Rapeseed, Sunflower and Soybean Meals as Protein Supplements in Dairy Calf Starters

Paul E. Stake

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RAPESEED, SUNFLOWER AND SOYBEAN MEALS AS PROTEIN SUPPLEMENTS IN DAIRY CALF STARTERS

BY

PAUL E. STAKES

A thesis submitted in partial fulfillment of the requirements for the degree Master of Science, Major in Dairy Science, South Dakota State University

1971
RAPESEED, SUNFLOWER AND SOYBEAN MEALS AS PROTEIN
SUPPLEMENTS IN DAIRY CALF STARTERS

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser         Date

Head, Dairy Science Department         Date
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INTRODUCTION

The world need for protein is ever-increasing causing the feed industry to seek new sources of protein supplementation for livestock (17). Urea and other non-protein-nitrogen (NPN) sources have received much attention in the past twenty years as protein substitutes, but their use is limited to functional ruminant animals. Pre-ruminant calves, unable to utilize NPN, need natural protein in their diets. Soybean meal (SBM) has been the common protein supplement in many dry calf meals in the Midwest for several years and has been proven to be an acceptable source of both protein and energy.

Since the early 1940's the production of rapeseed (Brassica napus and B. campestris) in Canada has risen tremendously due to the increased demand for the extractable oil. Presently, rapeseed production is second only to flax as Canada's most important oilseed crop, and it ranks first as Canada's largest oilseed export (33). Rapeseed meal (RSM) has been marketed for many years, but its acceptance has been plagued by toxicity and palatability problems due to its content of mustard oils. Recent developments in processing methods and plant breeding have considerably reduced the level of these undesirable oils. Compared to nonruminants, the nutritional value of RSM for cattle has received limited
attention because it is felt that ruminants are less susceptible than other classes of livestock to the effects of the toxic factors in RSM.

Sunflower meal (SFH) is also gaining importance as a feed ingredient for the livestock industry. Again, the demand for the oil is resulting in more meal being available as a livestock feed. Sunflower production is of special interest because of the expected increase in contracted acreage in South Dakota within the next five years (45). Minimal information is available on SFH as a protein supplement for cattle, notably dairy.

This study was designed to determine the feeding value of rapeseed, sunflower, and soybean meals as protein supplements in dairy calf starter rations. The objectives of the study were as follows:

1. To determine the rate of gain, feed efficiency and acceptability associated with each starter.
2. To determine the digestion coefficients for energy, dry matter and protein of each starter.
3. To determine the fate of the dietary protein by nitrogen balance technique.
4. To investigate the relationship between dietary protein and rumen volatile fatty acid (VFA) content.
LITERATURE REVIEW

Numerous animal and plant products have been used as protein supplements in dry calf starters. Early nutritionists concentrated on finding the proper combination of alfalfa hay, alfalfa meal, beet pulp, wheat bran, linseed meal and corn as a satisfactory dry calf meal to be fed along with skim milk for rearing dairy calves. During World War I the price of milk increased and became too costly as an animal feed. In an attempt to limit the amount of milk fed to young calves, several of the initial investigators (3, 46, 50, 54, 77, 83) added blood products to the dry feeds as replacements for the nutrients lost by the removal of milk. Spitzer and Carr (77) obtained good results by the daily feeding of liquid blood in conjunction with oil meal supplements, corn and wheat middlings. They acknowledged the impracticality of this form of supplementation but indicated that milk could be replaced by other ingredients. In later experiments these same researchers determined that dried blood was also an adequate ration constituent. Subsequent investigations with dried blood flour and dried blood meal by other researchers (3, 54) substantiated these findings, and blood products were a common component in dry calf meals fed in association with limited milk feeding regimes (46, 50, 83). Other animal
by-products were frequently recommended as supplements to cereal grain meals for calves. Dried and liquid skim milk were also used extensively for many years (12, 46, 49, 50, 73). Cereal and brewers yeasts were incorporated into the dry meals experimentally (31, 65) but were found to be of little value when fed in conjunction with whole or skim milk. By the mid-1930's most calf raising recommendations included limited milk and early feeding of dry meals and hay (49, 73) as compared to extended milk feeding periods which were recommended in earlier reports (3, 64, 65, 77).

Oil Meal Supplementation of Calf Starters

Linseed meal (LSM) and cottonseed meal (CSM) were the most prominent oil meals utilized in calf rations for many years. Both were included in starters at levels varying from 5 to 20 per cent, depending upon other ration components (12, 39, 46, 50, 54, 57, 64, 73, 77). Soybean meal was not widely used until the late 1930's and early 1940's as the supply was limited compared to LSM and CSM. As soybean production increased and flax acreage decreased, the acceptance of SBM as a livestock feed supplement grew rapidly (27, 37, 55). Production of SBM has increased 30-fold since 1930, and today it has replaced LSM in most regions of the country. Since World War II, SBM has been a standard protein
source for calf rations and has proven to be satisfactory in diverse types of feeding programs (6, 18, 77, 34, 35, 41, 58, 59, 75, 82). Rations supplemented with SBM have been commonly used as the control or basal diet in calf feeding trials comparing differing protein sources, methods of meal processing and forms of nitrogen addition.

