INVESTIGATION OF THE IMPORTANCE OF PROTEIN SOURCE AND PROTEIN LEVEL IN DAIRY CALF STARTERS

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ABSTRACT

INVESTIGATION OF THE IMPORTANCE OF PROTEIN SOURCE AND PROTEIN LEVEL IN DAIRY CALF STARTERS

by Delbert Kent Nelson

Seventy-two dairy calves were used to investigate the importance of protein source in calf starters at three different levels of crude protein.

All calves were removed from their dams and placed on experiment between two and four days of age. A stepwise weaning program was employed whereby each calf was weaned by three weeks of age and none received more than 125 pounds of milk. The experiment was conducted for 84 days.

All starter rations were pelleted and varied only with regard to level and source of protein.

Four 13% crude protein rations were fed in Experiment I. The various nitrogen sources of the respective rations were urea, soybean oil meal, fish meal and a combination of soybean oil meal and fish meal. Two levels of crude protein were fed in Experiment II. At 17.5% crude protein the main nitrogen sources were urea, soybean oil meal, and fish meal, and at 22% crude protein the main nitrogen sources were soybean oil meal and fish meal.

The evaluating criteria for Experiments I and II were daily gain, wither height increase, heart girth increase, milk consumption,

starter intake, and feed conversion. Analysis of variance of each criterion at each crude protein level showed no significant difference among the protein source groups.

Protein level effects were exposed by combining the data of the two experiments and performing analysis of variance on a factorial arrangement. This analysis indicated that daily gain, wither height, and feed conversion were improved by protein level, while heart girth, milk consumption, and starter intake were not.

Observations of blood composition of the calves in Experiment II show that at 17.5% crude protein urea caused significantly higher plasma urea nitrogen than did soybean oil meal or fish meal. Plasma protein levels were significantly greater for the fish meal group than for the soybean oil meal group.

A digestion trial was conducted in conjunction with Experiment II. Analysis of the data from three collection periods indicated that dry matter digestibility was significantly greater for the soybean oil meal than for the fish meal. Nitrogen digestibility significantly improved with crude protein level, while nonsignificant trends of greater dry matter digestibility, energy digestibility, and nitrogen retention were observed as crude protein level increased.

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INTRODUCTION

Raising dairy calves for herd replacements is one of the dairyman's most costly and time consuming operations, and feeding is the most expensive phase of this operation. In order to reduce the cost of feeding baby calves, dairymen have replaced milk in the diet with a less expensive milk substitute or removed milk from the calves' diet at an early age. Early weaning, however, places a hardship on the calf since the calf is dependent upon the milk for the quantity and quality of protein which it contains. In order to alleviate this hardship, calf starters containing high quality protein and having the optimum crude protein level may be needed in the diet of these young calves.

The primary purpose of these trials was to determine whether or not protein source was an important factor in calf starters fed to early weaned calves. Various protein levels were also examined in conjunction with protein source, since protein level and protein quality are not completely independent of each other.

REVIEW OF LITERATURE

Exact protein requirements of the dairy calf are complicated by the dynamic character of the calf's digestive development. At birth a calf is not actually a ruminant, for the rumen has developed little. Instead, its digestive process resembles that of the simple stomached animals and its protein requirements are similar to those of the dog or pig (Savage and McCay, 1942; Morrison, 1956).

From birth the calf undergoes a progressive transition from a simple stomached animal to a ruminant, and reaches the latter status at about one month of age (Lengemann *et al.*, 1959; Bryant and Small, 1960; Godfrey, 1961). This age is dependent, of course, upon the particular ration fed during the development period (Wardrop and Coombe, 1961; Church *et al.*, 1962).

Because of the lack of information about the protein level and protein quality requirement during the "simple stomached" and transitional stages, it is necessary to review experimental data concerning the protein requirements of the pig which may be applied to the very young calf.

Protein level values for growing swine are not completely applicable to the young calf. However, the work in this area should be briefly examined in order to lay the foundation for protein quality discussion.

Protein Levels for Growing Swine

Becker et al. (1963) has outlined the protein requirements for the pig at different stages of growth. Expressed as percent of the ration, these requirements are: suckling (5 to 30 pounds), 20%; weaned (10 to 30 pounds), 22%; grower (30 to 100 pounds), 16%; and finisher (100 to 200 pounds), 12%.

The recommendation of 22% for weaned pigs (10 to 30 pounds) is high compared to the results of Jensen et al. (1957) who found 17% crude protein to be the optimum for weaned pigs between the age of 14 to 56 days or 8 to 40 pounds. The work of Rutledge et al. (1961) also indicates that a lower crude protein level met the requirements of pigs between the age of 3 weeks and 8 weeks or 12 and 45 pounds. He found that a 16% ration supported growth as well as 20%, 24% or 28% crude protein rations.

