The effect of early weaning on the blood sugar and rumen acid levels of the growing calf

By R. D. NDUMBE, K. V. RUNCIE and P. McDONALD
Edinburgh School of Agriculture, West Mains Road, Edinburgh, 9

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The dry feeding of young calves, 'early weaning', has become the established practice on many farms. The system described by Preston (1957) consists in abruptly replacing the milk diet of the calf, at 3–4 weeks of age, with dry palatable concentrates which are first given to the animal when it is 7 days old. Because the level of milk given is restricted to about 6 pints daily the calf is encouraged to consume appreciable amounts of concentrates before it is weaned.

The favourable results obtained by Preston (1956) with this system have been confirmed by others. Though it is believed that the beneficial effects of the system result from the rapid establishment of adult rumen functions in the young animal, there is a lack of experimental appraisal of the development of these functions and of their effect on the animal's metabolism.

The purpose of this investigation was to study the effect of early weaning on the amounts of volatile fatty acids and lactic acid in the ruminal fluid and on the blood sugar levels of the growing calf.

EXPERIMENTAL

Animals and treatment. Twelve Ayrshire bull calves, 3–7 days old, were used in two experiments, each lasting for 84 days. In each experiment six animals were divided equally between two feeding treatments: control and early weaning. The control calves received milk throughout the experimental period, and milk was withdrawn from the diet of the early-weaned calves at 28 days. Both groups were offered concentrates from 10 days of age.

Feeding and management. The calves were housed indoors at The Edinburgh School of Agriculture dairy farm and kept in individual pens littered with sawdust. The animals were weighed and measured on the 2nd and 3rd days after purchase and allotted to the treatments. For each calf the means of the weights and measurements on both days were taken to represent the live-weight and body measurements at 3 days of age. Regular weighings were taken at 14-day intervals.

From the 2nd day all the animals were given liquid whole milk in amounts which were gradually increased for each calf over 3 days to the full daily allowance based on the standards of Roy, Shillam, Hawkins & Lang (1958).

The animals in the control group were offered milk to provide for maintenance plus 1 lb live-weight gain/day and the early-weaned calves were given milk sufficient for maintenance plus 0·5 lb live-weight gain/day. The difference was intended to induce

the experimental animals to take more readily to the concentrates offered to all the calves from 10 days of age.

The composition of the concentrate mixture was based on the early-weaning mixture described by Preston (1958) but was modified by the inclusion of dried grass. The percentage composition of the mixture was: flaked maize 36, bruised oats 22·5, molassine meal 13·5, soya-bean meal 4·5, fish meal 9·0, stabilized tallow 4·5, salt 0·32, vitamins A and D supplement 0·4, Aurofac 2A (Cyanamid Ltd) 0·2, grass meal 9·08.

The concentrate mixture was given to appetite, in two equal portions at 8 am and 4 pm. Refusals were weighed and discarded. From 10 days of age water was also offered *ad lib.*

During the first 4 weeks, the calves in Expt 1 were given dried whole milk reconstituted with eight times its weight of warm water. The use of this milk was discontinued when facilities for warming fresh milk were available.

Sampling. Samples of blood and rumen liquor were taken at 14-day intervals from each calf before it was fed and 1, 2, 3 and 4 h after feeding. Blood samples were withdrawn from the jugular vein by the technique of Preston & Ndumbe (1961) with heparin as anticoagulant. Samples of rumen liquor were obtained with a stomach tube and vacuum pump. In some instances the 3rd h postfeeding sample was not taken.

Before analysis, all samples were stored in a deep-freeze refrigerator at $-13°$.

Analytical methods. The concentration of reducing sugars in the blood was determined by the method of Somogyi (1952) with the colorimetric reagents of Nelson (1944).

Total volatile fatty acids in rumen liquor were determined by distillation after filtration, acidification and protein precipitation by the method described by Elsden, Hitchcock, Marshall & Phillipson (1946).

In Expt 1, selected samples of rumen liquor were analysed for individual volatile fatty acids by means of the Celite column chromatographic method described by Wiseman & Irvin (1957). The samples selected for detailed acid analysis were the prefeeding sample and the sample at peak volatile fatty acid production, taken at 28 and 84 days of age. Lactic acid in rumen liquor was determined by the method of Barker & Summerson (1941).