Sunflower meal supplementation of ruminant rations has received minimal attention by researchers in the United States. Pearson et al. (67), in a brief investigation with beef cattle, determined that SFM was equal to CSM as a protein supplement in growing rations. Although of no statistical significance, SFM supported a slightly higher rate of daily gain and was associated with a 4 per cent increased feed efficiency. Although SFM was slightly unpalatable, the results were still favorable toward its use in cattle rations. Utilization of sunflower oilseed processing residues in ruminant rations has been studied by European researchers (63, 71, 72). Radaeva (71) and Sarbasov (72) revealed that sunflower oil-cake supplementation of either the dry concentrate mixture or silage portion of the ration resulted in normal milk production and milk quality. Nehring et al. (63), using wethers, reported SFM to contain 87 per cent digestible protein, 80 per cent digestible organic matter and a biological value of 70.0 compared to casein.
Canada's expanded market for rapeseed oil has directly increased the production of rapeseed products during the last 30 years. Rapeseed meal production has also increased, but its utilization has been plagued by reports of toxicity and unpalatability (1, 10, 11, 15, 22, 30, 68, 79). In 1944, Pettit (68) reported that 20 per cent RSM in chick diets caused 35 per cent mortality, but that lesser amounts (10-12 per cent) promoted satisfactory growth. The main symptom associated with the high mortality appeared to be hyperplasia of the thyroid. These findings prompted several investigations into the substance(s) in RSM which caused this goitrogenic effect. The results of these explorations indicate that rapeseed meal contains water-soluble thioglucosides which upon hydrolysis by a naturally occurring enzyme, myrosinase, yield allyl and crotonyl-isothiocyanates and oxazolidinethione (11). These substances are most toxic to monogastric animals, especially poultry (1).

Ruminant studies with RSN supplementation indicate it to be an adequate source of protein and energy if used in small amounts. Burkitt (21) and Bell and Weir (9) compared LSM and RSM as protein supplements for sheep and found the digestible dry matter and total digestible nutrient content to be equal. Some palatability problems were associated with the RSM, but these
were circumvented by feeding less than 0.23 kg of the meal per head per day. Asplund (4) fed dairy cows 20 per cent RSM in the concentrate mixture with no effect upon dry matter intake, protein-bound-iodine or milk production as compared to LSM. Ingalls et al. (44) found contrasting results from RSM substitution of SBM in dairy rations. They experienced a significant decrease in feed consumption, although this did not have a significant effect on milk production. Wood and Stone (34) found RSM to be lower in digestible protein content than SBM when fed to dairy calves at both maintenance and growth levels of intake. They also noted that the digestible energy from RSM was more efficiently utilized for gain than was the digestible energy of SBM, although the differences were not significant. In these trials RSM provided up to 50 per cent of the total dry matter intake without causing any apparent ill effects to the calves. This fact is interesting because of other reports citing lower intake and unpalatability to be associated with RSM feeding. Possibly the reason for these varying results is that new methods of solvent processing have increased the nutritional value of RSM compared to the older expeller methods. Also, advances in plant breeding have lowered the levels of oxazolidinethione, the principal goitrogen, in the seed
types now being used (24). These advances are helping to enhance the image of rapeseed as a livestock feed.

**Relationship Between Amino Acids and Branched-Chain Volatile Fatty Acids**

Comparison of the amino acid compositions of RSM, SFM and SBM indicates that differences in their content of metabolically important amino acids may exist. Dehority et al. (29) have demonstrated that leucine, proline, valine, and isoleucine increase in vitro cellulose digestion by mixed cultures of rumen microorganisms. The VFA's produced by the anaerobic catabolism of these amino acids, both in vitro and in vivo, also produce the same stimulation effect (13, 28, 29, 32, 53).

Sunflower meal is 31 and 15 per cent lower in leucine than SBM and RSM, respectively, and RSM is 22 and 15 per cent lower in isoleucine content than SBM and SFM, respectively. The valine and proline content of the three meals is not appreciably different (24, 76, 81).

The interrelationship between amino acid catabolism, branched-chain VFA production and the ensuing amino acid synthesis is well understood (2, 13, 19, 28, 29, 32, 53, 59), but results of dietary VFA additions are conflicting (25, 32, 38, 43, 58). In this study the VFA composition...
and concentration of the rumen liquor were determined in an attempt to demonstrate if a relationship between VFA production, growth and different dietary protein sources existed.

Leucine has been intensively studied regarding its relationship to the branched VFA's. Bladen et al. (14) demonstrated that Bacteriodes ruminocola produced isovaleric acid-1-C\textsubscript{14} from leucine-2-C\textsubscript{14}. Bryant and co-workers (2, 19, 20), in definitive in vitro techniques utilizing radioactive isovalerate (Ci\textsubscript{5}) and isobutyrate (Ci\textsubscript{4}), determined that strains of Ruminococcus flavifaciens and R. albus synthesized leucine in response to Ci\textsubscript{5} addition. Leucine biosynthesis occurred even in the presence of excess exogenous leucine, thereby indicating a microbial preference for Ci\textsubscript{5} as a growth factor. The addition of both Ci\textsubscript{4} and Ci\textsubscript{5} caused increased synthesis above the levels resulting from individual supplementation, indicating a distinct function of each acid. This work substantiated previous reports (28, 53) and clearly indicated Ci\textsubscript{5} to be essential for the growth of Ruminococcus bacteria.

Recent investigations have shown that rumen microbial protein, ammonia and total volatile fatty acid (VFA) production can be affected by the addition of small amounts of VFA's to the diet of sheep and calves.
Hemsley and Noir (38) established that added isobutyric (C\textsubscript{4}), valeric (C\textsubscript{5}) and isovaleric (C\textsubscript{5}) acids increased the microbial protein, total VFA and ammonia concentrations in sheep fed a urea-based diet.

