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WATER ECONOMY IN RUMINANTS

II. Drinking water consumption in the course of suckling and weaning periods

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Introduction

Pre-ruminant calves have mainly subsisted on a liquid feed. Thus, the amount of water consumed with feed has been assumed to meet the requirement of water for calves in suckling period. In conventional feeding system, calves were hand-fed and were not offered drinking water for several months.

The development of an early weaning system has transferred a new concept of the calf rearing system to the dairy business. Under the system, calves are fed liquid diet for a period as short as possible, while they are forced to accustom themselves to subsisting on a dry feed. Ingestion of dry feeds may be able to accelerate the development of ruminal function which leads a calf in a pre-ruminant stage to a ruminant. Under these circumstances, calves would ingest dry feeds as early as 2 weeks of age. When amounts of consumption of dry feeds increase with age in the course of suckling period, what would happen to the animals without the access to drinking water for a period? The consideration on the drinking water has not been fully studied on the early weaning system.

The importance of an ample supply for drinking water has been subjected to considerable stress in the feeding for ruminant calf⁸⁾. In the period on fluid diet feeding, however, water supply has been paid little attention. Water consumption has been reported to relate to the amount of dry matter ingested⁹⁾. PETTYJOHN *et al.*⁷⁾ reported that with feeding of a liquid diet with a content of 5% dry matter, drinking water consumption was negligible. Additional amounts of water consumed increased with feeding of higher contents of dry matter in liquid diets. ROY⁹⁾ has recommended that clean fresh water should be available when concentrates are first offered, where

weaning at a young age is practiced in raising dairy calf.

The experiments were carried out to obtain information on the amount of drinking water consumed by calves reared on an early weaning system.

Experimentals

To obtain informations on water consumption by calves raised on the early weaning system, several circumstances in feeding of a liquid diet were adopted to make it applicable to the system practically performed. The experiment consisted of 5 trials.

Trial 1

The experiment was carried out to estimate the amounts of drinking water consumed by calves raised on milk replacer.

Four Holstein bull calves born in the experimental farm of Hokkaido University were fed milk replacer twice a day. Calf starter was started to feed calves at 2 weeks of age. Calves were also allowed to have a free access to second cutting good quality hay at the same age as the starter was fed. Calves were weaned at 8 weeks of age. Clean fresh tap water was provided at the beginning of the experiment in 5l. pails. With the same type of pail, check records were measured for evaporation. Amount of water consumption was recorded prior to morning and evening feeding. Milk replacer was added with 6 parts of warm water so as to make a liquid diet of 15% dry matter content.

Trial 2

The experiment was carried out to determine the effect of length of suckling period on drinking water consumption.

Three Holstein male calves born in the experimental farm of Hokkaido University were fed milk replacer twice daily. Feeding schedule was the same as trial 1 except calves were weaned at 11 weeks of age. Measurement of drinking water was done such manner as the method adopted in trial 1.

Trial 3

The experiment was performed to determine the effect of seasons at weaning on the consumption of drinking water.

Total of 12 Holstein male calves were purchased from dairy farms located in the vicinity of Sapporo in three different seasons. Additional 2 calves born in summer in the experimental farm of Hokkaido University were used. Group 1 of 4 calves were reared in spring months and were weaned at an early summer. Group 2 of 4 calves were raised in summer months

and were weaned at an early fall. Group 3 of 4 calves were reared and weaned in winter. Group 4 of 2 calves were raised and weaned in summer. Calves were fed a limited amount of milk replacer and calf starter. Second cutting mixed hay was fed *ad libitum*. Calves were weaned at about 7 weeks of age. Measurement of amount of free water drunk was such manner as that of trial 1.

Trial 4

The effects of whole milk and milk replacer were determined on intake of free water in suckling and weaning period.

Four Holstein bull calves were divided into 2 groups of 2 calves. Calves of group 1 were fed milk replacer and those in group 2 were offered whole milk. All calves received daily allowance of limited amount of calf starter and hay *ad libitum*. Amount of whole milk to be fed was determined to supply the same amount of dry matter as that of milk replacer.

Feeding of liquid diet was ceased when calves reached to 7 weeks of age. Intake of drinking water was measured as in trial 1.

Trial 5

Calves were fed the same amount of milk replacer throughout suckling period to obtain informations on the effect of amounts of milk replacer fed in suckling period on the consumption of drinking water.

