EFFECT OF DIETARY FAT AND MINERALS ON THE INCIDENCE OF DIARRHEA AND RATE OF PASSAGE OF DIETS IN THE DIGESTIVE TRACT OF DAIRY CALVES

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SUMMARY
Effects of adding minerals simulating whey ash, animal tallow, or both to a basal nonfat milk solids diet for calves were determined. Highly significant differences (P < 0.01) in the over-all incidence of diarrhea were observed among groups of calves fed the different diets in one trial extending for 21 days, but not in another trial of shorter duration. The added minerals increased the over-all incidence of diarrhea in the calves, whereas the animal tallow decreased its incidence in comparison to diets without added fat. The rather severe, apparently noninfectious diarrhea subsided after several days, even though the same amount of the respective diets was fed each day throughout the experiment, indicating a marked adaptation of the calves to diarrheic diets.

Addition of minerals to the diet appeared to accelerate, whereas added fat tended to delay, the rate of abomasal evacuation, as determined by radiography of 16 calves at four and 11 days of age. There was little evidence that the rate of abomasal evacuation was definitely related to the severity of diarrhea on the days the radiographs were made. The average weight, pH, and chemical composition of digestive tract contents in calves at 17 days of age were not related to fecal consistency at the time of slaughter.

The mineral content of various ingredients and the type of fat to use are among the factors that need to be considered in formulating milk replacers for dairy calves. Wing et al. (25) suggested that the high incidence of diarrhea observed in calves fed replacers containing a relatively large amount of dried whey or dried whey product (5, 23, 25, 26) was at least partially due to the high mineral content of these products. Further, Owen et al. (17) observed that the addition of minerals simulating whey ash to a skim milk diet caused diarrhea in calves 11 days of age and older, whereas a lower incidence of diarrhea resulted when the minerals were added to whole milk containing 3.1% fat.

Different fats have been observed to vary greatly in nutritional value for young calves (2, 6, 9, 11, 14, 24). Part of this variation can be attributed to differences in digestibility of the fats (1, 6, 10, 18, 19); however, other factors are also known to be involved, since

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Raven and Robinson (18) found palm oil to have a lower protein-sparing effect than milk fat, even though the digestibility of the two fats was nearly equal. The nutritive value of some fats is increased by the addition of lecithin (10), and several fats are improved by homogenization (3, 10, 12) or hydrogenation (2, 14). In contrast, Raven and Robinson (18, 19) found unhydrogenated palm oil and palm-kernel oil to be superior to the corresponding hydrogenated products, as measured by their effect on the nitrogen retention of calves. Other factors affecting the nutritive value of milk replacers for calves have been discussed by Schuh (20).

The objective of the present study was to determine the effects of adding minerals simulating whey ash, animal tallow, or both, to a basal nonfat milk solids (NFMS) diet for young calves under conditions of continuous feeding.

EXPERIMENTAL PROCEDURE
In each of two separate trials, 16 male Holstein calves were assigned at random to treatment groups as follows: (a) basal NFMS diet, (b) basal diet plus fat, (c) basal diet plus minerals, (d) basal diet plus minerals and fat. All calves were started on experiment at three days of age as they became available over a period of several months. In Trial I,
extending from May to February, calves were used for radiographic studies and afterwards killed at 17 days of age. The calves in Trial II, extending from February to July, were maintained on the experimental rations until 24 days of age.

The basal diet contained 10% dried nonfat milk solids. Diets containing 3% animal tallow were prepared by homogenizing the tallow at 2,000 psi with the basal diet. The mineral supplement simulating whey ash (450 g CaHPO₄·2H₂O, 360 g K₂HPO₄, 175 g MgSO₄, and 390 g NaCl) was added to the milk immediately before each feeding at the rate of 2.1% of the milk consumed. This level of minerals was used because it approximated the level in whey product reconstituted to have the same energy content as whole milk. Also, it appeared desirable to compare the effects of feeding this level of minerals to calves on a continuous basis starting at four days of age with results previously reported by Owen et al. (17) with older calves fed similar diets on an intermittent, short-term basis. Supplemental vitamins and trace minerals were added to all the diets in amounts similar to those previously used by other workers (6, 13, 21), to insure that the results would not be confounded by deficiencies of these nutrients.

