Feed Intake and Eating Characteristics of Lactating Cows Fed Silage Mixture and Supplemental Concentrates in Free-stall Housing

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Abstract

Studies were conducted of the estimated feed intake and eating behavioral characteristics of individual cows fed SM (Silage Mixture) and concentrates *via* CFS (Concentrates Feed Station) on an average of 14.1℃ by using 15 lactating Holstein cows kept in a barn with two rows of eight free stalls each. Daily eating time, bouts (visits) to bunk-fed SM and CFS, and meals of SM for each cow were measured for two periods of 3 d each. Ten minutes was adopted as the minimum inter-meal interval. Load cells were attached to measure the feed intake in 2 of 15 feed troughs. Those two measured the opening and shutting time of the door feeders and the intervening feed weight in each cow. The eating rate of each cow was calculated from the daily feed intake and the daily eating time of the cows in the two troughs that were monitored in this way. The daily voluntary DMI (Dry Matter Intake) of SM in each cow was estimated by multiplying the eating rate by the daily total eating time. The daily total eating time of SM averaged 221 minutes, which seemed to be shorter than that in tie stalls and to imply a higher eating rate. Shifts between feed troughs per meal were observed 6 times on average because the number of SM meals per day averaged 8 while the number of daily bouts to SM averaged 49. Older cows had a higher DV (Dominance Value), shorter daily distance traveled, fewer visits to SM and CFS, and also showed a tendency toward a larger meal size and longer meal duration. Heavier cows tended to have a shorter daily total eating time and a higher eating rate. Neither milk production nor DV influenced eating behavior aside from a significantly positive correlation between milk production and DMI in SM and CFS. The ratio of TDN (Total Digestible Nutrients) intake to TDN requirements varied from 86–126% with an average of 103%.

Key words: Dairy cow, Free-stall, Feed intake, Nutritional intake, Eating behavior

Introduction

Basic nutritional management of lactating cows in FS (free-stall) housing is done according to nutritional requirements of each group that is divided by the variety of lactation stage, age, and level of milk production. However, management of a single group, making no such distinctions, is widely popular in Japan. Small herds on Japanese farms engender the inability to expend efforts on group division and its inherent need for specialized feed preparation.

The nutritional intake of cows is determined by feed intake and its nutrient content. The feeding plan under herding management is made according to a nutrient content based on estimated feed intake.

Ad libitum feedings of TMR (Total Mixed Rations), with which depression of selective intake and labor-saving feedings are expected, are carried out at many FS dairy farms. The nutrient content of ingested TMR is nearly stable, but nutritional intake is not necessarily consistent with requirements be-

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cause of the feed intake variation. In particular, this variation seems to occur under a single group management with great variation in nutitional requirements. An automatic CFS (Concentrates Feeding Station) system managed *via* transponder control is used in combination with mainly bunk-fed quasi-TMR to minimize the extent of overfeeding or underfeeding resulting from differences in the cows' nutritional requirements by a single group.

The use of the CFS system in loose housing has been examined in terms of cattle behavior[9,12,15,16] and for evaluation system[3], but little is known about the estimated DM (Dry Matter) and nutritional intake of individuals or the relationship between eating behavior and cows' characteristics, such as body weight, by use of a TMR or a CFS in loose housing.

Therefore, treating the cows as a single group, we studied eating characteristics of cows given a group-fed silage mixture (quasi TMR) and supplemental concentrates *via* CFS and their relations with cow's characteristics, the estimated voluntary DM intakes of SM (Silage Mixture), and the ratios of the estimated TDN (Total Digestible Nutrients) and CP (Crude Protein) intakes to the requirements.

Materials and Methods

The cows and FS area used in this study were described in a previous paper[8]. Data presented here were collected during the investigation period of that paper[8].

A group of 15 lactating Holstein cows was maintained in a FS barn at the National Institute of Livestock and Grassland Science (the former National Grassland Research Institute). This group comprised 11 cows (Nos. 1-11) introduced from the headquarters of the National Livestock Breeding Center 10 mo before the study and 4 primiparous cows (Nos. 12-15) introduced as heifers from Hokkaido (Table 1). The cows had not been kept in this FS area before and were placed there soon after calving.

