WATER ECONOMY IN RUMINANTS

I. Water consumption and water turnover in growing calves

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Introduction

Animals must ingest water to balance its loss from their body. Water requirements for domestic animals have not been well established because of the magnitude of various factors involved. The importance of watering for domestic animals has been practically and physiologically well recognized. Water, however, as the most basic nutrient has been paid little attention due to its commonplace nature and abundance in this country. Thus, failure in the practice of watering on farms will be followed by a reduction in production, whatever it might be, of farm animals.

Studies on water metabolism of dairy calves are very scarce. The early work showed that the amount of free water ingested by calves receiving liquid milk had little importance for water requirement of the animals up to at least eight weeks of age when they were fed liquid skim milk for 26 weeks (4). The free water intake, however, was increased at six weeks after birth when liquid milk was removed from the diet at eight weeks of age (4). ATKESON *et al.* (4) found that the ratios of total water intake to the amount of dry matter consumed were 7.0 at 2 weeks of age for calves removed from liquid milk at 8 weeks of age and 6.4 at 3 weeks of age for calves receiving liquid milk for 26 weeks. AGRICULTURAL RESEARCH COUNCIL (2) of the United Kingdom reported that the water requirement for calves was 6.5 kg. per kg. of dry matter cosumed for the first 5 or 6 weeks of life.

Practical applications of milk replacers on nursing calves have been developing elsewhere in the country for this decade. Especially in Hokkaido several large nursery stations for dairy calves have been established and many more are projected. The nursing systems of those stations have not

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been well established because of a lack of information on water requirement of calves which are fed a milk replacer. Thus, to facilitate the establishment of a basic strategy for nursing operations, it needs to obtain information on the water requirements of animals on milk substitutes.

This study was carried out to acquire knowledge on water requirements of calves in suckling, weaning and post-weaned periods.

Materials and Methods

Animals used in this study were four Holstein male calves. They were purchased from dairy farms in the area adjacent to the university at the age of 3 to 5 days after birth. The calves were placed in an individual pen and were fed a commercial milk replacer. A commercial grain mixture for calf and second-cutting mixed hay produced in the Second Farm of the university were offered at the same time. Calves were fed liquid feed for 45 days and thereafter were changed to a dry grain mixture.

The experiment was commenced at one week of age when calves were individually placed in a metabolism cage. In the experimental periods three comparison periods with seven-day duration were set in 2, 7 and 12 weeks of age and other periods were adjusting periods. Animals were fed according to the requirements for maintenance and growth using N. R. C. recommendations as a basis of nutrient requirements. Feed and water were offered in the morning and in the evening in equal parts of daily allowance. Water was supplied in 10 litre pails. Check records showed evaporation to be a negligible factor. The amount of water ingested was recorded daily for comparison periods. Daily records for refusals of feed and amounts of urine and feces excreted were kept during the comparison periods. Body weight was measured at the beginning of and at the end of each comparison period. In comparison periods, water turnover was estimated by using tritiated water. On the first day of comparison periods tritiated water was injected into the left jugular vein and blood samples for analyses were drawn from the opposite jugular vein. The calves were kept for 6 hours away from water and feed to equilibrate the tritiated water before blood samples were taken and thereafter at an interval of 24 hours for 7 days. No correction was made for losses during equilibration.

Water turnover was calculated by the following equations:

$$\text{Total Body Water (TBW)} = \frac{\text{Activities of tritium injected}}{\text{Activities of tritium in plasma drawn at 6 hr. after injection}}$$

$$\text{Turnover} = 2.3 \times b \times \text{TBW}$$

where b was regression coefficient calculated from the rate of loss of tritium from the animal body. It is assumed that tritiated water distributes equally in the body water pool and moves the same as water pooled in the animal body. The half-life of water was also calculated from the rate of loss of tritium by using the following equation:

Half-life of body water = Biological half-life = $\log_e 2/2.3 \times b$.

Corrections for activities of tritium in plasma were made with the amounts of solids in plasma for each estimation. Activities of tritium were measured by ALOKA LSC-502 liquid scintillation counter, using the method described by SPRINGELL (12).

Heat production was measured on the second day of comparison periods and on every other day thereafter. For respiratory measurements the animals wore a mask constructed of a metal can covered with thick rubber and sheet rubber at the upper end to seal the muzzle. Respiratory measurements were made at 2, 4, 8 and 12 hours after the diet was offered. The samples of expired air were analysed on a modified Haldane apparatus. Heat production was calculated by the equation of BRODY (5):

Total Heat Production = O_2 consumed (1.) × Kcal/l. of O_2 at the corresponding RQ.

Feeds were analysed by recording bomb calorimeter CA-2 (Shimazu Co.) for a calculation of calorie intake.