Cline et al. in a later study (25) found that the additions of these same acids resulted in increased nitrogen digestibility and retention. Though not significant, the digestibility of cellulose and dry matter was also increased at the 3.5 per cent level of cellulose incorporation in the purified diet. When cellulose was raised to 59 per cent of the total diet dry matter, the acids had no effect upon any of the measurements. Miron et al. (59) also added VFA's to different diets and did not detect any difference over the control, unsupplemented ration. Their study, as opposed to other work, indicated that branched VFA addition had no value when included with natural feedstuffs.
Growth Trial

Forty-eight Holstein calves were randomly assigned at birth to three groups of sixteen calves with eight males and eight females per group. All calves were housed in individual outdoor hutches.

Each group received one of three experimental calf starters listed in Table 1, which differed only in source of protein supplement. The protein sources compared were solvent-processed RSM, SFM, and SBM, with each diet calculated to be isonitrogenous at a level of 16 per cent crude protein (CP).

Table 1. Composition of Experimental Calf Starters

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>RSMa</th>
<th>SFMb</th>
<th>SBMc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground shelled corn</td>
<td>91.6</td>
<td>105.2</td>
<td>105.2</td>
</tr>
<tr>
<td>Whole rolled oats</td>
<td>45.4</td>
<td>42.6</td>
<td>50.8</td>
</tr>
<tr>
<td>Beet pulp</td>
<td>17.2</td>
<td>14.1</td>
<td>17.2</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>5.7</td>
<td>5.9</td>
<td>5.7</td>
</tr>
<tr>
<td>Rapeseed meal, 32% CPd</td>
<td>59.0</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>Sunflower meal, 37% CPd</td>
<td>----</td>
<td>50.8</td>
<td>----</td>
</tr>
<tr>
<td>Soybean meal, 44% CPd</td>
<td>----</td>
<td>----</td>
<td>39.9</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>3.4</td>
<td>3.4</td>
<td>3.4</td>
</tr>
<tr>
<td>Trace mineralized salt</td>
<td>2.8</td>
<td>2.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Vitamin A (10^3 IU)</td>
<td>350.0</td>
<td>350.0</td>
<td>350.0</td>
</tr>
<tr>
<td>Vitamin D (10^3 IU)</td>
<td>55.0</td>
<td>55.0</td>
<td>55.0</td>
</tr>
<tr>
<td>Aureomycin® (10^3 mg)</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
</tr>
</tbody>
</table>

aRapeseed meal supplemented calf starter
bSunflower meal supplemented calf starter
cSoybean meal supplemented calf starter
dSolvent process, Cargill Inc., Minneapolis, Minnesota
eAurovet antibiotic, American Cyanamid, Princeton, New Jersey
Each calf received colostrum the first three days of life and thereafter was fed whole milk, supplemented with 50 milligrams antibiotic\textsuperscript{1}, up to a maximum of eight pounds daily. All calves were weaned at 68 kg body weight. Calf starter was limited to 1.81 kg per head daily with good quality chopped alfalfa-brome hay offered free-choice. Hay and grain consumption was measured daily throughout the entire 14-week trial period. Calves were weighed at birth, start of the trial, and weekly thereafter.

Rumen samples were taken by stomach tube at weaning, 10 and 14 weeks of age. Twenty-five ml aliquots were immediately mixed with 0.5 ml saturated mercuric chloride to stop bacterial action and the pH of the fluid determined with a conventional glass electrode pH meter. All samples were stored at -20°C for subsequent VFA analysis by gas chromatographic procedures as outlined by Baumgardt (8).

Feedstuffs were sampled every two weeks and composited every two months for proximate analysis by AOAC methods (5). The average chemical composition of the starters and hay is listed in Table 2.

\textsuperscript{1}Aureomycin 10D, American Cyanamid, Princeton, New Jersey
Table 2. Average Chemical Composition of Calf Starters and Hay

<table>
<thead>
<tr>
<th></th>
<th>DM Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crude DM</td>
</tr>
<tr>
<td>RSM starter</td>
<td>91.6</td>
</tr>
<tr>
<td>SFM starter</td>
<td>89.9</td>
</tr>
<tr>
<td>SBM starter</td>
<td>90.8</td>
</tr>
<tr>
<td>Alfalfa-brome hay</td>
<td>91.4</td>
</tr>
</tbody>
</table>

Digestion Trial

A modification of each starter was fed as the sole diet to one of three groups of four steers each in a total collection design digestion trial. The composition of each modified starter is given in Table 3. Twenty percent non-nutritive cellulose\(^1\) was added to each diet to prevent scouring. The diets were calculated to be isonitrogenous and isocaloric.

---

\(^1\)Solka Floc BW-20, Brown Co., 3166 Des Plaines Ave., Des Plaines, Illinois. 60018
Table 3. Composition of Digestion Trial Modified Starters