Aunan et al. (1961), using a different approach, weaned pigs at 3 weeks and fed them a 20% crude protein ration up to 8 weeks of age (approximately 40 pounds). Hereafter they fed a 17% and a 15% crude protein ration until the pigs reached 120 to 130 pounds at which time they decreased the protein level to 15% and 11%, respectively. Gains and efficiencies between the groups were not significantly different. Using the same technique they compared 16%, 14% and 12% crude protein rations. The 12% ration was the only one that was inadequate up to 125 pounds of body weight. Thereafter, it yielded normal gains. This observation agrees with the recommendation for finishing swine by

Becker et al. (1963).

Abernathy et al. (1958), comparing the growth of pigs from 40 to 110 pounds, found faster gains resulted from feeding an 18% crude protein ration rather then a 14% ration. However, Kennington et al. (1958) found no difference between a 14% and a 20% crude protein ration fed to 30 pound pigs.

The results reviewed thus far indicate that the optimum crude protein level must be near 14% for the growing pig. The variation in performance of animals among experiments may be partially explained on the basis of protein quality. Unless the protein in the ration is of highest quality, or in other words contains the essential amino acids in the exact proportions, minimum requirements for protein cannot be established (Lucas and Lodge, 1961; Becker et al., 1963).

Protein Quality and Weanling Swine

Becker et al. (1954) clearly demonstrated the importance of protein quality by comparing a corn-soybean oil meal ration with a corn-menhaden fish meal ration. Both rations were fed to weaner pigs between 40 and 100 pounds. At 18% crude protein the rations were equal with regard to gain and feed conversion efficiency. But the minimum requirement of crude protein for satisfactory performance was 14% for the corn-soybean oil meal ration and 16% for the corn-fish meal ration. These results indicate that soybean meal is of higher quality than menhaden fish meal.

Using white fish rather than menhaden, Smith and Lucas (1957) found that a 15% ration supplemented with fish meal produced 13% more gain and was 14% more efficient than a 17% ration supplemented with extracted decorticated groundnut meal. Evans (1962a) reported that a 14.08% crude protein ration containing white fish meal was superior in gain and efficiency to a 12.35% crude protein ration containing extracted soybean oil meal. Additionally, extracted decorticated groundnut meal was found to be inferior to extracted soybean meal when both were added to approximately 12.5% crude protein rations. At 18% crude protein, white fish meal rations have proved to be superior in regard to nitrogen retention when compared to groundnut meal rations with supplemental lysine (Jones et al., 1960; 1962).

Kifer and Young (1961) fed corn-soybean oil meal rations containing 14%, 15% or 16% crude protein. At each level a portion of the soybean oil meal was replaced by menhaden fish meal. However, there were no significant differences between levels or sources. The author concludes that the 14% crude protein ration, with or without fish meal, was in excess of the pig's requirement.

Using very young weaners from 10 through 25 pounds, Blair (1961) fed rations supplemented with white fish meal or soybean oil meal at the crude protein levels of 28%, 23% and 18%. White fish meal supplementation at 23% crude protein significantly increased gains over the 18% fish meal and the 18% or 23% soybean oil meal rations. The 28% rations showed no superior performance over the 23% rations and in the case of soybean oil meal proved to be detrimental. A definite level-quality interaction is indicated here.

The results thus far are inconsistent and inconclusive, therefore a further look into protein quality or more specifically amino acid supplementation is necessary.

Amino Acid Supplementation of Weanling Swine Rations

Becker *et al*. (1963) states that corn plus fish meal or meat and bone scrap is less effective than corn plus soybean oil meal. However, additions of tryptophan to the former rations will yield gains superior to those of the corn-soybean oil meal rations. The results of work by Terrill *et al*. (1954) are in complete agreement with this. At an 18% crude protein level, corn supplemented with meat and bone scrap was inferior to corn supplemented with soybean oil meal, but superior in the case where 0.1% tryptophan was added to the meat and bone scrap. Similarly, Miner *et al*. (1955) reported no improvement in gain by adding fish solubles or tryptophan alone to a corn-cottonseed ration, but when these supplements were added in combination gains were significantly improved.