Statistical analyses were made by the methods described by SNEDECOR (13).

Results and Discussion

Water consumption, amount of dry matter ingested, average heat production and average body weight were shown in Table 1.

Average daily consumption of water was lowered at the age of 7 weeks when calves were weaned ($P < .01$). This reduction of water intake may have resulted from a change from liquid diet to the dry grain mixture on account of the fact the calves were not able to adjust themselves to the change of diets immediately. Similar results were observed in the study of ATKESON *et al.* (4). At 12 weeks of age calves consumed water at the same level as that of 2 weeks of age. Thus, the animals may have become accustomed to the ingestion of dry diet in 12 weeks of age. Water consumption per kg. of body weight was a similar change as that of daily water consumption, although the level of the consumption at 12 weeks of age was not as high as that of 2 weeks of age. Average intake of dry matter was increased with age. Average heat production per metabolic body size was the same

TABLE 1. Changes of means in water and dry-matter consumptions, average heat production and average body weight in growing calves.

		Age (wk)		
		2	7	12
Water consumption[a)]	l./24 hr.	6.1±0.8[b)]	4.1±0.7	6.4±0.7
Dry-matter consumption	g./day	810±100	1180±184	2180±260
Average heat production	kcal./hr.	125±18	145±15	199±8
	kcal./$w^{3/4}$	147±21	147±12	168±12
Average body weight	kg.	55.4±0.9	67.9±0.8	87.7±4.8

a) Water consumption was a total of free water, water added to milk replacer and water in feed.
b) Standard deviation.

in the ages of 2 and 7 weeks. Average body weights in 2 and 7 weeks of age were similar to the values shown by BRODY (5), but that in 12 weeks was a little less comparing with the value shown by BRODY (5). Thus, the growth of calves used in this study was assumed to be approximately normal.

From extensive reviews of water consumption in cattle (6, 10, 14) it has been concluded that water intake is a function of the amount of dry matter ingested. Results of the ratios of water to dry-matter consumption and other factors are illustrated in Figures 1 and 2 and Table 2.

The ratio of water consumption to dry matter ingested was decreased as the calves grew older. At 2 weeks of age when the calves were mainly

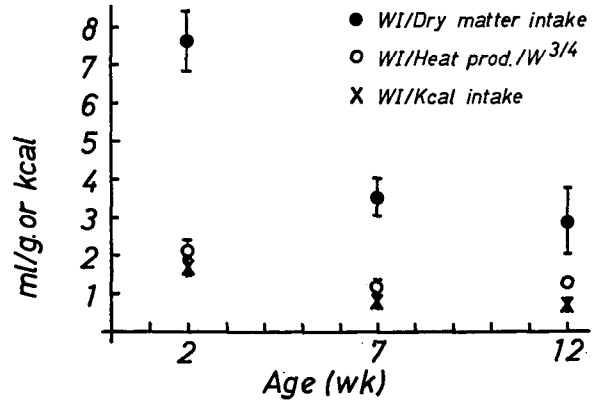

Fig. 1. Water intakes in growing calves.

consuming a liquid diet, water consumption was as high as 7.6 l./kg. of dry-matter intake. Similar results were reported by ATKESON *et al.* (4). In their study the ratio of water intake to dry matter ingested was 7.0 at 2 weeks of age in calves weaned at 8 weeks of age. When the calves assumed to be fed a liquid diet alone, concentration of dry matter in the liquid diet would be about 12% in this study. The value was somewhat similar to that reported by PETTYJOHN *et al.* (11). According to their study, calves fed a milk replacer containing 15% dry matter showed the best performance and efficiencies of nutrient utilization. The high ratio of water intake to dry-matter consumption in the calves mainly receiving a liquid diet decreased to 3.5 l./kg. of dry-matter intake for calves in a weaning period ($P<.01$). ATKESON *et al.* (4) obtained similar results (3.5 kg. water/kg. of dry matter consumed) for calves at weaning period (7 to 8 weeks of age). Their results also showed that the calves at 7 weeks receiving liquid milk consumed 3.5 kg. of water per kg. of dry matter consumed. At 12 weeks of age calves consumed an average of 2.9 l. of water per kg. of dry matter ingested. The figure was significantly lower than those at 2 and 7 weeks of age. WINCHESTER and MORRIS (14) reported that the average water intake per kg. of dry matter consumed was 3.1 kg. at low temperature (below 4.4°C.) for mature cattle. Similar results (3.5 kg. water/kg. of dry matter consumed) were obtained by MACDONALD and BELL (7) in a corresponding condition. In this study the control of environmental condition was not made and the environmental temperature ranged from 7.7°C. to 11.2°C. AGRICULTURAL RESEARCH COUNCIL (2) in the United Kingdom reviewed studies of water consumption in cattle and suggested that for temperatures of 10°C. and below, the water requirement of cattle above 100 kg. body weight would be 3.5 kg./kg. dry matter ingested.