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>RSM\textsuperscript{a}</th>
<th>SFM\textsuperscript{b}</th>
<th>SBM\textsuperscript{c}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground shelled corn</td>
<td>68.9</td>
<td>83.9</td>
<td>77.8</td>
</tr>
<tr>
<td>Whole rolled oats</td>
<td>18.1</td>
<td>18.1</td>
<td>45.4</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>4.5</td>
<td>4.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Rapeseed meal, 32% CP\textsuperscript{d}</td>
<td>82.8</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Sunflower meal, 37% CP\textsuperscript{d}</td>
<td>--</td>
<td>67.8</td>
<td>--</td>
</tr>
<tr>
<td>Soybean meal, 44% CP\textsuperscript{d}</td>
<td>--</td>
<td>--</td>
<td>46.7</td>
</tr>
<tr>
<td>Solka Floe, BW-20\textsuperscript{e}</td>
<td>45.4</td>
<td>45.4</td>
<td>45.4</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>2.3</td>
<td>2.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Trace mineralized salt</td>
<td>2.3</td>
<td>2.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Vitamin A (100\textsuperscript{3} IU)</td>
<td>350.0</td>
<td>350.0</td>
<td>350.0</td>
</tr>
<tr>
<td>Vitamin D (100\textsuperscript{3} IU)</td>
<td>55.0</td>
<td>55.0</td>
<td>55.0</td>
</tr>
<tr>
<td>Aureomycin\textsuperscript{f} (100\textsuperscript{3} mg)</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Rapeseed meal supplemented calf starter
\textsuperscript{b}Sunflower meal supplemented calf starter
\textsuperscript{c}Soybean meal supplemented calf starter
\textsuperscript{d}Solvent process, Cargill Inc., Minneapolis, Minnesota
\textsuperscript{e}Solka Floe, BW-20, Brown Co., 3166 Des Plaines Ave., Des Plaines, Illinois
\textsuperscript{f}Aurovet antibiotic, American Cyanamid, Princeton, New Jersey

Each digestion trial was 19 days in length with 14 days as a preliminary period followed by a five day collection period as suggested by Hattan and Owen (36). Daily consumption of starter was measured and each feed was sampled for nitrogen and gross energy content. Feces and urine were collected separately and measured and sampled daily. The crude protein content of the feed, fresh feces and urine was determined according to AOAC methods (5). Energy values of the feed and feces were determined using a Parr adiabatic oxygen bomb calorimeter.
Forced-air oven drying (48 C for 48 hr) was used to determine the dry matter content of the feed and feces. All animals were weighed before and after the collection period to determine body weight changes.

During the collection period blood and rumen samples were taken on three days two hours post-feeding. Rumen ammonia and blood urea were determined by Conway micro-diffusion methods (26). The colorimetric procedure of Nathan and Rodkey (61) was used for blood ammonia determination.

Statistical analyses were conducted according to procedures described by Steel and Torrie (78). Significant differences among treatment means were determined using Duncan's new multiple range test (78).
RESULTS AND DISCUSSION

Growth Trial

The results of the feeding period are summarized in Table 4. Average daily gain from birth to 8 weeks and 8 to 14 weeks of age, as well as the total feeding period, was lowest for the RSM fed calves. The SFN and SBM fed calves were nearly equal in rate of gain throughout the entire 14-week period. The decreased rate of gain associated with the RSM diet closely approached significance \( P < .05 \) during both the 0 to 8 weeks and 0 to 14 weeks of age period.

As indicated by the rate of gain during the period of 8 to 14 weeks of age, the RSM fed calves gained at a respectable rate after the first 8 weeks. This was apparently due to an increased development of the rumen in its ability to digest grain and hay.

A decreased palatability of the RSM is indicated throughout the duration of the trial. Compared to SFN and SBM, daily RSM starter DM consumption during the 0 to 8 weeks of age period, and also the 8 to 14 weeks of age period, was significantly less \( P < .01 \) and \( P < .05 \), respectively). The decrease in palatability associated with RSM feeding is in agreement with most previous reports of RSM supplementation of rations (9, 16, 21, 44) and accounts for the decreased rate of gain of the RSM fed
Table 4. Birth Weight, Weaning Age, Gain/Day, Dry Matter Intake, and Feed Efficiency of Calves Fed One of Three Experimental Starters

<table>
<thead>
<tr>
<th>Diet</th>
<th>RSM&lt;sup&gt;a&lt;/sup&gt;</th>
<th>SFM&lt;sup&gt;b&lt;/sup&gt;</th>
<th>SSM&lt;sup&gt;c&lt;/sup&gt;</th>
<th>S&lt;sub&gt;y&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of animals</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>----</td>
</tr>
<tr>
<td>No. of days</td>
<td>98</td>
<td>98</td>
<td>98</td>
<td>----</td>
</tr>
<tr>
<td>Av. birth wt, kg</td>
<td>40.0&lt;sup&gt;e&lt;/sup&gt;</td>
<td>39.1&lt;sup&gt;f&lt;/sup&gt;</td>
<td>44.3&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1.54</td>
</tr>
<tr>
<td>Av. weaning age, days</td>
<td>54.2&lt;sup&gt;e&lt;/sup&gt;</td>
<td>53.8&lt;sup&gt;e&lt;/sup&gt;</td>
<td>45.9&lt;sup&gt;f&lt;/sup&gt;</td>
<td>2.37</td>
</tr>
<tr>
<td>Av. gain/day, kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-8 weeks of age</td>
<td>0.52</td>
<td>0.58</td>
<td>0.59</td>
<td>0.028</td>
</tr>
<tr>
<td>8-14 weeks of age</td>
<td>0.71</td>
<td>0.71</td>
<td>0.74</td>
<td>0.045</td>
</tr>
<tr>
<td>0-14 weeks of age</td>
<td>0.58</td>
<td>0.64</td>
<td>0.65</td>
<td>0.026</td>
</tr>
<tr>
<td>DM intake/day, kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-8 weeks of age</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk</td>
<td>0.43&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.43&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.37&lt;sup&gt;f&lt;/sup&gt;</td>
<td>0.013</td>
</tr>
<tr>
<td>Starter</td>
<td>0.31&lt;sup&gt;n&lt;/sup&gt;</td>
<td>0.52&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.58&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.063</td>
</tr>
<tr>
<td>Hay</td>
<td>0.32&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.22&lt;sup&gt;f&lt;/sup&gt;</td>
<td>0.31&lt;sup&gt;e&lt;/sup&gt;,&lt;sup&gt;f&lt;/sup&gt;</td>
<td>0.033</td>
</tr>
<tr>
<td>8-14 weeks of age</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starter</td>
<td>1.16&lt;sup&gt;f&lt;/sup&gt;</td>
<td>1.46&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1.53&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.019</td>
</tr>
<tr>
<td>Hay</td>
<td>1.57</td>
<td>1.38</td>
<td>1.52</td>
<td>0.033</td>
</tr>
<tr>
<td>Total, 0-14 weeks of age</td>
<td>1.79</td>
<td>1.88</td>
<td>1.97</td>
<td>0.031</td>
</tr>
<tr>
<td>Feed efficiency,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>kg DM intake/kg gain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-8 weeks of age</td>
<td>2.13</td>
<td>1.99</td>
<td>2.16</td>
<td>0.066</td>
</tr>
<tr>
<td>8-14 weeks of age</td>
<td>3.92&lt;sup&gt;n&lt;/sup&gt;</td>
<td>4.40</td>
<td>4.40</td>
<td>0.330</td>
</tr>
<tr>
<td>Total, 0-14 weeks of age</td>
<td>3.10</td>
<td>2.96</td>
<td>3.08</td>
<td>0.150</td>
</tr>
</tbody>
</table>

