Studies on Substitute Milk Containing Dried Skimmilk with Tallow, Lecithin or Wheat Starch for Dairy Calves

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Four kinds of substitute milk containing spray-dried skimmilk were fed to eight Holstein male calves of about 1 wk. of age for 4 wk. In the skimmilk diet the growth rate and feed efficiency were the lowest. The addition of 4% crude soybean lecithin to the skimmilk diet was found to increase the growth rate and feed efficiency to a remarkable degree.

The apparent digestion coefficients of tallow were about 88% throughout three digestion periods and no age effect upon the digestibility was observed, whereas the digestibility of wheat starch showed a tendency to increase in accordance with the advanced age. The calves could not digest the starch to an appreciable extent for about 1 wk. after the starch-containing diet was offered. After a lag of about 1 or 2 wk. the adaptive mechanism to digest starch increased rapidly.

INTRODUCTION

Most substitute milks for dairy calves include dried skimmilk as the main component, whose quality is found to be influenced by the degree of heat denaturation in the preparation process. If the non-casein proteins of the dried skimmilk fed to the calves of 3 to 12 days of age were severely denatured by heat, such symptoms as diarrhea, growth retardation and increased mortality were observed.1

The calves of early age, only fed the reconstituted skimmilk after the colostrum intake, showed a marked depression of blood fat content together with digestive disturbances.2-4 By including hydrogenated vegetable oil or animal fat such as lard or tallow to the dried skimmilk ration, the quality of substitute milk was improved almost to the equal level of whole milk, and the homogenization of fat or the addition of lecithin to fat were effective in increasing the digestibility and utilization of the fat.5-7 Lecithin was found to increase the absorption of vitamin A by the calves of 1 to 7 days of age.8 Lecithin was ineffective as the sole lipid source to the lipid-free semi-synthetic milk.9 For the infant of suckling period, linoleic acid is an essential nutrient.10 In the calves of early wk. of age, the dietary fat containing no essential fatty acids was found to prevent the early death of the fat deficient calves.11

Calves up to 4 wk. of age apparently do not digest starch to any appreciable degree. This conclusion is based upon (a) studies in

which the blood glucose pattern following consumption of several different carbohydrates was followed,\(12-14\) (b) measurements of digestive enzyme secretions\(15,16\) and (c) carbohydrate digestion studies.\(17-21\) It appears that the calf has little capacity to digest starch until about 4 wk. of age.

The present experiments were designed to obtain the preliminary information which would contribute to the development of low-milk solids substitute milk. The growth responses of Holstein male calves fed four kinds of substitute milks containing dried skim milk as a main component were measured from 1 to 5 wk. of age, and the digestion coefficients of dried skim milk, tallow and wheat starch were obtained at three stages of growth. The effect of the addition of crude soybean lecithin to a dried skim milk ration was also examined.

**EXPERIMENTAL**

Two experiments (Experiments I and II) were conducted with eight colostrum-fed Holstein male calves obtained from local dairymen at 3 days of age. The periods of Experiments I and II were from Feb. 29th to April 2nd and May 9th to June 10th of 1964, respectively. In Experiment I, two calves (No. 1 and 2) were fed with the skim milk diet and two calves (No. 3 and 4) with the tallow diet. In Experiment II, two calves (No. 5 and 6) were fed on the lecithin diet, two calves (No. 7 and 8) on the starch diet. Each calf was confined in an individual, wire-floored metabolism cage and received 4 kg of whole milk per day for 2 days after arrival. The substitute milks were then fed abruptly instead of whole milk. The growth experiments of 4 wk. were started at 9 and 7 days of age in Experiments I and II, respectively. The body weights of these calves at the start of both Experiments I and II ranged from 42 to 50 kg.

The ingredients used in each diet are shown in Table I. Dried skim milk, tallow, crude soybean lecithin and wheat starch were all commercial products. This dried skim milk was prepared by the spray drying process, in which maximum temperature was reported to be below about 80°C. The non-casein proteins of this fraction were not so much heat-denatured as those of super-heated dried skim milk for baker's use. Crude soybean lecithin contained 64 to 68% lecithin and 32 to 36% other oily substances. Wheat starch contained maximum 0.25% lactic acid, 0.22% ash and 0.45% protein. The particle size of the starch ranged from 5 to 40 μ.

For mixing, the tallow was first melted and the crude soybean lecithin and wheat starch were added to the dried skim milk. The growth experiments of 4 wk. were started at 9 and 7 days of age in Experiments I and II, respectively. The body weights of these calves at the start of both Experiments I and II ranged from 42 to 50 kg.