Each calf was fed colostrum for two days after birth, and thereafter the respective experimental diets were fed at 12-hr intervals at the daily rate of 8% of initial body weight. The calves were housed in a barn in which the temperature was controlled within the limits of 60-85°F. Individual pens having metal screen floors were used, and ratings on fecal consistence were made at frequent intervals (3, 6, and 9 AM; 2, 5, 8, and 10 PM) during each day, using a geometric scale of 1, 2, 4, and 8, denoting normal, very soft, semifluid, and extremely fluid feces, respectively. Body weights were recorded daily and blood samples were taken at four-day intervals for hematocrit evaluation, to detect any marked dehydration of the calves. The diarrhea which occurred was considered to be of nutritional origin as long as the calves remained alert, consumed the allotted amount of feed, and the rectal temperature remained below 103.5°F. This temperature was chosen because calves were frequently observed to have a body temperature this high with no other clinical evidence of infection under the prevailing climatic conditions.

Radiographs were made of the 16 calves in Trial I at four and 11 days of age, to determine the time required for abomasal evacuation and passage of the diets through the intestinal tract. After making a survey radiograph, barium sulfate (Barotrast) was fed to each calf at the rate of 1 oz/pound of the usual diet. A series of radiographs was then made, beginning with one immediately after the test meal, and then at 0.5, 3, 9, 12, and 24 hr thereafter. Feeding of the calves was delayed at 12 and 24 hr until the radiographs were made.

The radiographs were made, using a Picker mobile machine, Kodak Royal Blue medical film, and 14- by 17-in. Picker Lysholm grid front cassettes with Patterson high-speed intensifying screens. The cassettes were placed in an upright cassette holder on the right side of the standing calf (Figure 3), with a focal-spot cassette distance of 30 in. The average exposure for a calf measuring 18 em in the anterior lumbar area was 50 ma at 0.3 sec and 73 kv. As the calves varied from 16

![Figure 1](https://example.com/figure1.png)  
**Fig. 1.** Average fecal consistency ratings for calves fed experimental diets for 14 days.

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Diets supplemented with vitamins, trace minerals, and antibiotics as follows: Amounts per calf daily: 5,000 IU vitamin A, 625 IU vitamin D₃, 20 mg thiamine, 20 mg riboflavin, 10 mg pyridoxine, 10 mg Ca pantothenate, 20 mg niacin, 100 mg inositol, 0.2 mg biotin, 12 mg p-amino-benzoic acid, 20 mg alpha-tocopherol, 1 mg folic acid, 1 mg menadione, 0.01 mg vitamin B₁₂, 60 mg chlortetracycline. Amounts per pound of diet: 11.1 mg FeSO₄·7H₂O, 2.1 mg CuSO₄·5H₂O, 8.0 mg MnSO₄·H₂O, 2.5 mg bacitracin, 1.0 mg penicillin, 170 mg choline chloride.
to 20 cm in thickness, the voltage was varied from 70 to 75 kv for the different-sized calves. The volume of ingesta in the abomasum at different periods was calculated from measurements on the radiographs, on the basis that the material approximated the shape of a prolate spheroid.

At 17 days of age each calf was killed 6 hr after feeding, and determinations were made of the weight and pH of the contents in the rumen-reticulum, omasum-abomasum, and the anterior and the posterior parts of the small and large intestines. Representative samples from each segment were analyzed for dry matter, ash, protein nitrogen, and crude fat, using AOAC methods (Official Methods of Analysis, 8th ed.), except that aliquots for ash and crude fat analyses were taken after the samples were dried to a constant weight under vacuum at 60 C.

In Trial II, calves were fed the experimental diets until 24 days of age, to provide additional time for possible adaptation to the high mineral diets. Carmine was administered to these calves by mixing with the milk immediately before feeding on the second, eighth, and fourteenth days of the experiment, to determine the interval required for passage of the respective diets through the digestive tract. Indigo carmine was used initially, but a change was made to carmine red because it was easier to see in the feces than was the other type.