Four Holstein male calves purchased from dairy farms were used. Calves were fed 500 g. of milk replacer daily and were allowed to eat calf starter and hay without any limitation. Milk replacer was ceased to feed when calves were 7 weeks of age. Measurement of drinking water consumption was done by the same method as in trial 1.

Results

Trial 1

Check records showed evaporation to be negligible. Daily record of water consumption was summarized by weeks of age. Average amounts of free water drunk per calf in the course of suckling and weaning period are shown in table 1 with standard deviation and coefficient of variation.

Consumption of drinking water by calves in suckling period was found to be minute with exception in that of one week of age. Figures, however, showed drinking water in suckling period had less importance, but was not negligible when calves were fed milk replacer. Differences in means of drinking water consumption for each age were statistically tested using the Duncan's new multiple range test.

TABLE 1. Average consumption of drinking water per calf in the course of suckling and weaning period

Age (wk)	Av. FWI ¹⁾ (g./day)	S. D. ²⁾	CV ³⁾ (%)	No. of observation (calf-day)
1	2301 ^{a,4)}	1708	74.2	16
2	704 ^b	663	94.2	28
3	601 ^b	521	86.7	28
4	552 ^b	716	129.7	28
5	646 ^b	637	98.6	28
6	587 ^b	777	132.4	28
7	740 ^b	931	125.8	28
8	2230 ^a	1287	57.7	28
9	4436 ^c	1107	25.0	28

1) Average free water intake, 2) Standard deviation, 3) Coefficient of variation, 4) Figures with different superscript are significantly different ($P < .05$).

TABLE 2. Daily variations for intake of drinking water in weaning individual calf

Animal No.	201		202		203		204	
	water with replacer	FWI ¹⁾	water with replacer	FWI	water with replacer	FWI	water with replacer	FWI
	g./day							
June 10	4800	450	4800	1750	4800	20	4800	40
11	4800	340	4800	910	4800	10	4800	450
12	2400	530	2400	950	2400	670	2400	320
13	2400	1320	2400	1970	2400	1260	2400	400
14	2400	1590	2400	1440	2400	1800	2400	810
15	0	1750	0	3440	0	3250	0	1710
16	0	3290	0	2870	0	2430	0	2260
17	0	5540	0	4060	0	3570	0	2440

1) Free water intake

Except for one week of age, consumption of drinking water in suckling period was considered a relatively constant value of 600-700 g./day. When calves were in weaning period at 8 weeks of age, free water consumption increased more than double of values in suckling period. After weaning, calves on a dry ration, that is, at 9 weeks of age, drank significantly more

water than those in suckling period. Consumption of drinking water was significantly higher than those in suckling period. In weaning period of 8 weeks of age, however, drinking water intake was similar to that for one week of age.

There were larger variations in consumption of drinking water. Coefficients of variation show that the variation was greater in suckling period than in weaning and weaned periods. Tendency was observed to decrease with weaning.

In the light of drinking water consumption, calves were adapted to a decrease of the amount of milk replacer in a relatively short term. After feeding of milk replacer discontinued, calves compensated water ingestion with increased intake of drinking water within two to three days (Table 2). From table 2, it was revealed that there was a considerable individual variation in daily consumption of drinking water. Day-to-day variation seemed to relate to the variation in the amount of liquid feed offered.

Trial 2

Daily record of water consumption was summarized by weeks of age. Means of drinking water consumption are shown in table 3 with standard deviation and coefficient of variation.

Average amounts of drinking water intake per calf ranges from 800 g.

TABLE 3. Daily average consumption of drinking water per calf fed milk replacer for 11 weeks

Age (wk)	Av. FWI ¹⁾ (g./day)	S. D. ²⁾	CV ³⁾ (%)	Replacer fed (g.)
2	1012 ^{a,4)}	842	83.1	500
3	1160 ^a	902	77.8	750
4	781 ^a	758	97.1	850
5	2075 ^a	1167	56.2	900
6	2512 ^a	1386	55.2	900
7	2324 ^a	1041	44.8	900
8	1303 ^a	793	60.9	900
9	2398 ^a	1118	46.6	900
10	5828 ^b	1256	21.6	900
11	7730 ^c	2850	36.9	330
12	9480 ^d	2291	24.2	0
13	11279 ^e	1580	14.0	0

1) Average free water intake, 2) Standard deviation, 3) Coefficient of variation,

4) Means with different superscript are significantly different ($P < .05$).