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**Table I. Ingredients Used in the Substitute Milks Fed to Young Dairy Calves**

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Exp. I</th>
<th>Exp. II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Skimmilk diet</td>
<td>Tallow diet</td>
</tr>
<tr>
<td>Dried skim milk</td>
<td>99.3</td>
<td>77.9</td>
</tr>
<tr>
<td>Tallow</td>
<td>19.5</td>
<td></td>
</tr>
<tr>
<td>Crude soybean lecithin</td>
<td>1.9</td>
<td>4.0</td>
</tr>
<tr>
<td>Wheat starch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additives*</td>
<td>0.7</td>
<td>0.7</td>
</tr>
</tbody>
</table>

*Chlortetracycline-HCl added per kg of the diet: 66 mg.
Vitamins added per kg of the diet: vitamin A, 20,000 I. U.; vitamin D₃, 4,000 I. U.; vitamin E, 20 I. U.; dibenzoyl thiamine, 2.9 mg; vitamin B₆, 24 mg; nicotinic acid, 4 mg; choline-HCl, 100.6 mg; Ca pantothenate, 30.2 mg; vitamin B₃, 2 mg; folic acid, 0.26 mg.
Trace elements added per kg of the diet: Cu, 4 mg; Fe, 40 mg; Zn, 0.1 mg; Co, 0.6 mg; Mn, 6.7 mg.
Cr₃O₃ added per kg of the diet: 0.25 to 0.30 g.

soybean lecithin was added to the melted tallow. This liquid mixture was then added to the dried skimmilk containing the additives.

All the diets contained 0.025 to 0.030% of chromic oxide as an indicator for digestion experiments, which were carried out at 11 to 14, 22 to 24 and 33 to 37 days of age in both Experiments I and II. The diets were reconstituted with warm water of 40°C at a ratio of one to six or seven immediately before feeding and fed to calves by open pail twice a day (8:30 a.m. and 4:30 p.m.). Roughage and water were not given. During the digestion experiments, as much feces as possible were collected four times per day in order to minimize the error caused by the diurnal variability in fecal composition.

Body weights were measured once a week at 8:00 a.m. before the morning feeding. Fecal samples were dried at about 60°C and equilibrated with atmospheric moisture. Moisture, crude protein, ether-extract, nitrogen free extract (NFE) and crude ash were measured by the AOAC method. The soap content of the feces from calves fed the tallow diet and chromic oxide were determined according to the procedures described by Hartfiel and Kameoka et al. respectively. The chemical composition of the diets used are shown in Table II.

### RESULTS AND DISCUSSION

Feed consumption, growth rates, feed efficiency and incidence of scours are presented in Table III. The amounts of feed consumed were different among four diets. The ratios of total digestible nutrients (TDN) intake calculated from the digestion experiments to the requirements proposed in the N.R.C. standard were 67 and 83, 79 and 74, 71 and 71 and 71% in the first and second two-wk. periods for the skimmilk, tallow, lecithin and starch diets, respectively. It is doubtful whether the N.R.C. standard can be correctly applied to the calves of pre-ruminant

<table>
<thead>
<tr>
<th>Exp. No.</th>
<th>Diet</th>
<th>Av. daily air dry matter intake (g)</th>
<th>Av. daily wt. gain (g)</th>
<th>Feed utilization</th>
<th>wt. gain air dry matter intake</th>
<th>wt. gain TDN intake</th>
<th>Total days of scour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp. I</td>
<td>Skimmilk diet</td>
<td>710</td>
<td>960</td>
<td>100</td>
<td>320</td>
<td>0.14</td>
<td>0.33</td>
</tr>
<tr>
<td>Exp. I</td>
<td>Tallow diet</td>
<td>710</td>
<td>830**</td>
<td>380</td>
<td>620**</td>
<td>0.53</td>
<td>0.75**</td>
</tr>
<tr>
<td>Exp. II</td>
<td>Lecithin diet</td>
<td>840</td>
<td>960</td>
<td>520</td>
<td>600</td>
<td>0.62</td>
<td>0.63</td>
</tr>
<tr>
<td>Exp. II</td>
<td>Starch diet</td>
<td>940</td>
<td>1060</td>
<td>450</td>
<td>570</td>
<td>0.48</td>
<td>0.54</td>
</tr>
</tbody>
</table>

* All above figures are the average of two calves, and the figures in parenthesis are the range of the two values (large value minus small value).
** The data from one calf (No. 3) are omitted owing to the severe diarrhea and the loss of appetite.