The shady northeast FS area had two head-to-head rows of 8 stalls with a floor space of 222 m^2 (Fig. 1). The feed alley on the south side was 3.7 m wide ; the stall alley on the north side was 2.7 m wide. Every individual was able to use any of 15 feed troughs along the central drive-through alley. After an adjustment period (7 d), the cows were observed 24 h per day for 3 d from 11-13 October and for the other 3 d from 21-23 October in 1998. Air temperature and relative humidity 2.2 m above the central ground of the FS area averaged 14.1℃ with a range of 9.4-21.4℃ and 86% during the observation periods.

The SM (Silage Mixture) was dispensed to the south feed troughs by an automatic continuous mixing feeder. The SM contained 65% corn silage, which was harvested from the same field and processed on

Table 1. Cow characteristics in the observed herd.

Cow No.	Age (mo)	BW[a] (kg)	MY[b] (kg/d)	Milk fat (%)	Milk protein (%)	Solid not fat (%)	4%FCM[c] (kg/d)	DV[d]	Days post-partum[e]	Distance traveled (m/d)
1	113	724	19.9	3.6	3.4	9.0	18.7	0.57	174	331
2	113	745	30.4	5.6	3.8	9.3	37.7	0.71	216	727
3	103	666	34.6	4.4	3.1	8.5	36.7	0.29	121	398
4	102	670	34.0	3.5	3.2	8.3	31.4	0.43	138	541
5	101	702	24.9	4.1	3.6	9.1	25.3	0.86	259	566
6	99	689	31.4	3.9	3.1	8.5	31.0	0.36	100	668
7	90	740	35.5	3.7	3.2	8.8	33.9	0.43	186	610
8	86	673	39.4	3.9	2.9	8.4	38.8	0.57	119	316
9	70	776	37.2	4.2	3.3	8.8	38.4	0.43	132	594
10	70	744	33.4	4.4	3.4	9.0	35.4	0.36	137	575
11	65	902	22.9	4.3	3.5	9.0	23.9	0.21	210	547
12	34	586	24.2	4.4	3.8	9.4	25.7	0.29	199	914
13	30	542	19.0	4.8	3.5	9.4	21.3	0.07	58	1010
14	29	566	31.2	5.0	3.2	8.9	35.8	0.14	42	1108
15	29	538	28.0	3.5	3.1	8.1	25.9	0.43	34	1411
Average	76	684	29.7	4.2	3.3	8.8	30.7	0.41	142	688
Sd	32	98	6.3	0.6	0.3	0.4	6.7	0.21	66	209

Notes [a] Mean body weight before and after each observation period.
[b] Daily mean milk yield through observation periods
[c] 4% fat corrected milk=15×kg of milk fat+0.4×kg of milk.
[d] Dominance value.
[e] At the first day of observation periods.

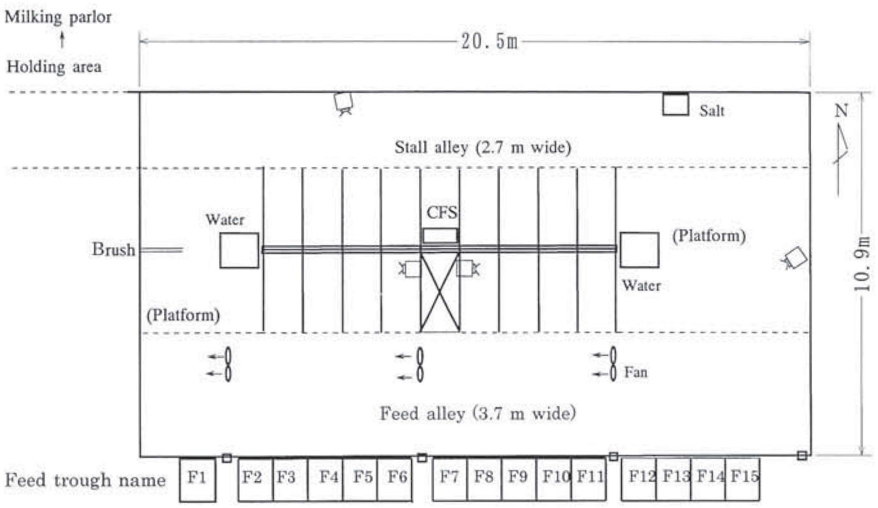

Fig. 1. Overhead view of observation pen in which the herd was kept
Notes CFS : Concentrates feed station.
Feed troughs of F6 and F11 have load cells.
: Camera mounted.