<sup>a</sup>Rapeseed meal supplemented calf starter  
<sup>b</sup>Sunflower meal supplemented calf starter  
<sup>c</sup>Soybean meal supplemented calf starter  
<sup>d</sup>Standard error of the mean  
<sup>e,f,g</sup>Values in the same row sharing a common superscript are not significantly different, using Duncan's new multiple range test (78).  
<sup>e,f,p < .05</sup>  
<sup>g,h,p < .01</sup>
calves. The use of SFM did not result in decreased palatability of the starter mixture, as there was no significant difference between the starter DM intake between the SFM and SBM fed calves.

Due to the procedure of weaning the calves as they reached 68 kg body weight and the lower average birth weight of the SFM group, the significance of the older weaning age of the calves in the SFM group compared to the SBM group is not considered meaningful. The weaning age data does indicate, however, that the use of RSM in the starter did affect a real difference in calf growth. Compared to the SBM fed calves, the RSM group had a slower early rate of gain which caused an extended milk feeding period even though average birth weights of both groups were not appreciably different.

The feed efficiencies for all groups did not differ significantly during any period of the trial. The difference between the SFM and SBM calves closely approached significance at the $P < .05$ level for the 0 to 8 weeks of age period. This may indicate a more efficient feed utilization for gain by the SFM fed group, but the increased milk feeding period of the SFM calves must also be considered. The SFM fed calves averaged 8 more days milk feeding than the SBM group, which added 0.42 kg DM daily from milk for each additional day. This would account for
some of the difference between the groups, as milk is higher in digestible energy than either starter or hay and would contribute to increased DM utilization for growth.

The feed efficiency of the RSM fed calves during the period of 8 to 14 weeks of age indicates that the calves were able to utilize the energy of the hay and grain very efficiently. The daily rates of gain for all groups were nearly equal during this period even though the RSM calves had a low daily DM intake.

Digestion Trial

The digestion trial diets were formulated to support the growth of a 150 kg steer, gaining at a rate of 0.80 kg per day with a daily DM intake of 2.5 kg/100 kg body wt as recommended by the National Research Council (62). The results of the trial are summarized in Tables 5 and 6.

A palatability problem with the RSM was again indicated, as per the feeding trial, by a significantly decreased (P < .01) average daily DM intake of the RSM modified starter compared to the SFM and SBM supplemented starters (Table 5).
Table 5. Daily Weight Change, Dry Matter Intake, and Digestion Coefficients of Dry Matter, Crude Protein and Energy of Steers Fed One of Three Digestion Trial Modified Starters

<table>
<thead>
<tr>
<th>Diet</th>
<th>RSM</th>
<th>SFM</th>
<th>SEM</th>
<th>S-d</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of animals</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>----</td>
</tr>
<tr>
<td>No. of days collection</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>----</td>
</tr>
<tr>
<td>Daily DM intake</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>kg/100 kg body wt</td>
<td>1.55&lt;sup&gt;h&lt;/sup&gt;</td>
<td>2.76&lt;sup&gt;g&lt;/sup&gt;</td>
<td>2.73&lt;sup&gt;g&lt;/sup&gt;</td>
<td>0.12</td>
</tr>
<tr>
<td>Av. wt at start, kg</td>
<td>143.8</td>
<td>137.1</td>
<td>159.8</td>
<td>----</td>
</tr>
<tr>
<td>Av. wt at end, kg</td>
<td>143.7</td>
<td>141.2</td>
<td>164.8</td>
<td>----</td>
</tr>
<tr>
<td>Daily wt change, kg</td>
<td>-0.02</td>
<td>0.82</td>
<td>1.00</td>
<td>----</td>
</tr>
<tr>
<td>Ration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross energy, Kcal/gm DM</td>
<td>4255.4</td>
<td>4188.8</td>
<td>4281.5</td>
<td>----</td>
</tr>
<tr>
<td>Crude protein, % DM</td>
<td>18.42</td>
<td>18.63</td>
<td>18.52</td>
<td>----</td>
</tr>
<tr>
<td>Coefficients of digestion, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>73.96&lt;sup&gt;e,f&lt;/sup&gt;</td>
<td>67.50&lt;sup&gt;f&lt;/sup&gt;</td>
<td>75.48&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2.28</td>
</tr>
<tr>
<td>Crude protein</td>
<td>79.38</td>
<td>81.54</td>
<td>81.72</td>
<td>1.74</td>
</tr>
<tr>
<td>Energy</td>
<td>74.35&lt;sup&gt;e,f&lt;/sup&gt;</td>
<td>67.24&lt;sup&gt;f&lt;/sup&gt;</td>
<td>75.46&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2.38</td>
</tr>
</tbody>
</table>