Since the daily fecal consistency values represented an average of all the ratings made during each day, a normal distribution was assumed. The analysis of variance for each trial followed essentially that for a split plot in time, Sec. 12.5 of Steel and Torrie (22), with sources of variation of the main plot being days, days times treatments, and days times calves within treatments (Error A); sources of variation for the subplots were days, days times treatments, and days times calves within treatments (Error B). The mean square for error for evaluating treatment-period interactions was the pooled value for animals within days (periods) by treatments, yet the degrees of freedom for determining statistical significance were that for a single period.

**RESULTS AND DISCUSSION**

In Trial I, the calves fed diets with added minerals had a higher over-all incidence of diarrhea than those fed diets without the added minerals, and the calves fed added fat had less diarrhea than those fed diets without added fat. However, neither these main effects nor the interaction of the two factors was statistically significant (P > 0.05) for the entire trial. On the second day of the experiment, when barium sulfate was administered for the purpose of taking the first series of radiographs, there was a significant interaction (P < 0.005) of the two factors, with a high incidence of diarrhea in the group fed the basal diet plus added minerals, but not in the group fed both added minerals and fat (Figure 1). These results were interpreted as evidence that administration of barium sulfate at four days of age had an adverse effect on the calves fed the basal diet with added minerals, but no immediate effect on calves fed the other diets. It is possible that the response of the calves in this trial was affected sufficiently by administration of the barium sulfate to the calves at four and 11 days of age to account for a lack of complete agreement of results in the two trials reported herein.

In Trial II, there was also a higher over-all incidence of diarrhea in calves fed the diets containing added minerals than in those fed the other diets, whereas the calves fed diets with added fat had less diarrhea than those fed diets without added fat. The independent effects of both minerals and fat were statistically significant (P < 0.01), but neither the interaction of these two factors nor the interaction of these factors with periods (days) was statistically significant (P > 0.05). The calves fed the basal diet plus added minerals had very severe diarrhea within one to two days after feeding of the experimental diets was begun. Equally severe, but less persistent, diarrhea was evident within five or six days in the group receiving the diet to which both minerals and fat had been added. Thus, the added fat did not prevent severe diarrhea in calves fed a high-mineral diet, although its duration was reduced. In a similar experiment, Owen et al. (17) observed that milk fat had an antidiarheic action when added to diets containing added minerals; however, the latter workers used older calves (11 vs. three days of age) and an experimental design wherein the diets were tested during periods of only four days, with minimal three-day adjustment periods of whole milk feeding before subsequent test feedings.

There was a general increase in the incidence of diarrhea within a few days after the trial began and a decrease toward the latter part of the trial (Figure 2). These differences among days on the experiment were statistically significant (P < 0.05) and indicative of a rather marked adaptation of the calves to the diets following periods of severe diarrhea. Thus, in the absence of infection, the
calves exhibited a high tolerance for the diarrheic diets.

The addition of minerals to the diet appeared to accelerate, whereas added fat tended to delay, the rate of removal of ingesta from the abomasum (Table 1). The effects of both the
**TABLE 1**

Removal of barium test diet from the abomasum of calves as determined by radiographs at specified intervals after feeding

<table>
<thead>
<tr>
<th>Diet</th>
<th>Amount of test diet (days)</th>
<th>Fecal consistency rating a</th>
<th>Per cent of test diet remaining after following number of hours</th>
<th>Time required for removal of following percentage of test diet from abomasum (hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basal NFMS</td>
<td>4</td>
<td>1.12</td>
<td>0.5</td>
<td>60 16 1 0 1.0 2.2</td>
</tr>
<tr>
<td>Basal + fat</td>
<td>4</td>
<td>3.3</td>
<td>3.5</td>
<td>71 15 5 5 1.2 2.0</td>
</tr>
<tr>
<td>Basal + minerals</td>
<td>4</td>
<td>3.3</td>
<td>5.38</td>
<td>30 14 4 2 0.4 1.2</td>
</tr>
<tr>
<td>Basal + fat + minerals</td>
<td>4</td>
<td>3.6</td>
<td>1.62</td>
<td>61 10 4 2 0.8 1.5</td>
</tr>
<tr>
<td>Basal NFMS</td>
<td>11</td>
<td>3.3</td>
<td>5.00</td>
<td>41 10 2 0 0.4 0.8</td>
</tr>
<tr>
<td>Basal + fat</td>
<td>11</td>
<td>3.5</td>
<td>1.25</td>
<td>53 10 1 1 0.6 1.2</td>
</tr>
<tr>
<td>Basal + minerals</td>
<td>11</td>
<td>3.2</td>
<td>3.79</td>
<td>26 11 1 1 0.3 0.7</td>
</tr>
<tr>
<td>Basal + fat + minerals</td>
<td>11</td>
<td>3.6</td>
<td>6.00</td>
<td>62 19 6 2 1.0 2.4</td>
</tr>
</tbody>
</table>