the same day at an underground square silo, 17% CC (Commercial Concentrates), 5% beet pulp, 12% alfalfa pellets, and 1% vitamins and minerals on a DM basis with DM 32.4%, actual TDN 65.8%/DM and CP 10.8%/DM. Actual TDN was calculated from each TDN of the feedstuffs by the total collection method of 7 d digestion trials with 4 wethers. The SM feedings occurred five times daily at 9 : 15, 13 : 15, 16 : 15, 19 : 15, and 22 : 15 ; they began from the east-end feed trough and moved westward. Actual ratios of feed refused to feed offered were an average of 14.1% on a DM basis.

The CC in the SM and *via* a CFS contains DM 89.2%, actual TDN 83.4%/DM and CP19.5%/DM. Its allocations for the CFS *via* transponder settings were based mainly on lactation stages with ranges of 2-5 kg/day : 4-5 kg for early lactation between 1-100 days after calving, 3-4 kg for mid-lactation between 101-200 days, and 2 kg for late lactation over 201 days. Based on this feeding criterion initially, the feed amounts were adjusted also by milk yields and body condition score.

The CFS automatic feeding system was divided into two cycles of 12 h. The 12-h cycles started at 10 : 00 and 22 : 00. For cows fed 3 kg or less, all allotted amounts were set out at 10 : 00, whereas for cows fed more than 3 kg, 3 kg were set out at 10 : 00 and the remainder at 22 : 00. The cows were given a portion of 75 g every 20 s, at a rate of 225 g/min.

Drinking water and salt licks were supplied *ad libitum*. The cows were removed from the barn area to a milking parlor twice daily, once from 8 : 45 to 9 : 10 and once from 18 : 00 to 18 : 20. An automatic alley scraper collected manure five times daily.

Observations were made using both two CCD (Charge-Coupled Device) cameras with super-wide lenses mounted on the ceiling above the center of the FS area and two CCD cameras with wide lenses which covered dead angle areas (Fig. 1). The time of the comings and goings of each individual to the 15 feed troughs was recorded during the observation periods. The FS area was always lighted so that cows' behavior could be recorded at night.

The eating behavior of each cow in the SM and CC at the CFS was recorded every minute with a time-lapse video. The cows were identified by numbers painted on their flanks and from photos of both side views of their bodies.

All of the 105-cm-wide feed troughs had door feeders, but any cow could utilize any trough freely. Load cells were attached to measure the feed intake at 2 of the 15 troughs (Fig. 1). The two load cells measured the opening and shutting times of door feeders and the intervening feed weight in each cow through individual identification of each cow at the two troughs by a video camera. The eating rate (gDM/min.) of each cow was determined by dividing the daily feed intake by the daily eating time of each cow at the two monitored troughs. The daily total eating time of each cow in the SM summed her duration of visits to each feed trough. The daily DMI (Dry Matter Intake) of the SM in each cow was estimated by multiplying the eating rate by the daily total eating time.

One visit to a feed trough of the SM and the CFS was defined as a "bout"[4]. We determined the point of inflection from the cumulative frequency of the lengths above an inter-bout length of the SM (Fig. 2) to be 3 min by finding the correlation of initial −0.98 between the cumulative frequency and the inter-

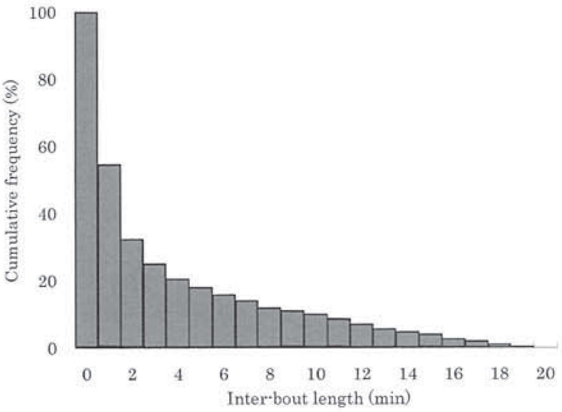

Fig. 2. Cumulative frequency of length greater than one inter-bout length in the SM (<21 min n=955).

