A HIGH-ROUGHAGE SYSTEM FOR RAISING CALVES BASED ON THE EARLY DEVELOPMENT OF RUMEN FUNCTION. X. WHOLE BLOOD, PLASMA, AND CORPUSCLE GLUCOSE RELATIONSHIPS IN CALVES FED HIGH-ROUGHAGE RATIONS WITH AND WITHOUT CHLORTETRACYCLINE

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SUMMARY

In the first of two experiments, the changes in the blood glucose (reducing sugar) of five high roughage-fed calves was studied to 12 wk. of age. In the second experiment, 20 calves fed high-roughage pellets with or without chlortetracycline were compared from birth to 16 wk. of age. Much of the decline in the blood glucose of all calves during the 7-wk. milk feeding period was the result of decreased corpuscle glucose. Plasma glucose was found to decline markedly after milk intake was reduced at 6 wk. Chlortetracycline-fed calves maintained a higher whole blood glucose level. This higher blood glucose level was shown to be largely the result of increased plasma glucose which persisted following termination of milk feeding until 12 wk. of age, when chlortetracycline was withdrawn from the ration. At this point, the plasma glucose of the experimental group returned to the level of the controls. The data lend further support to the postulate that improved calf growth resulting from chlortetracycline feeding is due to its energy-sparing effects, reflected in the plasma glucose level.

In previous experiments involving high roughage-fed calves the blood glucose level was shown to decline markedly during the 7-wk. milk feeding period; whereupon, it leveled out at approximately the level maintained by adult ruminants, 40 to 60 mg. % (2).

Earlier, McCandless and Dye (6) had shown that a decline in blood glucose was characteristic of young ruminants and suggested that this represented the change from primary dependence on abomasal digestion to dependence on ruminal digestion for energy. Reid (10), working with lambs, showed that most of the decline during the first 4 wk. was the result of decreased corpuscle glucose and was not considered to be associated with rumen development. In a preliminary report including part of the data in this paper the same observation was made with calves (14). Rateliff et al. (9) later observed that the decline in blood glucose also occurred in calves fed whole milk and a gruel-type replacer diet. Staubus et al. (12) observed a less marked drop in calves fed a starter free-choice.

Chlortetracycline (aureomycin) has been reported to be a growth stimulant for calves by many investigators (4). In earlier work we observed that both increased rate of growth and a higher blood glucose level was maintained, even after milk feeding was terminated, when chlortetracycline was included in the
ration of high roughage-fed calves (2). Voelker et al. (15) also showed that the blood glucose level of calves fed antibiotics was higher than their controls following oral administration of glucose, and that calves with higher blood glucose levels gained more in body weight.

It was noted (3) that the proportion of volatile fatty acids in the rumen juice was shifted, butyric acid being higher and propionic acid lower in the aureomycin-fed calves compared to the controls. On the basis of these observations, it was postulated that chlortetracycline increased growth through conservation of energy resulting from deterred fermentation associated with depressed action of certain rumen microorganisms. This seemed likely because certain typical rumen microorganisms which were present in the cud material from older cows became established in the control calves but did not become established in the rumens of the chlortetracycline-fed calves (3).

In this study the changes in plasma- and corpuscle glucose (reducing sugar) were studied from birth to 12 or 16 wk. of age in calves fed a 2:1 mixture of coarsely ground hay and grain or a similar pelleted high-roughage ration (1, 2) with and without chlortetracycline. This was done in an effort to elucidate which blood fractions were affected by the change-over from milk feeding to a high-roughage ration and by feeding chlortetracycline.

Growth, feed consumption, digestibility, and rumen function data obtained in conjunction with these experiments were reported previously (1, 2).

EXPERIMENTAL PROCEDURES AND RESULTS

In two experiments, 25 calves were used to study the changes in blood glucose. All calves nursed their dams for approximately three days and then were fed whole milk at the rate of 1 lb. per 10 lb. of birth weight to 6 wk. of age; the amount of milk fed was gradually reduced to zero during the 7th wk. The ground or pelleted high-roughage rations were offered free-choice after the third day and, from the end of the milk feeding period, constituted the only feed. Wheat straw bedding was used. Water, salt, and bonemeal were available free-choice.

Weekly blood samples were drawn from the jugular vein at approximately 3 hr. after the morning feeding. Whole blood and plasma glucose were determined immediately by the method of Somogyi (11), using Nelson's reagent (8). Red cell volume and plasma volume were determined on separate aliquots by centrifuging for 30 min. at 2,000 × G. The glucose values of various blood fractions were expressed in two ways: (a) the partition of the total glucose in 100 ml. of whole blood into the amount in the plasma (mg/100 ml. of whole blood) and the amount in the corpuscles (mg/100 ml. of whole blood) and (b) the concentration of glucose expressed as mg/100 ml. in each of these two fractions. In order to accomplish this, analyses were made for whole blood glucose, plasma glucose, packed red cell volume, and plasma volume. Milligrams of plasma glucose (mg/100 ml. of whole blood), corpuscle glucose (mg/100 ml. of whole blood), and corpuscle glucose (mg/100 ml.) were then calculated using the following formulae:
Plasma glucose (mg/100 ml. whole blood) =
\[ \text{Plasma vol. (%) × Plasma glucose (mg/100 ml.)} \]
\[ \frac{100}{\text{Plasma vol. (%)}} \]

Corpuscle glucose (mg/100 ml. whole blood) =
\[ \text{Whole blood glucose (mg/100 ml.) - Plasma glucose (mg/100 ml. whole blood)} \]
\[ \frac{100 × \text{Corpuscle glucose (mg/100 ml. whole blood)}}{\text{Red cell volume (%)}} \]

**Experiment 1.** This experiment was conducted to study the changes in plasma and corpuscle glucose in calves during and after the 7-wk. milk feeding period to 12 wk. Five calves, four Holsteins and one Jersey, were fed whole milk to 7 wk. of age and from the third day to 12 wk. they were offered, free-choice, a high-roughage mixture composed of two parts coarsely ground, third-cutting alfalfa and one part simple grain mixture. The formula and composition of this ration are shown in Table 1. Changes in the concentration of plasma, corpuscle, and whole blood glucose are shown in Figures 1 and 2.