RESULTS

Health of animals. All the calves in Expt 1 scoured during the 1st month. The incidence was more severe in the control animals, and treatment with streptomycin and sulphadimidine (BP) had little effect. Scouring ceased as soon as powdered milk was replaced by fresh milk.

One calf (K 95) in the early-weaned group of Expt 1 died of pneumonia in the 6th week. Apart from this animal, the health of all the calves appeared to be normal.

Growth and feed intake. The overall mean values of live-weight gain and body measurements are shown in Table 1. The early-weaned calves ate the concentrate mixture readily, and before weaning, at 28 days, they were consuming about $\frac{1}{2}$ lb of it (air-dry)/head daily. Growth was slow in both the experimental and control groups during the period of scouring from 3 to 14 days of age when mean gains of 1·3 and

2·5 lb/head occurred. No significant differences between treatments were found in live-weight gains over the 84-day period. The control animals, however, gained significantly more ($P = 0{\cdot}01$) in live weight during the period 28–42 days. With respect to skeletal growth from 3 to 84 days, significant differences in favour of the control calves were observed in height at withers ($P = 0{\cdot}05$) and in width of hooks ($P < 0{\cdot}05$).

Table 1. *Growth and feed intake of six control and six (five)† experimental calves from 3 to 84 days of age*

Measurement	Control	Early-weaned	SE of difference
Weight at 3 days (lb)	75·0	71·6	—
Feed consumption, 3–84 days (lb/head) :			
Liquid whole milk	771·0	163·5	—
Concentrate ration	62·7	177·2	—
Gain in weight (lb/head)			
3–14 days	2·5	1·3	± 2·60
14–28 days	9·1	11·7	± 3·56
28–56 days‡	32·0	25·9	± 4·78
56–84 days	47·9	36·7	± 5·10
3–84 days	91·5	75·6	± 10·64
Gain in body size, 3–84 days (cm/head):			
Height at withers	12·0	9·7	± 1·00*
Length	18·0	14·3	± 2·35
Heart girth	22·1	18·2	± 1·93
Middle girth	39·3	40·3	± 3·78
Width of hooks	6·1	4·2	± 0·63*

* Significant at $P < 0{\cdot}05$.

† Calf K95 died 6 weeks after the beginning of the first experiment.

‡ Live-weight gains (lb) during the period 28–42 days for individual animals were: control 17·7, 20·5, 15·5, 24·0, 6·2, 19·0; early-weaned 3·0, 2·7, 5·5, 10·7, 10·2, 7·0.

Changes in blood sugar concentration. The mean blood sugar levels for the two experiments before and after feeding are shown in Fig. 1. During the first 4 weeks when all the animals were getting milk and concentrates, there was little difference between treatments. In both groups the blood sugar levels increased markedly 1 h after feeding and then declined rapidly during the next 2 h. At 6 weeks, that is 2 weeks after early weaning of one group, the prefeeding blood sugar values of the early-weaned calves decreased markedly below the levels at 4 weeks (a fall from 81·4 to 69·3 mg/100 ml) and remained below the corresponding levels of the control animals over the remainder of the experimental period. Blood sugar values of the control animals continued to show marked fluctuations throughout the experiment, but similar changes were not observed in the early-weaned calves after feeding from the 6th week.

Volatile fatty acids and pH of rumen contents. The total volatile fatty acid (VFA) content and pH of the rumen liquor samples are shown in Table 2. The peak values for VFA for the two groups are shown in Fig. 2.

The total VFA content of the rumen liquor increased with age more rapidly for the early-weaned animals than for the control animals. In the early-weaned group, peak concentrations were relatively stable at 6–8 weeks but the values for the control group continued to increase up to 12 weeks. Except at the beginning of the experiment, the

levels of VFA were higher in the early-weaned than in the control calves, the most striking difference occurring at 6 weeks. In both groups peak concentrations usually occurred 2–3 h after feeding.

The mean pH values of the rumen liquor samples from both groups did not differ significantly.