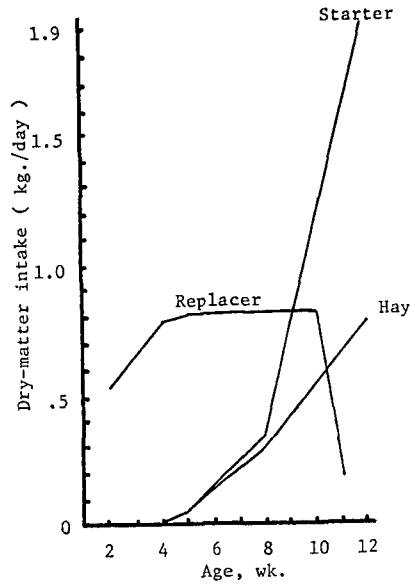


Fig. 1. Changes in dry-matter intake for different feeds in calves fed milk replacer for 11 weeks

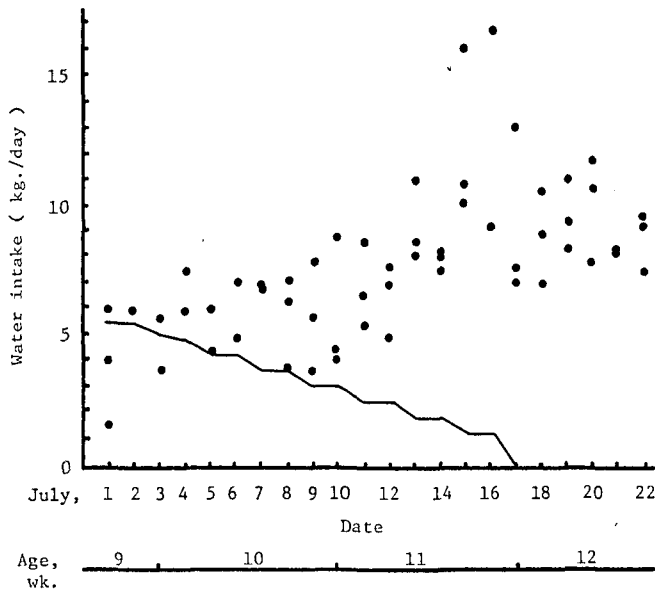


Fig. 2. Changes in water ingested with milk replacer and free water intake in calves fed milk replacer for 11 weeks (Solid line shows water ingested with replacer and a dot shows the amount of free water drunk.)

to about 11,000 g. per day at the age between 2 weeks and 13 weeks. The test of statistical differences among means was examined using Duncan's new multiple range test.

An increasing tendency of the consumption of drinking water was observed in the course of suckling period, but significant differences were not found among the ages of 2 through 9 weeks. From 10 weeks of age, free water intake significantly increased with age.

Variation of free water intake larger in suckling period. A decreasing tendency of the variation was observed with an increase of the age. Calves have already drunk relatively large amount of water at 10 weeks of age. As shown in figure 1, intakes of dry matter for dry feeds considerably augmented at 10 weeks of age. The daily record revealed such a tendency that the withdrawal of liquid feed drove a calf to drink much more free water (Fig. 2).

Trial 3

Table 4 shows means of drinking water consumption for calves weaned in different seasons.

Consumption of drinking water was not different between calves weaned in early summer and in early fall. Calves raised in summer months drank free water significantly more than those raised in winter months. At weaning period of 7 weeks of age, calves reared in winter consumed significantly less drinking water those raised in any other seasons. Calves raised and

TABLE 4. Average amounts of free water drunk by calves weaned in different seasons¹⁾

Age (wk)	Av. free water intake (g./day/calf)			
	Group 1	Group 2	Group 3	Group 4
2	—	1337 ^{a,2)} ±1342 ³⁾	130 ^a ± 71	2818 ^b ± 497
3	—	—	574 ^a ±168	1961 ^b ± 755
4	—	—	—	2210 ±1308
5	1223 ^a ± 713	1453 ^a ±1311	264 ^b ± 91	4174 ^c ±1519
6	2102 ^a ± 941	—	984 ^b ±500	8048 ^c ±1401
7	5773 ^a ±1146	6172 ^a ±1991	2208 ^b ±423	7994 ^c ±1390
8	6628 ^a ± 738	—	—	7864 ^b ±1041

1) Calves in group 1 were weaned in early summer, those in group 2 in early fall, those in group 3 in winter and those in group 4 in summer. 2) Figures in the same line with different superscript are significantly different ($P < .05$). 3) Standard deviation.

weaned at summer ingested the greatest amounts of drinking water than those raised in any other seasons.