Animals at 12 weeks of age are far from being regarded as mature cattle, however, the ratio of water consumption to the amount of dry matter consumed may be similar to that of mature cattle.

The ratio of water consumption to heat production per metabolic body size was 2.1 ml./kcal. in 2 weeks of age and in 7 and 12 weeks of age decreased to half the amount of 2 weeks of age. The ratio was higher in 2 weeks than those in 7 and 12 weeks of age ($P<.01$). Water intake per calorie intake was 1.7 ml. per kcal. in 2 weeks of age and 0.8 and 0.7 ml./kcal in 7 and 12 weeks of age, respectively. ADOLPH (1) reported that in rats the amount of water drunk per calorie intake showed considerable constancy despite differences in composition of diets. Similar results were

TABLE 2. Ratios of water consumption to dry-matter intake, heat production, calorie intake and metabolic body size.

	Age (wk)		
	2	7	12
Water intake[a] (WI)/dry matter consumption (l./kg.)	7.6±0.8[b]	3.5±0.5	2.9±0.9
WI/heat production (ml./kcal/$w^{3/4}$)	2.1±0.3	1.2±0.2	1.3±0.1
WI/calorie intake (ml./kcal.)	1.7±0.2	0.8±0.1	0.7±0.1
WI/$W^{3/4}$ (ml./kg.)	299±39	173±32	223±23
WI/body weight (ml./kg.)	110±14	60±11	73±7

a) Water intake was a total of free water, water added to milk replacer and water in feed.
b) Standard deviation.

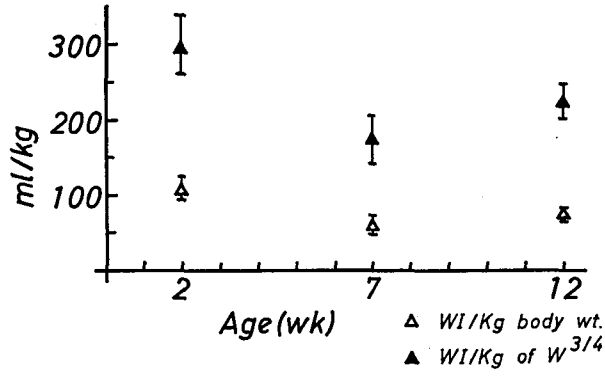

Fig. 2. Water intakes per unit of body size in growing calves.

observed in 7 and 12 weeks of age in this study. Higher value in 2 weeks of age may arise from high content of protein in milk substitutes (over 30% in air drymatter) which were a major source of calorie intake in early weeks of life for calves. It has been generally considered that an increase in protein content in a diet was associated with an increase in water intake (8). Water consumptions per units of metabolic body size and liveweight showed the highest amount in 2 weeks of age and the lowest in 7 weeks of age ($P<.01$). The water consumptions increased in 12 weeks of age comparing with those in 7 weeks of age ($P<.05$).

Table 3 and figures 3 and 4 show water turnover and half life of water pooled in the body. Water turnover, litre per 24 hours, was a little higher than water consumption observed at corresponding age. The figures,

however, were relatively similar to water intakes of the corresponding age. The dilution technique may be used for determining water consumption when direct measurements are associated with diffiiculty and laborious work.

TABLE 3. Means in water turnover and half life of water

		Age (wk)		
		2	7	12
Turnover	l./24 hr.	6.4±0.9[a)]	5.0±0.6	8.6±0.6
	ml./kg./24 hr.	120±15.6	76±9.4	100±1.1
	ml./$W^{3/4}$/24 hr.	324±42	216±27	305±8
Half life of water pool (day)		4.8±0.6	6.9±0.8	6.4±0.1

a) Standard deviation

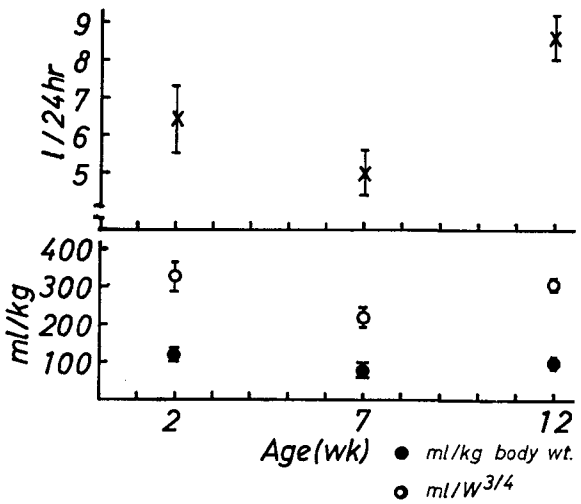

Fig. 3. Water turnover in growing calves.