<table>
<thead>
<tr>
<th>Ration group</th>
<th>Experiment 1</th>
<th>Experiment 2</th>
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<tbody>
<tr>
<td></td>
<td>High-roughage mixture</td>
<td>Pellets A</td>
</tr>
<tr>
<td>Ground alfalfa hay (%)</td>
<td>66.6</td>
<td>66.0</td>
</tr>
<tr>
<td>Ground shelled corn (%)</td>
<td>14.7</td>
<td>25.2</td>
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<td>Ground whole oats (%)</td>
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<tr>
<td>Wheat bran (%)</td>
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</tr>
<tr>
<td>Soybean oil meal (%)</td>
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<tr>
<td>Salt (%)</td>
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<td>0.3</td>
</tr>
<tr>
<td>Aurofac 2-A (%)</td>
<td>............</td>
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<td></td>
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* Contains 3.6 g. chlortetracycline hydrochloride (aureomycin) per pound.

**Experiment 2.** In this experiment, 20 Jersey calves were divided into two groups and used to study the influence of chlortetracycline on the whole blood, plasma, and corpuscle glucose to 16 wk. of age. Half the calves in each group were inoculated with fresh cud material (2). Starting at three days of age and continuing to 16 wk., high-roughage pellets (a) composed of two parts ground alfalfa hay and one part simple grain mixture were fed free-choice to the control group. Chlortetracycline (Aurofac 2-A) was added at the rate of 20 mg/lb as a micro-ingredient in the pellets (b) fed the experimental group to 12 wk. of age. From 12 to 16 wk. these calves were also fed pellets (a) containing no chlortetracycline. The composition of the rations used is shown in Table 1. The results of the blood analyses in this experiment are presented in Figures 3 and 4. No differences in the blood picture were found between inoculated and uninoculated calves; thus, the data for each pellet group, (a) and (b), were combined.
FIG. 1. Changes in concentration of glucose (reducing sugar) in whole blood, plasma, and corpuscles (mg/100 ml. of whole blood) and red cell volume (per cent) in calves fed a high-roughage ration. Experiment 1.

DISCUSSION OF RESULTS

These data confirm previous reports (9, 10, 14) that much of the decline in the blood glucose of young calves during the first 7 wk. is the result of a precipitous decline in corpuscle glucose (Figures 1, 2, 3, and 4). The lowered
Fig. 2. Changes in concentration of glucose (reducing sugar) in plasma, whole blood, and corpuscles (mg/100 ml.) in calves fed a high-roughage ration. Experiment 1.
corpuscle glucose appeared to be the result of loss of fetal red cells and replacement with postnatal red cells in which the concentration of glucose was lower (13).

Plasma glucose also declined during the 7-wk. milk feeding period, but the sharpest drop occurred upon withdrawal of milk from the ration (Figures 1, 2, 3, and 4). It is interesting to note that plasma glucose levels for the calves shown in Figures 1 and 2 and the control groups in Figures 3 and 4 were lowest just after milk feeding was terminated. From this point they were shown to increase about 14 mg. % by the end of the feeding period. The low point and gradual rise in plasma glucose suggest that the calves were under-
going a substantial adjustment in energy metabolism after being changed to complete dependence on the high-roughage rations and probably represent a period of suboptimum energy availability. However, since no serious break occurred in the growth rate of the calves at this point (2), the depression in plasma glucose at weaning may not be a critical problem.

As previously observed (3), chlortetracycline-fed calves maintained higher whole blood glucose levels ($P < 0.01$). These higher blood glucose levels were shown to be largely the result of increased plasma glucose (Figures 3 and 4). An analysis of variance of the means during the 8- to 12-wk. period, following removal of milk from the ration, revealed that the plasma glucose values, both
on the basis of mg/100 ml. of whole blood and mg/100 ml. of plasma, were significantly higher than the controls (P < 0.01). In the period after the chlortetracycline was removed from the ration, 12-16 wk., there were no significant differences between the groups. It is noteworthy that chlortetracycline prevented the depression of plasma glucose observed in the control calves following withdrawal of milk from the diet (Figures 3 and 4).

These data strongly support the postulate that the influence on calf performance resulting from feeding low levels of chlortetracycline arises from its energy-sparing effects, reflected in the plasma glucose level. Other data published by the authors (3) suggest that this may result from the conservation of glucogenic substances as they pass through the rumen, associated with a shift in volatile fatty acid concentration in the rumen.

It was shown previously (3, 5) that sudden withdrawal of chlortetracycline from the ration of calves resulted in decreased rate of growth and decreased efficiency of feed utilization. Rumen inoculations administered after aureomycin feeding was terminated improved calf performance (7). These observations, considered together with the observation that these effects were not found when the rumen was by-passed by feeding chlortetracycline in the milk (2), also implicate the rumen as the primary site of action of chlortetracycline on the energy metabolism of high roughage-fed calves.

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REFERENCES