Trial 4

Means of drinking water consumed by calves fed either milk replacer or whole milk are summarized in table 5. Means were tested statistical differences using Duncan's new multiple range test.

Drinking response for free water in suckling period was almost similar between calves fed milk replacer and those fed whole milk. In suckling period calves drank less free water. Consumption of drinking water, then, increased in weaning period of 6 weeks of age. After weaning, calves on milk replacer consumed similar amounts of free water at 7 and 8 weeks of age. On the other hand, free water intake for calves on whole milk increased with age after weaning. Amounts of free water consumed, however, were significantly greater in a replacer-fed calf than a milk-fed calf at any corresponding ages. Coefficients of variation show that the variation of free water intake was smaller in calves fed milk replacer than those fed whole milk. The variation, however, tended to decrease toward weaning in both groups.

TABLE 5. Average consumption of drinking water by calves fed either milk replacer or whole milk

Age (wk)	Av. free water intake (g./day/calf)				Coefficient of variation (%)	
	replacer fed	SD ¹⁾	milk fed	SD	replacer fed	milk fed
2	2818 ^{a,2),3)}	497	328 ^d	233	17.6	71.2
3	1961 ^a	755	258 ^d	183	38.5	71.1
4	3210 ^{a,b}	1308	181 ^d	181	40.7	100
5	4174 ^b	1519	853 ^d	820	36.4	96.1
6	8048 ^c	1401	2759 ^e	1830	17.4	66.3
7	7994 ^c	1390	4628 ^f	939	17.4	20.3
8	7864 ^c	1041	5765 ^g	969	13.2	16.8

1) Standard deviation, 2) Means in the same column with different superscript are significantly different ($P < .01$), 3) Means in the same line with different superscript are significantly different ($P < .01$).

Trial 5

Results were summarized in Table 6. The test of statistical differences among means was examined using Duncan's new multiple range test.

A pattern of increment in amount of free water drunk by calves fed

TABLE 6. Average consumption of drinking water by calves fed fixed amount of milk replacer up to 6 weeks of age

Age (wk)	Av. FWI ¹⁾ (g./day/calf)	SD ²⁾	CV ³⁾ (%)
2	2513 ^{a,4)}	1488	59.2
4	1687 ^a	979	58.0
6	3854 ^b	2023	52.5
7	6245 ^c	1563	25.0

1) Average free water intake, 2) Standard deviation, 3) Coefficient of variation,

4) Means with different superscript differ significantly ($P < .01$).

milk replacer was almost similar to the results obtained in other trials, although calves were offered a fixed amount of milk replacer. Consumption of drinking water in 6 weeks of age was higher than those in 2 and 4 weeks of age, even though calves were fed milk replacer up to 6 weeks of age inclusive. When calves were fed a dry feed as a ration, consumption of drinking water increased in a greater rate.

The average consumptions of dry matter by calves in each week of age were 413 g., 585 g., 1,403 g. and 1,777 g. per calf for 2, 4, 6 and 7 weeks of age, respectively. Thus, the dry-matter consumption was found to increase rapidly from 4 to 6 weeks of age. Milk replacer supplied only about 24% of the total dry matter ingested in 6 weeks of age, while in 4 weeks of age, calves obtained about 77% of the total from milk replacer. Increment of dry feed consumption suggested to be a cause for an increase in drinking water consumption at 6 weeks of age.

Discussion

Drinking water consumption in suckling period

In the present study, drinking water in suckling period seems to contribute in less extent to water economy in calves. It is, however, not suggested to be negligible in suckling period, especially in calves fed milk replacer. Even though in the time when the early weaning system has not been established and when feeding of whole milk and skim milk for 6 months has been universally practiced, ATKESON *et al.*¹⁾ has pointed out that free water intake has become important source of water supply for a calf reached to 8 weeks of age and receiving 5.4 to 7.2 kg. of skim milk. When the feeding of skim milk has been discontinued at 8 weeks of age, daily consumption of free water by calves has increased from 1.85 kg. at 6 weeks

of age to 5.72 kg. at 9 weeks of age. Daily free water intakes at 2, 3, 4, 5, 6, 7 and 8 weeks of age have been reported to be 0.21, 0.25, 0.68, 0.67, 1.85, 4.03 and 5.07 kg., respectively. While consumptions of skim milk at corresponding age have been 4.3, 4.7, 4.6, 4.5, 2.4, 0.6 and 0.3 kg. per day, respectively. In the present study, it was shown that consumption of drinking water has increased in a significant rate as the amounts of liquid feed have designedly reduced. JOHNSON *et al.*⁵⁾ reported that Holstein calves kept under the constant ambient temperature of 10°C drank 2.08 l./day of free water at the age of 1 to 2 months and 6.21 l./day at 2 to 3 months of age when they were fed whole milk up to 6 months of age. The free water intake increases with age as indicated with the results of the present study.