Changes with age in water turnover (l./24 hr.) were similar to those in water consumption, although water turnover in 12 weeks was relatively higher than that in 2 weeks. Water turnover per unit of body weight changed from 120 ml./kg./24 hr. in 2 weeks to 76 ml. in 7 weeks ($P<.05$) and then increased to 100 ml. in 12 weeks ($P<.05$). The pattern of this change and the values were close to those of water intake per unit of body weight. ASAHIDA (3) reported that water turnover was around 100 g./kg. of body weight in weaned-lambs under temperate climatic conditions. Of the turnover metabolic water was comprised to range form 10 to 16 percent.

In this experiment metabolic water was not included in water consumption. Thus, it may be partly responsible for a slightly higher water turnover measured comparing with that of water intake per kg. of body weight. Water turnovers per unit of body weight in 2 and 12 weeks of age were not different significantly, but showed a trend to be lower in 12 weeks of age. ASAHIDA (3) observed in weaned-lambs that water turnover was reduced in a lower environmental temperature. The ambient temperatures were relatively low in comparison periods of this study. Corresponding data, however, is not available and discussion will not be made in this connection. Thus, should be taken into consideration, the effects of environmental temperature, and electrolytes which are closely related to water metabolism, and protein intake in combination with intakes of calorie and dry matter.

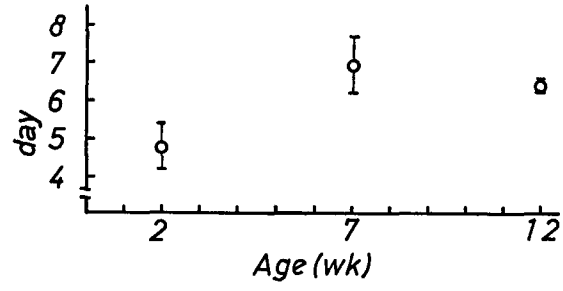

Fig. 4. Half life of body water ($T_{1/2}$)

Half life of water pool of the body was 4.8, 6.9 and 6.4 days for calves in 2, 7 and 12 weeks of age, respectively. Relatively short half life of water pool in 2 weeks may suggest a high rate of water exchange in animals mainly receiving a liquid diet. This tendency may also be assessed from a large water turnover per unit of body weight in 2 weeks of age. Half life of body-water pool in 12 weeks, however, was not so short as to that in 2 weeks, although water turnover per unit of body weight was similar in both ages. The discrepancy may have resulted from the difference in the size of body-water pool. It will be observed from Table 1 that water consumption in 2 weeks of age is very close to that of 12 weeks. When water influx is the same amount, a larger pool size will have less water flux than a small pool size. Thus, the larger body pool will be greater in half life of body-water pool than the smaller one. In 7 weeks of age declined water consumption may be responsible for the longer half life. Water may be conserved in the body as long as possible to meet metabolic demands because of less water ingested by calves.

Summary

Water consumption and water turnover were studied in growing calves fed milk substitute and dry grain mixture.

Measurements of water consumption, water turnover, dry-matter consumption and heat production were undertaken in 2, 7 and 12 weeks of age. The calves were fed liquid diet for 45 days and thereafter were changed to a dry grain mixture. Growth of calves was approximately normal. Average water consumptions were 6.1±0.8 l./24 hr. in 2 weeks, 4.1±0.7 l./24 hr. in 7 weeks and 6.4±0.7 l./24 hr. in 12 weeks of age. Amount of dry matter consumed increased with age from 810±100 g./day in 2 weeks to 2180±260 g./day in 12 weeks of age. Average heat production also increased as calves grew. The ratio of water intake to amount of dry matter consumed was 7.6±0.8 l./kg. in 2 weeks and declined to 3.5±0.5 l./kg. and 2.9±0.9 l./kg. in 7 and 12 weeks of age, respectively. The ratios of water consumption to heat production per kg. of metabolic body size and calorie intake were significantly higher in 2 weeks than those in 7 and 12 weeks of age. Changes in water intake per kg. of body weight were similar to those in average water consumption (l./24 hr.). Water turnover (l./24 hr.) and water turnover per kg. of body weight per 24 hr. showed a similar pattern of changes to that of average daily consumption of water.

Calculated half life of body-water pool was greater in 7 and 12 weeks than in 2 weeks of age. The possible involvement was discussed.

Acknowledgments

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