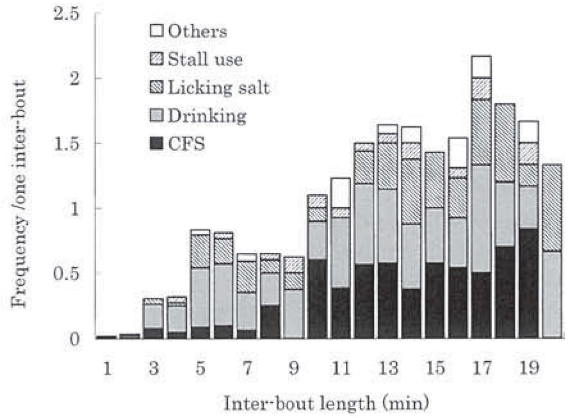

Fig. 3. Other behavior frequency occurred in each inter-bout in the SM.

bout length. The occurrence of other behavior within each inter-bout length showed step-wise increases at 3, 5 and 10 min (Fig. 3). To determine a "meal"[4] in this study, 10 min, which showed both other behavior in inter-bout greater than the daily average 1.0 and sharp increases in visits to the CFS, were defined as minimum inter-meal in the SM[4].

Calculation of DV (Dominance Value) in each cow is shown in the previous paper[8]. Milk weights were recorded at each milking throughout the observation periods. Milk fat was determined monthly by Nakagawa DHIA (Dairy Herd Improvement Association). Cows were weighed at the beginning and end of each observation period to calculate their average weights.

Pearson product moment correlation coefficients were calculated between eating characteristics and cow characteristics such as body weight. The TDN and CP intakes of cows were compared with their requirements calculated from the 1999 edition of the Japanese Feeding Standard for Dairy Cattle[1].

Results

Table 2 shows eating characteristics of cows in the bunk-fed SM and CC *via* the CFS. The estimated DMI of the SM averaged 19.5 kg/day ; the daily total eating time averaged 221 min. The average number of shifts between feed troughs per meal unit was observed to be six because the number of daily meals of the SM averaged eight while the number of daily bouts (visits) to SM averaged 49. Cows consumed all of their CC allowances at the CFS. The mean time spent in the CFS was 23 min/cow. The daily total use time by all cows was 338 min, 24% of the 24-h period. Variation in the number of bouts between individuals was large, in the range of 44-53% CV, which resulted in larger variations in bout-related characteristics, such as bout size and bout duration, than in meal-related characteristics, such as meal size and meal duration. Meal-related characteristics in Table 2 are based on 10-min minimum inter-meals. The number and meal size of 3-min meals averaged 10.3 and 1.9 kgDM, respectively. Those of 5-min meals averaged 9.0 and 2.2 kgDM, respectively.

Table 3 expresses the degree of correlation between the two variates to show the influence of cow characteristics on each eating characteristic. Between the cow characteristics, the month of age showed positive correlations with body weight ($P<0.05$) and DV ($P<0.01$) ; age and body weight showed negative correlations with distance traveled ($P<0.01$). Significantly positive correlations in the number of bouts, eating rate, bout size, and bout duration between the SM and CC *via* the CFS (Table 4) resulted in having influences of the same cows characteristics on both groups of eating characteristics : the number of bouts correlated negatively with month of age and body weight and positively with distance traveled ; eating rate correlated positively with body weight ; bout size and duration correlated positively with month of age and body weight and correlated negatively with distance traveled. Correlations with cow characteristics were smaller for meal-related characteristics than for bout-related ones. Correlations of milk production (4%FCM) with eating characteristics were low except with DMI. The DV had no significant correlations with eating characteristics.

Table 5 shows ratios of intakes to requirements in TDN and CP. Respective TDN and CP ratios of the group averaged 103% and 91% : they varied 86-126% and 77-110%. Nine cows had a TDN ratio below 100%, which corresponded to 60% of all cows.

The TDN and CP ratios tended to have lower correlations in ration (SM plus CFS) than in SM with cow and eating characteristics (Table 6). They showed positive correlation ($P>0.05$) with the month of age, negative correlation ($P>0.05$) with milk production, and positive correlation ($P<0.05$)

Table 2. Eating chracteristics of cows in SM[a] and concentrates at CFS[b].