Henson *et al*. (1954) also found tryptophan to be limiting in corn-meat-by-product rations for growing swine, and postulated the requirement of tryptophan to be greater than 0.1% of the diet. In agreement with this Shelton *et al*. (1951b) had found that 0.2% DL-tryptophan gave a higher growth response than a ration containing 0.1% DL-tryptophan. The levels of 0.132% (Meade, 1956) and 0.137% tryptophan

(Meade and Teter, 1956) were both found to be adequate in 15.9% and 14.2% crude protein rations, respectively. Becker et al. (1954) determined that 0.13% tryptophan was adequate. Later Becker et al. (1955a) did an extensive study on the tryptophan requirement of the young pig and found it to be 0.115% in a diet containing 15.3% crude protein, and postulated this value to be very near the minimum requirement. This value is comparable to the recommendation for the rat, which is 0.11% tryptophan (Rama Rao et al., 1959).

Amino acid supplementation of a corn-tankage ration by Pfander and Tribble (1957) resulted in satisfactory gains from 0.11% tryptophan in the diet. However, superior performance resulted from adding a combination of amino acids to the diet. No response was obtained from separate additions of tryptophan, methionine or lysine. Similarly, Clawson and Matrone (1963) found no response from additions of tryptophan, lysine or isoleucine separately to an 8% crude protein corn-soybean oil meal ration, but the combination of all three significantly improved performance.

In contrast, Pfander and Tribble (1955), feeding a corn-soybean oil meal ration at 18%, 16% and 14% crude protein, found that L-lysine, DL-methionine or DL-tryptophan supplementation in any combination failed to yield gains equal to that of L-lysine additions alone. This indicates that lysine may be deficient in rations of this type. Agreeing with this, Chance et al. (1960) found lysine to be the most limiting amino acid in a 12% protein corn-soybean oil meal ration.

Yet Becker et al. (1963) claims that soybean oil meal is an outstanding source of supplementary amino acids for growing swine when fed with corn at a 16% crude protein level.

In agreement with both Chance et al. (1960) and Becker et al. (1963), Acker et al. (1959) found that 23 pound pigs responded to lysine supplementation when fed a 12% crude protein ration, but not when fed a 14% crude protein ration. This indicates that the 12% ration was lysine deficient, but the 14% ration was not. Catron et al. (1953) reported a similar response with pigs of the same age. Further information which indicates that lysine additions are important at low levels of crude protein, but not at high levels in corn-soybean oil meal rations, is provided by Pond et al. (1953) and Neilsen et al. (1959). Magruder et al. (1961) observed similar results when lysine was added to corn-cottonseed-dried whey rations. In this particular case a lysine supplemented 12.5% crude protein ration produced gains equal to an unsupplemented 14% crude protein ration and did it more efficiently. Lysine supplementation had previously been shown to improve corn-cottonseed rations (Miner et al., 1955).

Using wheat and barley, plus soybean oil meal, Bowland (1962) promoted gains by lysine supplementation of a 13% crude protein ration. These gains were equal to those produced by a 16% ration which had no additional lysine. Similarly, Jones et al. (1962) found that a 12% crude protein barley-groundnut meal ration, supplemented with 0.2% L-lysine monohydrochloride, produced gains equal to an 18%

crude protein ration without added lysine.

Schnarre and Tribble (1962), unlike the two previous groups, noticed a depression in gain of pigs from 30 to 125 pounds in body weight when 0.1% lysine was added to 20%, 16% and 12% crude protein corn-soybean oil meal rations. They blamed this depression on the already existing amino acid imbalance. Henson et al. (1954) noticed no beneficial result from additions of lysine to a 14.5% crude protein corn-meat-by-product ration. They concluded that the basal rations, which already contained as little as 0.63% lysine, were not deficient in this amino acid. The 0.63% level is higher than that recommended by Hutchinson et al. (1957) who found 0.52% lysine to be adequate for weaning pigs fed a 11.69% crude protein ration. Germann et al. (1958), feeding a 12.9% crude protein and a 13.4% crude protein ration to 6 week old pigs, found the minimum requirement of lysine to be near 0.6% of the diet or 4.7% of the protein portion. This is in close agreement with Becker et al. (1954) who noticed that 0.63% lysine in the diet or 4.5% in the protein supported growth of pigs between 40 and 100 pounds.

Satisfactory nitrogen retention was realized when Meade and Teter (1956) fed a 14.2% crude protein corn-soybean oil meal ration which contained 0.62% lysine. At a slightly higher crude protein level of 15.9%, 0.69% lysine appeared to be adequate (Meade, 1956). This is comparable with the recommendation of 0.70% to 0.90% lysine in a 16% crude protein ration for weaning pigs, by Mitchell et al. (1962).