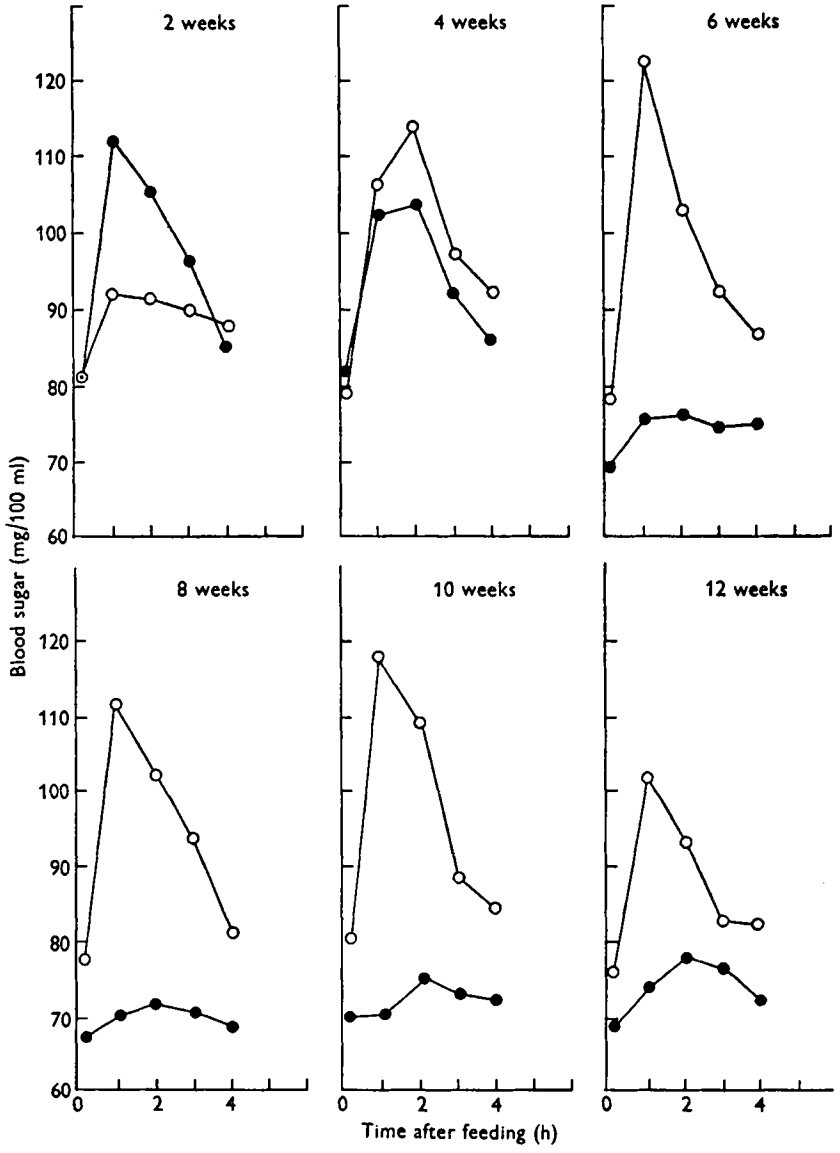

Fig. 1. Mean concentration of blood reducing sugar of control (○—○) and early-weaned (●—●) calves at different ages.

Table 3 shows the amounts of the individual VFA present in some of the rumen liquor samples. The detailed analysis of the acids was carried out in Expt 1 only, and it was done only on prefeeding samples and on those showing peak VFA values.

The total VFA values for twenty-one samples determined by the distillation method agreed reasonably well with the sum of the individual acids determined by the Celite column chromatographic method. Recovery of VFA from the column was 98·4% (SE ± 0·94).

Although the results suggest that there was little or no difference between treatments in the relative proportions of acetic, propionic and butyric acids at 4 and 12

Table 2. *Difference in mean values for concentration of ruminal total volatile fatty acids (VFA) and pH between the early-weaned and the control calves*

Measurement	Week	Control	Early-weaned	Difference	SE of difference	Significance
VFA concentration (m-moles/l.)	2	78	71	− 7	± 10·3	NS
	4	90	119	+29	± 11·6	$P < 0.05$
	6	100	144	+44	± 8·0	$P < 0.001$
	8	120	137	+17	± 18·3	NS
	12	126	146	+20	± 8·6	$P < 0.05$
pH	2	5·53	5·35	− 0·18	± 0·28	NS
	4	5·58	5·32	− 0·26	± 0·24	NS
	6	5·42	5·17	− 0·25	± 0·12	NS
	8	5·43	5·24	− 0·19	± 0·28	NS
	12	5·48	5·36	− 0·12	± 0·13	NS

NS, not significant.