Cow No.	Visits to SM feed trough per 24 h									Visits to CFS per 24 h					
	DMI[c] (kg/d)	Eating time (min/d)	Eating rate[d] (gDM/min)	Number of bouts (visits)	Bout size[e] (kgDM)	Bout duration[f] (min)	Number of meals[g]	Meal size[h] (kgDM)	Meal duration[i] (min)	DMI (kg/d)	Eating time (min/d)	Eating rate (gDM/min)	Number of bouts (visits)	Bout size[e] (kgDM)	Bout duration[f] (min)
1	18.2	187	97	23.5	0.8	8.0	6.7	2.7	27.9	1.7	12	142	1.8	0.9	6.7
2	20.5	234	88	46.7	0.4	5.0	7.5	2.7	31.2	2.7	22	123	5.3	0.5	4.2
3	27.0	223	121	24.3	1.1	9.2	7.2	3.8	31.0	4.5	28	161	4.2	1.1	6.7
4	23.4	248	94	40.7	0.6	6.1	9.5	2.5	26.1	4.5	30	150	6.5	0.7	4.6
5	19.5	256	76	39.3	0.5	6.5	9.5	2.1	26.9	1.8	12	150	3.7	0.5	3.2
6	17.2	250	69	51.2	0.3	4.9	9.2	1.9	27.2	3.6	27	133	6.8	0.5	4.0
7	20.2	185	109	42.8	0.5	4.3	7.8	2.6	23.7	3.6	20	180	4.8	0.8	4.2
8	21.2	276	77	25.7	0.8	10.7	7.3	2.9	37.8	4.5	29	155	6.2	0.7	4.7
9	20.0	190	105	39.2	0.5	4.8	7.7	2.6	24.7	4.5	22	205	4.8	0.9	4.6
10	21.4	189	113	49.7	0.4	3.8	6.7	3.2	28.2	2.7	20	135	6.3	0.4	3.2
11	16.6	125	133	21.5	0.8	5.8	6.7	2.5	18.7	2.7	17	159	2.3	1.2	7.4
12	16.1	295	55	76.5	0.2	3.9	8.5	1.9	34.7	1.8	16	113	6.8	0.3	2.4
13	15.8	235	67	91.0	0.2	2.6	8.2	1.9	28.7	3.6	30	120	10.3	0.3	2.9
14	17.9	223	80	78.8	0.2	2.8	9.2	1.9	24.2	3.6	28	129	9.7	0.4	2.9
15	17.7	201	88	77.0	0.2	2.6	8.3	2.1	24.2	3.6	25	144	11.3	0.3	2.2
Average	19.5	221	91	48.5	0.5	5.4	8.0	2.5	27.6	3.3	23	146	6.1	0.6	4.2
Sd	3.0	43	22	22.5	0.3	2.4	1.0	0.5	4.7	1.0	6	24	2.7	0.3	1.6
CV (%)	15	19	24	46	53	44	13	22	17	31	27	16	45	45	38

Notes [a] Silage mixture. [b] Concentrates feeding station. [c] Daily eating time×eating rate. [d] Calculated using two feed troughs with load cells. [e] Eating size per bout unit. [f] Eating duration per bout unit. [g] Based on the minimum inter-meal of 10 min. [h] Eating size per meal unit. [i] Eating duration per meal unit.

Table 3. Pearson's correlation coefficients (r) between cow characteristics and with their eating parameters.