<sup>a</sup>Rapeseed meal supplemented digestion trial starter
<sup>b</sup>Sunflower meal supplemented digestion trial starter
<sup>c</sup>Soybean meal supplemented digestion trial starter
<sup>d</sup>Standard error of the mean
<sup>e,f,g,h</sup>Values in the same row sharing a common superscript are not significantly different, using Duncan's new multiple range test (78).
<sup>e,f<0.05</sup> g,h<0.01

Due to the lower feed intake, the RSM calves lost weight during the collection period, whereas the calves fed the SFM and SEM rations gained in body weight. Although the RSM fed group decreased in body weight, all calves were in positive nitrogen balance as indicated in Table 6.
There was no significant difference between the protein digestibility of each diet, although the daily nitrogen (N) intake was significantly lower \((P < .01)\) for the steers fed the RSM diet. It would be meaningful to determine the protein digestibility of RSM at a level of intake equal to the intake level of the SBM and SBN rations because digestibility is affected by amounts of DM and N intake. At low levels of N intake the protein is used more efficiently than at levels high enough to produce gain \((23, 42, 48, 60)\).

Sunflower meal had the lowest digestibility coefficient of DM (DDM) and energy (DE). In each instance it was significantly less \((P < .05)\) digestible than SBM but not significantly different than the RSM. There were no significant differences in DE and DDM between the RSM and SBM; however, the SBM was slightly more digestible in each case. Again, as with the protein digestion, it is important to have equal DM and protein intake of each starter when evaluating the DDM and DE content, as it is known that low N intake will cause decreased DM digestion \((7, 60)\).

The N utilization data is summarized in Table 6.
Table 6. Nitrogen Utilization of Steers Fed One of Three Digestion Trial Modified Starters

<table>
<thead>
<tr>
<th>diet</th>
<th>RSMa</th>
<th>SPMb</th>
<th>SBMc</th>
<th>SDd</th>
</tr>
</thead>
<tbody>
<tr>
<td>daily nitrogen intake g/100 kg body wt</td>
<td>45.68f</td>
<td>81.90e</td>
<td>76.79e</td>
<td>3.74</td>
</tr>
<tr>
<td>nitrogen digested, %</td>
<td>79.38</td>
<td>61.54</td>
<td>81.72</td>
<td>1.74</td>
</tr>
<tr>
<td>nitrogen retention, g/day</td>
<td>31.70f</td>
<td>62.00e</td>
<td>68.74e</td>
<td>4.12</td>
</tr>
<tr>
<td>nitrogen absorbed, %</td>
<td>47.97</td>
<td>55.03</td>
<td>54.71</td>
<td>4.84</td>
</tr>
<tr>
<td>rumen ammonia, mg/100 ml</td>
<td>18.95</td>
<td>17.30</td>
<td>23.54</td>
<td>3.86</td>
</tr>
<tr>
<td>blood urea, mg/100 ml</td>
<td>17.89f</td>
<td>14.71e</td>
<td>21.22e</td>
<td>0.57</td>
</tr>
<tr>
<td>blood ammonia, ug/ml</td>
<td>0.92f</td>
<td>1.84e</td>
<td>0.88f</td>
<td>0.086</td>
</tr>
</tbody>
</table>

a; Rapeseed meal supplemented digestion trial starter
b; Sunflower meal supplemented digestion trial starter
c; Soybean meal supplemented digestion trial starter
d; Standard error of the mean
e; f; e; Values in the same row sharing a common superscript are not significantly different P < .01, using Duncan's new multiple range test (78).

Due to the very low DM intake of the calves in the RSM group, the daily N intake/100 kg body weight was significantly lower (P < .01) compared to the SPM and SBM groups. The daily N intake of the SPM and SBM groups paralleled their respective daily ration DM intake, and no significant difference in N intake occurred.

Nitrogen absorption did not differ significantly, although the RSM fed calves were distinctly lower than the SPM and SBM groups. All calves were in positive nitrogen balance.
The lower rumen ammonia and blood urea values in the SFM fed group indicate that the SFM protein was less soluble than the protein in RSM and SBM. Rumen ammonia results when the rate of proteolysis and deamination are greater than the rate of microbial ammonia utilization. The ammonia not utilized is absorbed into the bloodstream through the rumen wall and transported to the liver where it is converted to urea (23). Blood urea is directly dependent upon the ammonia concentration of the diet and rapidly reflects changes in the ammonia pattern of the rumen (51, 70). Little et al. (52) and Chalupa et al. (23) investigated this relationship and determined that rumen ammonia formation is indicative of protein solubility in the rumen.

The rumen ammonia and blood urea values of the calves fed the RSM diet are somewhat higher than expected from the low amount of N intake, but this may be due to rapid rumen hydrolysis of the RSM protein. Another factor that may affect these values is the possibility of increased urea recycling to the rumen in the calves fed the RSM diet. When ruminants were maintained on a low N intake diet, the amount of N recycled as urea increased (23, 40, 42, 48, 56, 60, 66, 74). Holstein steer calves fed a diet that provided only 70 per cent of the N requirement conserved significant amounts of nitrogen by increased
salivary urea (40). The RSM fed calves in the present digestion trial were consuming 83 per cent of their daily N requirement.