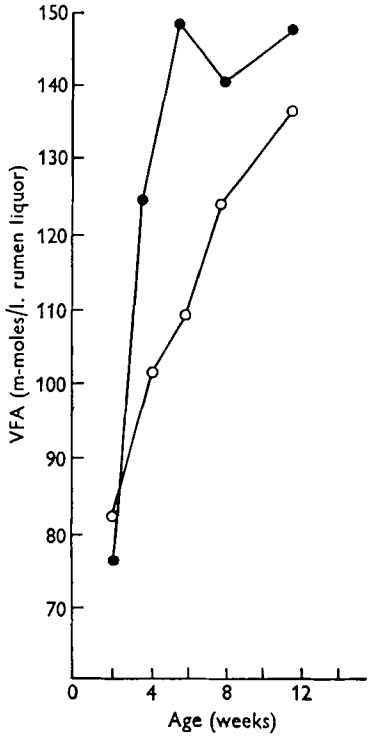

Fig. 2. Total volatile fatty acids (VFA) (peak values) in the rumen of control (○—○) and early-weaned (●—●) calves at different ages.

weeks, there was some indication that the proportion of butyric acid in the early-weaned calves was lower at 12 weeks than at 4 weeks.

Lactic acid production in the rumen. The ranges in concentration of lactic acid in the rumen liquor samples are given in Table 4. Apart from a few instances in which high levels of lactic acid were found in the liquor sample taken before feeding, the pre-feeding concentration generally ranged from 0 to 5 mg/100 ml. This value increased markedly 1 h after feeding. One calf in the early-weaned group which showed a high prefeeding level (68·5 mg/100 ml) at 8 weeks also exhibited distress, lassitude and anorexia. The signs were transitory and the animal had apparently recovered by the next day.

Table 3. *Individual volatile fatty acids (VFA) in the rumen liquor of calves in Expt 1 at 4 and 12 weeks*

			Total VFA (m-moles/l.)		Butyric acid (% VFA)		Propionic acid (% VFA)		Acetic acid (% VFA)	
Week	Treatment	Calf no.	Pre-feed	Post-feed-	Pre-feed	Post-feed	Pre-feed	Post-feed	Pre-feed	Post-feed
4	Control	K 94*	58	62·8	19	19	23	30	58	51
		K 97*	31	99·9	21	18	30	28	49	54
		K 100	92	No sample	21	—	33	—	46	—
		Mean	60	81·4	20	18	29	29	51	52
4	Early weaning	K 95*	98	139	19	16	28	38	52	45
		K 98*	115	132	20	19	34	33	47	48
		K 99†	105	146	16	17	28	32	56	50
		Mean	106	139	18	17	30	34	52	48
12	Control	K 94‡	192	290	24	22	32	34	44	44
		K 97†	161	317	16	22	38	34	46	44
		K 100†	121	190	25	21	32	31	42	48
		Mean	158	266	22	22	34	33	44	45
12	Early weaning	K 98*	163	281	19	17	30	34	51	49
		K 99*	198	303	12	13	24	32	64	55
		Mean	180	292	15	15	27	33	55	52

* Sample taken 3 h after feeding. † Sample taken 4 h after feeding. ‡ Sample taken 2 h after feeding.

The lactic acid values showed considerable variation between individual animals, making a statistical comparison valueless.

The relationship between VFA, lactic acid and pH at 2, 6 and 12 weeks for the two experiments is shown in Fig. 3. The levels of total VFA appeared to be inversely related to the pH.

DISCUSSION

It is known from previous work with calves (Preston & Ndumbe, 1961) that blood sugar concentration increases after a feed of milk and then falls rapidly to normal levels. It has been shown also that the rate of flow of liquid milk from the abomasum to the duodenum is fairly rapid (Barhydt & Dye, 1957) and that virtually all the milk

lactose is quickly digested and absorbed from the small intestine and rapidly utilized by the animal (Davis & Brown, 1962). In view of these findings the changes in blood sugar concentration that occurred in our studies were to be expected.