	Age (mo)	BW (kg)	4%FCM (kg)	DV	Distance traveled (m/d)
Cow characteristics					
Age (mo)	1.00				
BW (kg)	0.55*	1.00			
4%FCM (kg/d)	0.21	0.14	1.00		
DV	0.66**	0.28	0.10	1.00	
Distance traveled (m/d)	−0.79**	−0.66**	−0.20	−0.37	1.00
Eating characteristics of visits to SM feed troughs					
DMI (kg/d)	0.57*	0.16	0.61*	0.25	−0.52*
Eating time (min/d)	0.01	−0.60*	0.14	0.21	0.07
Eating rate (gDM/min)	0.29	0.69**	0.19	−0.08	−0.41
Number of bouts (visits) (/d)	−0.79**	−0.78**	−0.20	−0.46	0.89**
Bout size (kgDM)	0.63*	0.52*	0.19	0.22	−0.80**
Bout duration (min)	0.67**	0.34	0.19	0.43	−0.82**
Number of meals (/d)	−0.16	−0.51	−0.05	0.04	0.41
Meal size (kgDM)	0.50	0.40	0.47	0.15	−0.62*
Meal duration (min)	0.14	−0.36	0.25	0.24	−0.23
Eating characteristics of visits to CFS					
DMI (kg/d)	−0.02	−0.14	0.60*	−0.30	−0.03
Eating time (min/d)	−0.20	−0.45	0.45	−0.45	0.23
Eating rate (gDM/min)	0.28	0.51	0.35	0.17	−0.41
Number of bouts (visits) (/d)	−0.72**	−0.82**	0.05	−0.44	0.84**
Bout size (kgDM)	0.51	0.72**	0.09	0.04	−0.71**
Bout duration (min)	0.57*	0.69**	−0.04	0.03	−0.72**

*P<0.05 **P<0.01.

Table 4. Pearson's correlation coefficients (r) in each eating parameter between SM and concentrates at CFS.

In SM and concentrates at CFS	r
DMI (kg)	0.49
Eating time (min/d)	0.26
Eating rate (gDM/min)	0.60*
Number of bouts (visits)	0.87**
Bout size (kgDM)	0.86**
Bout duration (min)	0.67**

with bout size in SM.

Discussion

Group-fed cows show distinctive eating behavior compared with individually fed tethered cows.

One distinction is a shorter daily eating time and higher eating rate. Nishimura *et al.*[14] have reported a significantly shorter daily eating time in FS housing than in individual stall pens, which results in a higher eating rate. Although strict comparisons can not be drawn, when *ad libitum* feeding of a TMR in tethered cows was undertaken, the daily eating time averaged 336 min in cows fed two times[7], 354 min in cows fed four times[7], 330 min in cows fed more than 15% residuals to intake[6], and 343 min on a commercial dairy farm[5]. The eating time of these tethered cows was longer than 221 min in results of the present study. Moreover, the eating rate in those reports decreased by 72-82 gDM/min, compared with 92 gDM/min in this study.

The shorter daily eating time in group-fed cows is said to be the result of social environments, e.g. the competition between individuals[14]. Disappearance of short intermittent eating time involving small intake results in decreased daily eating time because the amount of time with access to feed troughs is longer in group-fed cows than in tethered cows.

Secondly, higher bout (visit) frequencies to bunk-fed SM were observed in group-fed cows ; these result in a shorter bout duration. The higher bout frequencies to feed troughs of the SM are not only caused by access to feed troughs from other behavior, such as resting in free-stalls, but also to shifts between feed troughs after once beginning to eat. The reason for the latter seems to be mainly the selection of concentrates in the SM. It is reported that cows' eating behavior in free-stall housing consists of short meals, including a large number of times when a cow would eat briefly, leave a feed trough for few minutes, and then return either to the

Table 5. Ratios of intake to requirements for TDN and CP.

Cow No.	TDN ratio (%)			CP ratio (%)		
	SM	CFS	Total ration[a]	SM	CFS	Total ration[a]
1	109	13	122	94	16	110
2	78	13	90	64	15	79
3	104	22	126	84	25	109
4	100	24	124	80	28	108
5	98	11	109	82	13	95
6	74	20	94	61	23	83
7	80	18	98	65	21	85
8	77	21	97	61	23	85
9	72	20	92	58	23	82
10	83	13	96	68	15	83
11	81	17	98	69	20	90
12	77	11	88	65	13	78
13	88	25	113	76	31	107
14	69	17	86	57	20	77
15	84	22	106	70	26	96
Average	85	18	103	70	21	91
Sd	12	5	13	11	5	12
CV (%)	15	26	13	15	26	13

Note [a] SM+CFS.

Table 6. Pearson's correlation coefficients (r) between ratios of TDN and CP and cow and eating characteristics.