Thus, it was concluded that consumption of free water in suckling period has been less prominent for calves in a first few weeks of their life when they received ample supply of a liquid feed, but in later phase of suckling period when the amount of a liquid feed was purposely limited, the supply of free water would take a priority of total water consumption.

In trial 1, free water intake at first week of the trial showed higher consumption than those at other ages in suckling period. These phenomena were observed in other trials in this study. This tendency might have originated from a shortage of the amount of liquid feed offered to animals because calves were fed less amount of milk replacer relative to the requirement to control the incidence of diarrhea⁹⁾.

When the term of liquid diet feeding was extended, an increase in drinking water consumption has occurred in more delayed time than in the case of weaning at younger age unless the consumption of a dry feed has augmented. The results suggest that an intake of dry matter or a dry feed may affect the consumption of drinking water, even though calves were fed liquid feed. In calves receiving either skim milk or whole milk for six months, the consumption of drinking water has increased as early as 8 weeks of age^{1,6)}.

Effect of the weaning season

Calves weaned in summer months drank more free water than those weaned in any other seasons. MACDONALD and BELL⁶⁾ reported the significant correlation between free water consumption and daily minimum ambient air temperature in cows. JOHNSON *et al.*⁵⁾ observed that calves kept at the constant ambient temperature of 10°C drank less free water than those kept at the constant temperature of 26.7°C. The growing dairy heifer ingested more water with a rise in mean environmental temperature²⁾.

There has been no study reported on the effect of either ambient tem-

perature or seasons during suckling and weaning period on the consumption of drinking water. Taking in the consideration of results obtained in the much elder cattle, the results of the present study show that calves raised in a warmer season consume more free water than those in a cooler season.

Thus, drinking water intake might relate to the fluctuation of environmental temperature.

Effect of type of the liquid feed

When calves were fed whole milk under the regime of early weaning schedule, drinking water consumption increased in later suckling period toward the weaning. This pattern was similar to those on milk replacer. Amounts, however, of free water consumed have been less than those on milk replacer. Content of dry matter in whole milk is lower than that of a liquid milk replacer. The difference in the dry-matter content may exert upon the response of calves to drinking water. When the water content of a liquid diet increased, intake of free water decreased for calves in suckling period.⁴⁾ The effect of whole milk feeding on drinking water consumption was not clarified in the present study.

Effect of the fixed amount of liquid feed

Calves fed a fixed amount of milk replacer tended to consume more free water compared to those in other trials when the season in which calves were raised was taken into account. Actually, the calves were reared in almost similar season to those of group 2 in trial 3. BURT³⁾ reported that once-daily feeding of 340 g. of milk substitute in 2.3 l. of water drove calves to drink more free water than calves fed milk substitute in 3.4 l. of water. Feeding a fixed amount of milk replacer throughout the suckling period may cause some shortage of water to compensate its loss from the animal body, especially in later phase of suckling period. Results obtained in trial 5 have again suggested that dry-matter intake might have influenced the consumption of drinking water in a younger calf.

Summary

The experiment consisting of 5 trials was carried out to measure consumption of drinking water by calves in suckling and weaning periods. Drinking water is to be less important for calves receiving ample supply of liquid feed. Drinking water consumption doubled in the weaning period (trial 1). When liquid-diet feeding was extended up to 11 weeks of age, drinking water consumption increased significantly at 10 weeks of age as an increased dry-feed intake (trial 2). When calves were reared in different

seasons, those raised in winter drank less water and those raised in summer drank more than those raised in any other seasons (trial 3). Calves fed milk replacer consumed more drinking water than those fed whole milk (trial 4). The variation of drinking water intake was smaller in calves fed milk replacer than those on whole milk. When calves were fed a fixed amount of milk replacer, drinking water consumption increased in a fast rate as the dry-matter intake increased rapidly from 4 to 6 weeks of age (trial 5).

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