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stage, however, it is helpful in order to compare the differences of TDN intakes among different diets. From the above values it was estimated that the amount of TDN intake during the first 2 wk. for the calves on the skimmilk diet was lower than those on the other diets. The digestible crude protein (DCP) intakes were more than 85% of the N.R.C. standard in all diets.

In the first 2 wk. in the calves fed the skimmilk and starch diets, scours of semi-liquid feces were often observed, and even at best the fecal consistency was softer than those on the lecithin and tallow diets. For the lecithin diet, general fecal consistency was rather loose compared with that of the tallow diet. In the latter diet looseness was observed for only a few days after the diet replaced the whole milk. However, the No. 3 calf on the tallow diet showed severe diarrhea from 22 to 24 days of age, when its appetite was essentially nil and white feces containing undigested fats were observed. This was the only case requiring medical treatment. The calf was starved for one night and a streptomycin-containing drug was fed. Two days after the treatment the calf recovered, but no body weight gain was observed during that week.

The scours in the skimmilk and starch diets may be caused by the unbalanced nutrients, especially by high carbohydrate to low fat content. It was reported that excessive amounts of carbohydrate fed caused scours\(^{26}\) and that the addition of fat was effective in preventing such scours.\(^{41}\) According to our unpublished data, when the whole milk containing 3% sucrose or maltose was fed to 23 days old calves for 5 days, liquid feces were observed within 12 hr. after the first feeding and continued uninterrupted with little influence upon appetite and body weight gain. However, the whole milk containing 2% soluble starch was fed to 23 days old calf for five days, and no soft or liquid feces were observed.

In that period the digestion coefficients of sucrose, maltose and soluble starch were 76, 72 and 39%, respectively. According to our another unpublished data, if the skimmilk diet containing 30% sucrose was reconstituted by warm water and fed to the calf of early age for 4 wk., liquid feces were observed continuously and body weight gain was not enough. After the post-mortem examination the enlargement and necrosis of the kidney were observed. It was postulated that the cause of scours of the nutritional origin such as these was the flow of water into the gut as a result of the osmotic pressure caused by the high concentration of mono- and disaccharides in the gastrointestinal tract.

In the skimmilk diet, the growth rate and feed efficiency were the lowest. From the middle of the second wk. both calves on the skimmilk diet appeared slightly unthrifty and displayed the symptoms of leg weakness. In the last 2 wk., the calves were in much pain and had difficulty for getting up because of the damage of the skins of front kness by rubbing against the wire-floor. Appetite, however, was normal throughout the experimental period. Cunningham and Loosli\(^{11}\) also reported the symptoms of leg weakness by the calves fed fat-free diets. The addition of emulsified tallow, crude soybean lecithin or wheat starch to the skimmilk diet improved the growth rate and feed efficiency. The addition of 4% crude soybean lecithin improved the quality of the diet remarkably. In the case of lipid-free, semi-synthetic milk, the addition of lecithin has been reported to be ineffective.\(^{9}\) This lecithin in crude soybean might have helped the absorption of vitamin A\(^8\) or that crude soybean lecithin contained known essential nutrients such as linoleic acid. The conversion of TDN to body gain was the most efficient for the lecithin diet, which suggested that the net utilization of digestible energy was improved by the addition of crude soybean lecithin to the skimmilk diet.

It was unexpected to have such a good

TABLE IV. APPARENT DIGESTIBILITIES AND FEED VALUES OF DIFFERENT SUBSTITUTE MILKS FED TO YOUNG DAIRY CALVES AT THREE GROWTH STAGES*

<table>
<thead>
<tr>
<th>Diets</th>
<th>Age</th>
<th>Digestibility</th>
<th>Feed value (Air dry matter basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Organic matter %</td>
<td>Crude protein %</td>
</tr>
<tr>
<td>Skimmilk</td>
<td>11~14</td>
<td>93.0 (1.8)</td>
<td>87.7 (1.8)</td>
</tr>
<tr>
<td></td>
<td>22~24**</td>
<td>94.7 (2.0)</td>
<td>89.4 (2.0)</td>
</tr>
<tr>
<td></td>
<td>34~37</td>
<td>94.0 (1.1)</td>
<td>89.2 (1.4)</td>
</tr>
<tr>
<td>Tallow</td>
<td>11~14</td>
<td>95.0 (2.5)</td>
<td>88.0 (3.1)</td>
</tr>
<tr>
<td></td>
<td>22~24**</td>
<td>93.7 (2.1)</td>
<td>84.0 (4.6)</td>
</tr>
<tr>
<td></td>
<td>34~37</td>
<td>93.7 (4.0)</td>
<td>88.3 (8.8)</td>
</tr>
<tr>
<td>Lecithin</td>
<td>11~14</td>
<td>73.6 (9.4)</td>
<td>61.7 (8.4)</td>
</tr>
<tr>
<td></td>
<td>22~24</td>
<td>82.8 (2.0)</td>
<td>65.1 (2.0)</td>
</tr>
<tr>
<td></td>
<td>34~37</td>
<td>90.3 (1.4)</td>
<td>77.2 (4.7)</td>
</tr>
</tbody>
</table>