	TDN ratio (%)		CP ratio (%)	
	SM	Ration	SM	Ration
Cow characterisitics				
Age (month)	0.47	0.38	0.39	0.25
BW	0.01	−0.10	−0.01	−0.14
4%FCM	−0.45	−0.37	−0.59*	−0.49
DV	0.26	0.09	0.22	−0.03
Distance traveled	−0.40	−0.32	−0.33	−0.22
Eating characteristics of visits to SM feed troughs				
DMI (kg)	0.46	0.42	0.30	0.26
Eating time (min/d)	−0.05	−0.05	−0.08	−0.10
Eating rate (gDM/min)	0.24	0.25	0.19	0.20
Number of bouts (visits)	−0.39	−0.31	−0.31	−0.21
Bout size (kgDM)	0.56*	0.54*	0.48	0.46
Bout duration (min)	0.45	0.42	0.37	0.32
Eating characteristics of visits to CFS				
DMI (kg)	−0.18	0.13	−0.30	0.10
Eating time (min/d)	−0.22	0.08	−0.31	0.10
Eating rate (gDM/min)	0.01	0.11	−0.07	0.05
Number of bouts (visits)	−0.39	−0.21	−0.38	−0.13
Bout size (kgDM)	0.32	0.34	0.27	0.30
Bout duration (min)	0.43	0.42	0.41	0.40

same or a different spot[2].

Table 1 shows a single group of cows comprising those with a variety of lactation stages, ages, body weights, and level of milk production. To meet different nutritional requirements of cows, the CC, made mainly on the basis of lactation stages, was fed at the CFS in addition to the *ad libitum* feeding of a constant nutrient content of the SM. There were positive correlations in eating characteristics between the SM and CC at the CFS, but cows fed *at libitum* on the SM and restrictively on the CC at the CFS (Table 4).

Regarding the use of CFS, when 8.6–8.9 kg of concentrates were fed to 20 cows at two cycles of 12 h, all of the fed amounts were ingested with a daily average eating time of 41–51 min and an average of 8–10 visits[16]. When 6.3–6.6 kg of concentrates were fed to 15–19 cows in two 12-h cycles, all of the fed amount was ingested in an average of 5.9 visits[15]. In this study, when 1.7–4.5 kg of concentrates were fed to 15 cows in two 12-h cycles, all of the fed amount was ingested with a daily average eating time of 12–30 min. in an average of 6.1 visits. In comparison with the previous paper[15,16], feeding a smaller amount make it possible to ingest all of the feed.

According to these reports, the reason that the number of bouts (visits) was not proportional to the amount fed *via* CFS is that there is a difference in the number of unrewarded visits. Sato *et al.*[15] reported that more than half of all visits seem to have been unrewarded visits, but the number of unrewarded visits in the present study is unknown. Therefore, because eating characteristics of the CFS were given in apparent values, their actual values can be estimated to include a shorter average eating time, smaller number of bouts, higher eating rate, larger bout size, and longer bout duration[12].

Ten minutes was defined as the minimum (critical) inter-meal interval based on the frequency of other behavior in inter-bouts shown in Fig. 3, because it was not easy to determine the meal only on the basis of the cumulative frequency of inter-bout length in Fig. 2. This criterion concurs well with values in previous studies[11-13]. However, CFS use, drinking, and licking salt increased certainly in inter-bouts of 10 min or more, while they also occurred within 9 min. Moreover, variation between individuals is reported to be smaller for eating behavior related to meals than for that related to bouts[13], a finding which agrees closely with results of this study (Table 2). Such meal distinction and the fuzzy meal criterion seemed to lead to lower correlations of meal-related eating characteristics (number of meals, meal size and meal duration) than of bout-related characteristics (number of bouts, bout size, and bout duration) with cow characteristics (Table 3).

Body weight and month of age influenced eating in the single group with a large variation in cow characteristics. The fact that body weight and month of age related to distance traveled, i.e. the activity in FS, seemed to have influenced eating : Cows with a higher age and heavier weight had a fewer number of bouts with a larger bout size and bout duration ; cows with heavier body weight had a shorter eating time and higher eating rate. Miyashige *et al.*[10], who used beef cows for breeding in a loose barn, reported that the distance traveled was shorter in high-ranking cows with heavier weights than in low-ranking cows with lower weights.