Houpt (42) has demonstrated the direct transfer of endogenous blood urea into the rumen through the rumen wall in sheep fed a N deficient diet. Schmidt-Nielsen et al. (70) reported a urea conservation mechanism to be of primary importance to ruminants on low N intake. Their findings suggest that urea excretion is regulated by the amount of N intake and that when dietary N is low the amount of urea excreted is only a fraction of the amount cleared by the kidney.

Blood ammonia is directly affected by added dietary MPN, liver impairment, excitement and high environmental temperatures (69). None of these factors appear to be prominent in this study, and no explanation is given for the elevated blood ammonia values in the calves fed the SFM diet.

Rumen VFA Analysis

Table 7 summarizes the molar per cent and total composition of the rumen fluid volatile fatty acids obtained at weaning, 10 and 14 weeks of age, during the feeding trial. The VFA's measured were the following: acetic (C2), propionic (C3), isobutyric (C14), butyric (C4), isovaleric (C15), and valeric (C5).
Table 7. Rumen Volatile Fatty Acids and pH at Weaning, 10 and 14 Weeks of Age, of Calves Fed One of Three Experimental Starters

<table>
<thead>
<tr>
<th>Age</th>
<th>Starter</th>
<th>C2</th>
<th>C3</th>
<th>C14</th>
<th>C4</th>
<th>C15</th>
<th>C5</th>
<th>Total VFA</th>
<th>Rumen pH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Molar %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>um/ml</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weaning</td>
<td>RSM</td>
<td>64.745</td>
<td>23.50h</td>
<td>0.97</td>
<td>7.75</td>
<td>1.36</td>
<td>1.96</td>
<td>71.78</td>
<td>6.05</td>
</tr>
<tr>
<td></td>
<td>SFM</td>
<td>56.09h</td>
<td>33.485</td>
<td>0.87</td>
<td>6.19</td>
<td>0.91</td>
<td>1.69</td>
<td>64.10</td>
<td>5.98</td>
</tr>
<tr>
<td></td>
<td>SBM</td>
<td>61.33h</td>
<td>28.345</td>
<td>0.91</td>
<td>6.24</td>
<td>1.02</td>
<td>1.53</td>
<td>69.56</td>
<td>5.81</td>
</tr>
<tr>
<td></td>
<td>S&lt;sub&gt;x&lt;/sub&gt;</td>
<td>1.96</td>
<td>2.21</td>
<td>0.11</td>
<td>0.62</td>
<td>0.15</td>
<td>0.17</td>
<td>6.62</td>
<td>0.14</td>
</tr>
<tr>
<td>10 weeks</td>
<td>RSM</td>
<td>68.76e</td>
<td>17.68f</td>
<td>0.93</td>
<td>8.18</td>
<td>1.98</td>
<td>1.61</td>
<td>72.16</td>
<td>6.02</td>
</tr>
<tr>
<td></td>
<td>SFM</td>
<td>64.80f</td>
<td>21.41e</td>
<td>0.85</td>
<td>9.12</td>
<td>1.56</td>
<td>1.54</td>
<td>65.26</td>
<td>6.18</td>
</tr>
<tr>
<td></td>
<td>SBM</td>
<td>65.40e</td>
<td>22.28e</td>
<td>1.00</td>
<td>7.71</td>
<td>1.56</td>
<td>1.43</td>
<td>79.44</td>
<td>6.91</td>
</tr>
<tr>
<td></td>
<td>S&lt;sub&gt;x&lt;/sub&gt;</td>
<td>1.24</td>
<td>1.21</td>
<td>0.061</td>
<td>0.63</td>
<td>0.34</td>
<td>0.11</td>
<td>6.91</td>
<td>0.115</td>
</tr>
<tr>
<td>14 weeks</td>
<td>RSM</td>
<td>69.64</td>
<td>18.00</td>
<td>1.15£</td>
<td>7.43</td>
<td>1.76</td>
<td>1.42</td>
<td>73.27</td>
<td>6.32</td>
</tr>
<tr>
<td></td>
<td>SFM</td>
<td>66.84</td>
<td>19.03</td>
<td>1.05£</td>
<td>7.28</td>
<td>1.73</td>
<td>1.42</td>
<td>78.47</td>
<td>6.28</td>
</tr>
<tr>
<td></td>
<td>SBM</td>
<td>67.80</td>
<td>17.47</td>
<td>1.24£</td>
<td>7.74</td>
<td>2.19</td>
<td>1.38</td>
<td>66.51</td>
<td>6.33</td>
</tr>
<tr>
<td></td>
<td>S&lt;sub&gt;x&lt;/sub&gt;</td>
<td>1.13</td>
<td>1.63</td>
<td>0.066</td>
<td>0.51</td>
<td>0.21</td>
<td>0.10</td>
<td>6.78</td>
<td>0.062</td>
</tr>
</tbody>
</table>

<sup>a</sup>Rapeseed meal supplemented calf starter  
<sup>b</sup>Sunflower meal supplemented calf starter  
<sup>c</sup>Soybean meal supplemented calf starter  
<sup>d</sup>Standard error of the mean  
<sup>e</sup>,<sup>f</sup>,<sup>g</sup>Values in the same column within each age group sharing a common superscript are not significantly different, using Duncan's new multiple range test (73).  
<sup>e</sup>,<sup>f</sup>P < .05  
<sup>g</sup>,<sup>h</sup>P < .01
No direct relationship between $C_{14}$, $C_5$, and $C_{15}$ content of the rumen fluid, growth and protein source is apparent. The amounts of these acids present in the rumen fluid are very small; and, due to the diet being composed of several dietary sources of protein, the exact effect of the RSM, SFM and SEM cannot be determined.