Table 4. *Concentration (mg/100 ml) of lactic acid in the rumen liquor of calves*

Week	Time after feeding (h)	Control		Early-weaned	
		Range	Mean	Range	Mean
2	Prefeeding	0·2–14·5	8·5	0·5– 3·2	2·0
	1–2	1·8–44·2	18·1	11·7–38·1	25·4
	4	0·0–13·2	5·6	2·3–48·0	14·5
4	Prefeeding	0·0– 9·0	3·0	0·2– 9·0	2·7
	1–2	1·1–27·1	7·5	2·0– 7·7	5·4
	4	0·3–13·5	5·1	1·6–14·4	4·9
6	Prefeeding	0·4–20·2	6·3	0·7–21·5	8·6
	1–2	1·0–13·6	7·4	6·4–63·2	19·9
	4	0·7–19·8	9·3	4·6–29·9	13·1
8	Prefeeding	3·4–14·5	8·5	4·9–68·5	20·4
	1–2	3·1–31·9	19·4	1·5–64·3	33·2
	4	2·5– 7·2	4·2	2·4– 8·7	5·3
12	Prefeeding	0·0– 6·0	2·5	1·0– 4·0	3·1
	1–2	4·6–40·6	17·2	14·9–56·3	36·0
	4	0·0– 5·8	4·1	1·0– 5·6	4·2

A marked decline in the blood sugar levels occurred in the early-weaned animals at 6 weeks, that is 2 weeks after weaning. Hibbs, Conrad & Pounden (1952) found a similar decline in blood sugar in calves at 7 weeks when the calves were given roughage diets.

It is well known that blood sugar levels in young ruminants decline steadily with age. Reid (1953) demonstrated that a decline in the postabsorption blood glucose level in lambs began in the 1st week of life, that a large proportion of the decline was due to the disappearance of glucose from the corpuscles, and that plasma glucose level began to decline rapidly at about 4–5 weeks of age to reach stable adult levels between the 7th and 9th weeks. Hibbs *et al.* (1952) observed that much of the decline in blood glucose level of calves during the postnatal 7-week period of milk feeding resulted from a decrease in corpuscle glucose. Plasma glucose level declined markedly only after withdrawal of milk from the diet. These workers also found that the level of plasma glucose in animals given antibiotics was higher than in control animals. In our studies the sharp fall in total blood sugar level which occurred at 6 weeks may therefore be attributed largely to a decline in plasma glucose level because of abrupt withdrawal of milk from the diet, depriving the animal of a readily available supply of sugar. The relatively high blood sugar levels in all groups and the slow decline in blood sugar level with age, especially in the control animals, may be attributed to the inclusion of an antibiotic in the concentrate supplement, which according to Hibbs *et al.* (1952) deters fermentation in the rumen by depressing the activity of certain bacteria. At 6 weeks, the blood sugar values in the early-weaned calves did not show any marked fluctuation after feeding.

It is clear from the total VFA values shown in Table 2 and Fig. 2 that fermentation in the rumen was developed more rapidly in the early-weaned animals than in the control animals because of the ingestion of relatively large amounts of concentrates at an early age.