* Consistency rating on day radiographs were taken.

added minerals and fat on the per cent of initial contents remaining in the abomasum one-half hour after feeding were statistically significant (P < 0.05) at four days of age. Although the minerals and fat appeared to have a different effect when added in combination than when added singly, this interaction was not statistically significant (P > 0.10). There was little relation between the diet and the per cent of initial contents estimated to be in the abomasum at the other intervals when radiographs were made.

The addition of fat resulted in a significant decrease (P < 0.01) in the rate of abomasal evacuation at 11 days of age. The added minerals consistently increased the rate of removal when added singly, but appeared to have the opposite effect in some calves fed the diet with both minerals and fat. The interaction of the two factors was not statistically significant (P > 0.10), however, possibly because of the relatively small number of calves involved.

Inconclusive evidence was obtained regarding the relationship of the rate of abomasal evacuation to the fecal consistency ratings on the days the calves were radiographed. A statistically significant (P < 0.05) correlation coefficient of −0.53 was found between the fecal ratings at four days of age and the per cent of test diets remaining in the abomasum at one-half hour after feeding; however, a small, nonsignificant correlation of −0.03 was found when the number of hours required for removal of one-half of the ingesta was used as the criterion of abomasal evacuation. Moreover, the comparable correlation coefficients computed on data pertaining to the calves at 11 days of age were 0.17 and 0.29, respectively. These observations coincide with the results of other recent work (8, 16), wherein the prevention of curd formation in the calf’s stomach by the addition of sodium citrate did not affect the growth or health of young dairy calves.

Some of the barium sulfate passed into the small intestine within a short time after feeding (Figure 3), and had traversed the digestive tract to the rectum of the calves by the time the 9-hr radiographs were made, in most instances. These results agreed with the observations of Benzie and Phillipson (4), that barium reached the large intestine of 4-wk-old calves by 3.5 hr after feeding. In the present experiment, 13 ± 6.5 hr (mean ± standard deviation) was required for the carnmine to pass through the tract and appear in the feces of calves having fecal consistency ratings from 2.0 to 8.0, whereas it was not evident in the feces until 26 ± 13.6 hr after feeding in calves with fecal consistency ratings of 1.0-2.0. Thus, it was concluded that the time required for carnmine to appear in the feces did not give an accurate measure of the rate of passage of diets through the digestive tract of calves with normal fecal consistency.

With the exception of one group of calves discussed above, there was no evidence that the micronized barium sulfate used in this study had any adverse effect on the calves, and it is certain that studies can be made on calves at an earlier age, using a radiographic technique, than would be feasible by other techniques involving palpation via a rumen fistula. Moreover, the determinations made of the time re-
quired for abomasal evacuation in this work substantiate the results obtained by other workers (7, 15) using a palpation technique.

Calves having diarrhea were often observed to have a considerable amount of fluid in the large intestine, causing marked distention, in contrast to the more typical situation in calves without diarrhea (Figure 4). Evidence of colitis was seen on the radiographs of several calves, but it was not related to any specific diet.

There were no differences among groups in chemical composition of the digestive tract contents associated with fecal consistency at the time of necropsy. However, the possibility that differences in the composition may have existed when the range in fecal consistency ratings was greater than at the time of sacrifice cannot be discounted, since adaptation to some diets had occurred by the time the animals were killed (Figure 1). Similarly, Owen (15) found no relation between the incidence of diarrhea in calves and the weight or pH of digestive tract contents 14 hr after receiving whole milk or high lactose-mineral diets.

Fig. 4. Radiographs of calves 12 hr after administration of contrast media: a) typical peristalsis in calf having normal fecal consistency; b) marked distention and fluid level in large intestine of calf with diarrhea.

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