* The above figures are the average of two calves, and the figures in parenthesis are the range of the two values (large value minus small value).
** Owing to the diarrhea in the digestion experiment, the data of one calf were discarded.
*** These values were corrected for the fecal soap content.

performance from the starch diet, because many data showed poor responses for starch (especially corn starch) by the calves of up to 3 or 4 wk. of age.17~21) The average daily weight gains of the two calves fed the starch diet were 270, 630, 530 and 610g in the 1st, 2nd, 3rd and 4th wk., respectively. The growth rate increased rapidly from the 2nd wk. and this rapid increase might reflect an increase in the digestibility of starch.

Digestibility and feed values data are presented in Table IV. The apparent digestion coefficients of the whole milk reported earlier27) were as follows (%): organic matter, 97.4; crude protein, 93.9; ether-extract, 98.2; NFE, 99.7. In comparison to these values, the apparent digestion coefficients of reconstituted dried skimmilk were relatively low. The differences in average digestion coefficients of organic matter, crude protein and NFE between the skimmilk and lecithin diets were less than 2 percent and not significant. Only for the starch diet, the increase in digestibility and feed values with advancing age was observed. This is the same trend obtained by Shaw et al.17)

The digestion coefficients of ether-extract in the tallow diet were calculated by correcting for the fecal soap content, which equaled about 11.8, 37.1 and 42.5% of the total fecal fat at 11 to 14, 22 to 24 and 34 to 37 days of age, respectively. The digestibility of emulsified tallow was higher than the values reported by Hopkins et al.,6" but almost the same with

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the values obtained by Thomke\textsuperscript{28} concerning the well-homogenized tallow whose particle size was smaller than 4\(\mu\). During the incidence of diarrhea by the No. 3 calf, at 22 to 24 days of age, the digestion coefficient of ether-extract of the tallow diet dropped to about 31\%. This diarrhea was not of nutritional cause and accompanied by the loss of appetite; there were no body weight gain and the decrease of digestibility of fat, as mentioned earlier. If the fecal soap content was not considered, the digestion coefficients of the ether-extract of the tallow diet would become 91, 92 and 93\% at 11 to 14, 22 to 24 and 34 to 37 days of age, respectively.

The digestion coefficients of starch were calculated by assuming that all the NFE fractions of feces were derived from the indigestible residues of starch. The average percentage of the reducing sugar content in the fecal NFE fraction fed the starch diet was 14.3\% and its range was from 5.3 to 25.1\%. If the fecal reducing sugars were considered to come from the skimmilk portion of the starch diet, then the average digestion coefficients of starch were 31, 74 and 89\% at 11 to 14, 22 to 24 and 34 to 37 days of age, respectively. The difference of the digestion coefficients of starch between the two calves at 11 to 14 days of age was 56.6\% and this might reflect the different ability for digesting starch between the two calves.

During the first week, the calves fed the starch diet did not digest the starch well and their body weight gain was low. But after a lag of about 1 or 2 wk. the calf's ability to digest starch increased rapidly and the increase of the growth rate followed. In these experiments no solid feeds were given and therefore the development of rumino-reticulum was undoubtedly negligible. One of the mechanisms of digesting starch is thought to depend on the adaptive formation of hydrolytic enzymes in the pancreas or small intestinal tracts. New-born calves were reported to be essentially deficient in amylase and maltase, and that with advancing age the activities of these enzymes gradually increased\textsuperscript{13,16,161}. There is also a possibility that the activity of microorganisms might increase in the lower intestinal tracts and result in the starch hydrolysis. The length of such adaptation period may be influenced by many factors such as kinds of starch-containing ration fed and ages of calves. According to the literatures\textsuperscript{17,18,21} the calves at 4 wk. of age acquire the ability to digest starch to the extent of 80 to 90\%. From the present experimental results, however, it is suggested that not the ages of calves but the adaptation period may be more important and that if the starch-containing diets are fed to the calves of pre-ruminant stage over the period of 1 wk., the adaptive mechanism to digest starch increases rapidly. Further investigations will be necessary for clear understanding of such adaptive mechanism.

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