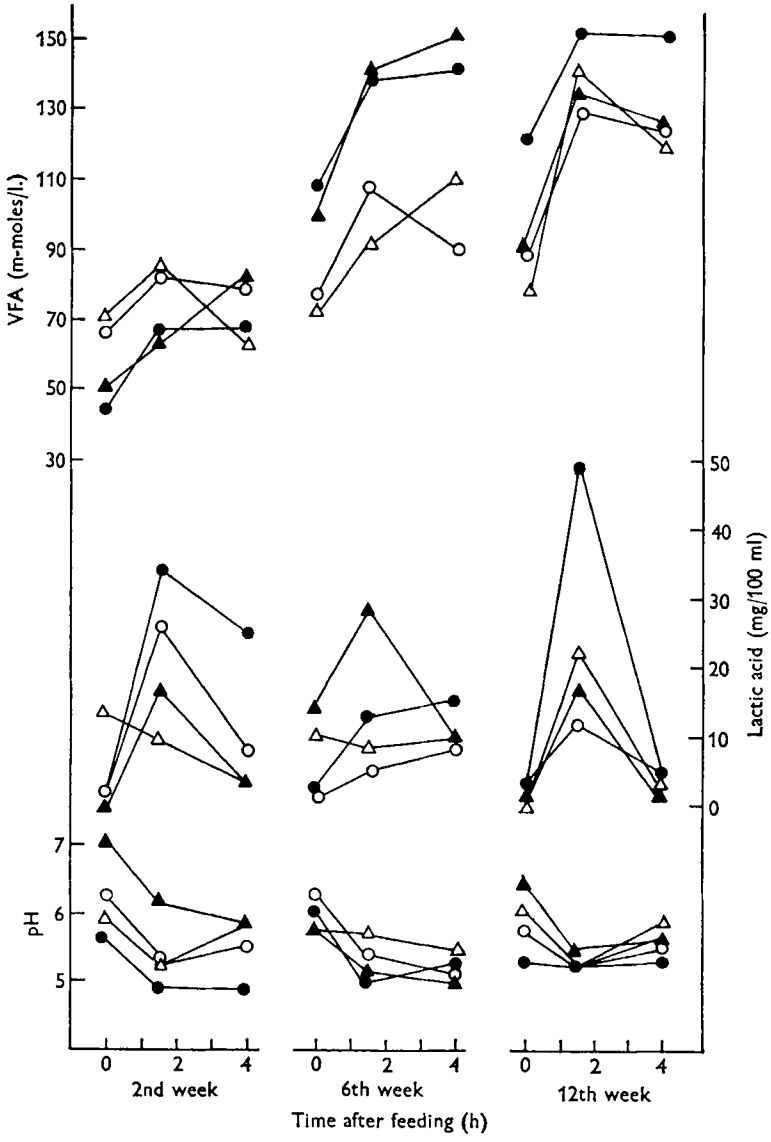

Fig. 3. Relationship between pH, lactic acid and total volatile fatty acids (VFA) in the rumen liquor of control and early-weaned calves at different ages. Expt 1: △—△, control; ▲—▲, early-weaned calves. Expt 2: ○—○, control; ●—●, early-weaned calves.

With regard to the mixture of the ruminal acids, the relatively high proportion of propionic and butyric acids and the correspondingly low levels of acetic acid observed in both the control and the early-weaned calves agree with previous results obtained

with sheep (Phillipson, 1952) and dairy cows (Balch & Rowland, 1957) given diets rich in soluble carbohydrates.

The postfeeding distribution of the rumen fatty acids at peak values indicates in general that an increase in the proportion of propionic acid occurred with a corresponding decrease in acetic acid. Stewart, Stewart & Schultz (1958) and Reid, Hogan & Briggs (1957) reported that propionic acid is produced faster than butyric or acetic acid and that peak propionic acid values coincide with the peak VFA concentrations. The high concentration of ruminal lactic acid in both groups after feeding substantiates the results of Phillipson (1952) and Balch & Rowland (1957) and was due to the rapid fermentation of soluble carbohydrates. It is also probable that the presence of antibiotics stimulated lactic acid production (Dinda, 1960).

With regard to the relative effects of lactic acid and VFA on the rumen pH, Briggs, Hogan & Reid (1957) studied this relationship in sheep on a wide range of diets and concluded that rumen pH is largely a function of rumen VFA level. Lactic acid exerts a stronger effect than VFA and is associated with considerably lower pH levels than would be recorded in its absence.

Our results also suggest that there is an inverse relationship between total VFA and pH over a fairly wide range of values and that low pH values are associated with relatively high concentrations of lactic acid in the rumen.

SUMMARY

1. Changes in blood sugar level and in the concentrations of volatile fatty acid (VFA) and lactic acid in rumen liquor were studied in two groups of six Ayrshire bull calves from 3 to 84 days of age. One group was weaned from milk at 28 days; the other continued to receive milk for 84 days.

2. There was no significant difference between the groups in body-weight over the 84-day period although significant differences in favour of the control calves were observed in height at withers and in width of hooks.

3. The blood sugar concentrations of the early-weaned calves fell markedly after weaning whereas the values for the control animals steadily declined with age.

4. The levels of total VFA in rumen liquor increased with the age of the calves and were significantly higher at 6 weeks in the early-weaned group than in the late-weaned group.

5. In both groups, the VFA contained a relatively higher proportion of propionic acid and a lower proportion of acetic acid than is commonly found with adult ruminants on diets containing adequate amounts of roughage.

6. The concentration of lactic acid in the rumen liquor of the animals in both groups increased immediately after feeding but great variation occurred in the amount of the increase.

7. The results indicate that adult blood and rumen characteristics can be induced in the calf at 6 weeks of age by the early withdrawal of milk from the animal's diet.

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