Correlations between eating and milk production or DV were low, but there were positive correlations between milk production and DMI ($P < 0.05$). As CC allowances were mainly for lactation stages and milk yield, a high correlation between DMI of CC *via* CFS and 4%FCM was expected. Higher feed intakes of the SM in high-lactating cows, which are related to nutritional intakes, are the most important eating factor in single-group nutritional management despite the cows' indefinite eating characteristics.

Changes in the ratios of intakes to TDN requirements were rather large, with a range of 86–126%, but the ratios averaged 103%. The fact that about 60% of cows had an under-TDN below 100% is not desirable for nutritional management (Table 5). Corn silage of 7.5% CP was used as the single roughage resource of the SM. As a result, the CP of lactating cows based on the actual intakes averaged 12.1% ± 0.3 (sd), lower than the reccomended CP of more than 14%[1]. These seemed to result in a 91% intake-to-requirement of CP as the group average. The feeding design of low CP did not seem to accelerate the tendency of milk protein (3.3% ± 0.3) and solid not fat (8.8% ± 0.4) to decline (Table 1).

The TDN and CP ratios seemed to decrease with cows of higher milk production, lower month of age, or smaller bout size (Table 6) : High lactating cows or young primiparous cows tended to have the potential for becoming underfed. These cows may benefit by improving underfeeding by feeding concentrates individually using automatic gang lock stanchion or by increasing more concentrates in the CFS.

Variation in the nutritional ratios of intakes to requirements indicates that SM is not necessarily consumed according to nutritional requirements despite short-term research results. The fact that coefficients of variation in TDN and CP in ration (SM plus CFS) (13%) were lower than those in SM alone (15%) seemed to reduce changes in nutritional intakes that result from the use of CFS.

These results concerning the relationship between cow characteristics and eating seem to depend on the stocking density and the number of feed troughs. In this study, the stocking density was 0.94 (head/FS), equal numbers of feed troughs and cows were prepared, and the SM was supplied *ad libitum*. Limited feeding of SM and/or an excessive number of cows per feed trough would introduce the possibility of having great influence on young cows with low weight such as primiparous cows, so that there might be high correlations between DV and eating characteristics, particularly DMI. Dairy cows fed *ad libitum* have been reported to show no effects on eating behavior when bunk space per cow is reduced from 0.6 m to 0.3 m[2], but the effect on DMI is not known in detail. Studies are needed to clarify these points.

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サイレージ混合飼料と個体別配合飼料給与時における フリーストール飼養泌乳牛の採食量と採食特性

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摘　要

対頭二列式16床のフリーストール（FS）施設に飼養するホルスタイン種泌乳牛15頭からなる一群管理牛群を用い，15の飼槽へのサイレージ混合飼料（SM）不断給与（給飼量に対する残飼量のDM比14%）と，個体識別式制限給飼装置（CFS）による配合飼料給与条件下で，各個体の採食量と採食行動を調査した。10月（平均気温14.1℃）にビデオカメラによる2期各3日間の観察で，各牛1日の採食時間，SM飼槽とCFSへのbout（訪問），meal（SM採食期）を測定した。最小meal間隔は10分とした。また15のSM給飼飼槽のうち2基の秤量計付き飼槽を用い，ウシによるドアフィーダ開閉時刻と飼料重量から，2基の飼槽でSMの日採食量と採食時間を求め，各牛の採食速度を算定した。各牛SMの自由乾物摂取量/日は，その採食速度に全採食時間/日を乗じることにより推定した。FS飼養では，SM平均採食時間が221分/日で，つなぎよりも短く，採食速度も速いと推察された。ウシは，1日平均8回のmealを持ち，49回飼槽を訪問し，1mealあたり平均6回飼槽間を移動した。高月齢個体は，優位度（DV）が高く，一日の歩行距離が短く，SM・CFSのbout数が少なかった。また，1boutあたりの採食量が多く，1bout時間が長い傾向を示した。体重の重い個体は採食時間が短く，採食速度が速い傾向にあった。乳生産量とDVは，乳生産量がSMとCFSの各採食量と正の相関を認めた以外，採食行動との関連が明確でなかった。各個体のTDN充足率は86～126%（平均103%）と変動した。高産乳牛，低月齢牛，boutサイズが小さい牛ほど，充足率が低下する傾向を示した。

キーワード：乳用牛，フリーストール，採食量，養分摂取量，採食行動