The rumen fluid of the RSM fed calves had a significantly higher ($P < .01$) $C_2$ and significantly lower ($P < .01$) $C_3$ content at weaning than that from the SFM fed calves. This same trend was also apparent at 10 weeks of age, but the differences were not as great as at weaning. At 14 weeks of age no significant differences among treatments in $C_2$ and $C_3$ content of the rumen fluid were present. This trend toward smaller $C_2$ and $C_3$ rumen fluid differences with age is probably due to the increased early consumption of hay by the RSM fed calves. In the 0 to 8 week age period the RSM calves consumed significantly more hay and less starter ($P < .05$) than the SFM and SEM calves. The ratio of starter to hay DM intake for the RSM calves was near 1:1 during this period, whereas the starter to hay ratios for the SFM and SEM calves were 2.4:1 and 1.9:1, respectively. During the 8 to 14 week age period, the differences in starter to hay intake ratios were not as great. These ratios were 0.74, 1.06 and 1.01:1,
respectively, for the RSM, SFM and SBM fed groups. Hay and other roughages, compared to grain and concentrates, cause increased C2 and decreased C3 composition of the rumen fluid (47, 80).
SUMMARY AND CONCLUSIONS

Rapeseed (RSM), sunflower (SFM), and soybean (SBM) meals were evaluated as protein supplements in dairy calf starters. Forty-eight Holstein calves were randomly allotted at birth to three groups balanced for sex and fed one of three experimental starters for 14 weeks. The starters were isonitrogenous at 16 per cent crude protein. All calves received colostrum the first three days after birth and thereafter were fed 3.63 kg of whole milk/day until weaning at 68 kg body weight. Starter was limited to 1.81 kg/day and alfalfa-brome hay was fed free-choice. Rate of gain and feed intake data were summarized for three separate age periods: 0 to 8 weeks, 8 to 14 weeks, and 0 to 14 weeks of age. Rumen fluid samples of all calves were taken by stomach tube at weaning, 10 and 14 weeks of age, to determine if a relationship between rumen volatile fatty acids, calf growth and protein supplements existed.

Average daily rate of gain during the 0 to 8 weeks of age period was 0.52, 0.58 and 0.59 kg/day for the RSM, SFM and SBM fed groups, respectively. The lower rate of gain of the RSM fed calves approached significance at the P < .05 level. In the 8- to 14-week period the rates of gain were more nearly equal: 0.71 kg/day for the RSM
and SFM groups and 0.74 kg/day for the SBM fed group. The daily rates of gain for the 0 to 14 week period were 0.58, 0.64 and 0.65 kg/day for the RSM, SFM and SBM fed groups, respectively.

The SBM fed calves were weaned earlier (P < .05) than the other two groups, but the lower birth weight (P < .05) of the SFM calves accounted for their longer milk-feeding period. The older weaning age of the RSM fed calves, as compared to the SFM group, does indicate reduced growth attributed to the RSM calf starter.

Daily starter intake of the RSM fed calves was significantly lower (P < .05) for the 0 to 14 week period, indicating unpalatability of the RSM. Starter intakes of the SFM and SBM groups did not differ significantly during either period of the trial.

The RSM fed calves consumed significantly more (P < .05) hay during the 0 to 8 week period than the SFM group. During the 8 to 14 week period, hay consumption among groups did not differ significantly. No significant differences in feed efficiencies among groups were detected throughout the trial. The kg dry matter/kg gain for the 14 week period was 3.10, 2.96 and 3.08 for the RSM, SFM and SBM groups, respectively.

Volatile fatty acid analyses of the rumen fluid samples obtained at weaning, 10 and 14 weeks of age,
indicated no relationship between rumen volatile fatty acids, calf growth and protein supplements. The RSM fed calves had significantly higher C2 and lower C3 (P < .01) content of their rumen fluid at weaning, but these differences decreased with age. The higher roughage intake of the RSM group, especially during 0 to 8 weeks, accounts for the differences in C2 and C3.

An isocaloric and isonitrogenous modification of each starter was fed to three groups of 150 kg Holstein steers in a total collection design digestion trial. Non-nutritive cellulose was added to each starter at 20 percent of the diet to prevent scouring. Following a 14 day adjustment feeding period, feces and urine were collected for five days. Unpalatability of the RSM was again indicated, as the RSM fed calves consumed significantly less (P < .01) of the digestion starter than the SFM and SBM fed steers. As a result, the RSM fed calves lost an average of 0.02 kg body weight/day, whereas the SFM and SBM fed steers gained 0.90 and 1.00 kg/day, respectively.

Digestible protein content was not significantly different among starters: 79.38, 81.54 and 81.72 percent for the respective RSM, SFM and SBM diets. The coefficients of digestible dry matter (DDM) and energy (DE) of the SFM starter were significantly lower (P < .05) than the corresponding coefficients for the SBM starter: 67.50 and 67.24 vs 75.43 and 75.46 percent, respectively.
The DDM and DE coefficients of the RSM diet were 73.96 and 74.35 per cent, respectively, and were not significantly different than the SBM supplemented starter. No significant differences among treatments were detected in nitrogen absorption or rumen ammonia concentration. Rumen ammonia values were 17.30, 18.95, and 23.54 mg/100 ml for the SFM, RSM and SBM groups. Blood urea values were significantly different (P < .05) among all groups, averaging 21.22, 17.89 and 14.74 mg/100 ml for the SBM, RSM and SFM calves, respectively. The SFM fed calves had a significantly higher (P < .05) blood ammonia level: 1.84 mg/ml vs 0.92 and 0.88 mg/ml for the RSM and SBM groups.
LITERATURE CITED


