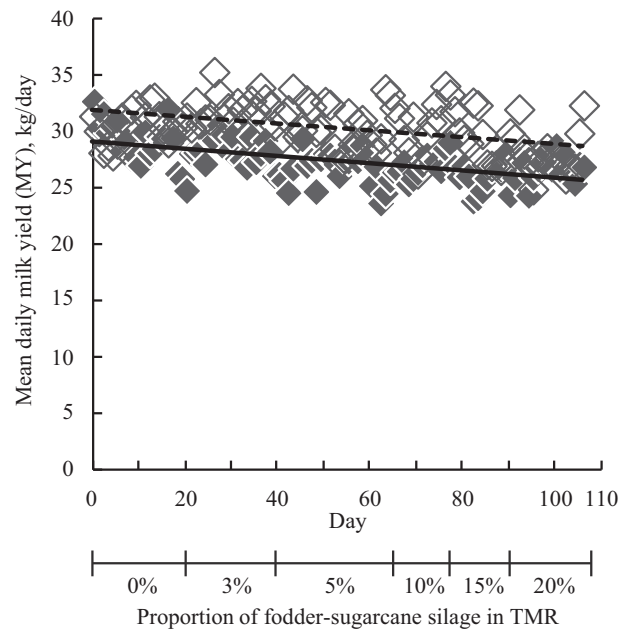
Fig. 6. **Milk fat, protein and lactose concentrations of cows fed total mixed ration (TMR) including 0 to 20% of fodder-sugarcane silage (◆; n=7), and cows fed TMR without fodder-sugarcane silage (◇; n=5) (Exp. 2)**

Fig. 7. **Mean daily milk yield of cows fed total mixed ration (TMR) including 0 to 20% of fodder-sugarcane silage (◆; n=7), and cows fed TMR without fodder-sugarcane silage (◇; n=5) (Exp. 2)**
The linear regression line for cows fed TMR, including 0 to 20% of sugarcane silage (solid line; MY = -0.032DIM + 33.002, r = -0.554, P < 0.001) and that for cows fed TMR without sugarcane silage (dashed line; MY = -0.029DIM + 35.440; r = - 0.422, P < 0.001) were shown.

over 100 days did not adversely affect the physiological condition of the non-lactating cows, nor did feeding fodder-sugarcane silage in TMR to lactating cows adversely affect milking performance. However, the higher proportion of fodder-sugarcane silage in TMR caused greater sorting of fodder-sugarcane stems by cows, consequently increasing the BUN concentration. Fodder-sugarcane silage could be fed to cows as well as conventional roughage, but low CP content and sorting behavior must be taken into consideration.

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