Jones _et al._ (1962), feeding an 18% crude protein ration to weaners, obtained maximum gains and efficiency when lysine levels were near 1.0%. The lysine requirement, when expressed as percent of the ration, appears to increase as percent of crude protein increases (Pfander and Tribble, 1957). Further evidence of this is given by Chance _et al._ (1958). They found that the requirement of lysine increased from 0.7% at 10% and 15% crude protein to 0.9% at 20% crude protein. McWard _et al._ (1959), when feeding semi-purified diets to 30 pigs, concluded that the lysine requirement for a 12.78% and a 21.71% crude protein ration was 0.71% and 0.95% respectively. When expressed as a percent of the crude protein, the respective values were 5.55% and 4.38%. This agrees with Becker _et al._ (1963) who points out that the requirement of lysine in the protein decreases as the protein portion of the ration increases.

Some work has been done with lysine supplementation in combination with methionine. Brooks and Thomas (1959) noticed improved gains when lysine or lysine plus methionine was added to corn-peanut oil meal rations. Where 0.15% L-lysine had no affect on corn-soybean oil meal rations Pfander and Tribble (1953) improved gains and feed conversion efficiencies by adding 0.04% methionine with the lysine. Dyer _et al._ (1952) noticed the same effect when lysine and methionine were added to a corn-cottonseed ration while additions of L-lysine alone produced only satisfactory gains. Other experiments have shown the benefit from adding lysine and methionine in combination to low protein diets (Evans, 1961, 1962a).

In a detailed study, Evans (1960) provided evidence that lysine and methionine each have their optimum values for different stages of growth.

Berry *et al.* (1962), unlike the previous researchers, noticed no benefit when adding lysine and methionine to a low protein soybean oil meal supplemented diet. However, methionine additions alone proved to be very beneficial. Their only explanation was that methionine is the most limiting amino acid in soybean protein. Becker *et al.* (1963) agrees with this, but considers it to be only slightly lacking in corn-soybean oil meal rations. Benefits from methionine supplementation of a 16% crude protein corn-soybean oil meal ration have been observed by Long *et al.* (1962). As percent methionine increased, feed intake, gains, dry matter digestion and nitrogen digestion all showed significant improvement.

On the other hand, there is much work indicating little or no benefit from additions of methionine to corn-soybean oil meal rations at low crude protein levels (Catron *et al.*, 1953; Sewel and Keen, 1958; Acker *et al.*, 1959) or at high protein levels (Maner *et al.*, 1961). It has also failed to improve groundnut meal protein (Jones *et al.*, 1962; Jones *et al.*, 1960).

Using purified diets, Becker *et al.* (1955b) calculated the methionine-cystine requirement of a 12.6% crude protein ration to be 0.42% of the diet or 3.33% of the protein. Kroening *et al.* (1961)

also obtained maximum performance with these values at 12% protein. Feeding a 16% crude protein ration, Pfander and Tribble (1955) found that 3.5% methionine-cystine in the protein or 0.56% in the diet met the requirements of the weanling pig.

An unusually low level of 0.27% methionine in the diet satisfied requirements in a 15.9% crude protein corn-soybean oil meal ration (Meade, 1956). Becker et al. (1954) also found very low levels would satisfy the weaning pigs needs. These values were 0.23% of the diet or 1.65% of the protein. The only possible explanation for these last two low requirement values is that neither group considered the cystine content of the diet.

At the high level of 21% crude protein Shelton et al. (1951a) calculated the methionine-cystine requirement to be 0.6% of the diet. This high level is acceptable because the methionine requirement, when expressed as percent of the diet, increases with the crude protein percent (Lucas and Lodge, 1961).

One of the less popular but important amino acids is isoleucine. Meade and Teter (1956) found it to be limiting in a 12.1% crude protein corn-soybean oil meal ration. However, the same ration at 14.2% crude protein provided 0.63% isoleucine which satisfied requirements for ample nitrogen retention. This value closely agrees with the value of 0.60% given by Evans (1962b) which is a minimum level for maximum growth.

Studying two levels of protein, 13.35% and 26.7%, Becker et al. (1957) found isoleucine requirements to be 0.46% and 0.65% of the respective diets or 3.4% and 2.4% of the protein, respectively. This and other trials point out that the isoleusine requirement, when expressed as percent of the diet, increases with crude protein levels. But when expressed as percent of the protein, decreases as crude protein levels increase (McWard et al., 1959; Becker et al., 1963; Lucas and Lodge, 1961).

Importance of Protein Level in Ruminant Rations

Compared to the extensive and detailed studies of swine protein nutrition, the protein data for ruminants are very scarce. This is especially true for the immature ruminant (Morrison, 1956).

Brown et al. (1958) conducted a study with Jersey and Holstein calves during the period from two days of age to 86 days of age. Milk was fed at the rate of 8% of body weight for the first three weeks; thereafter it was fed at the rate of 6%, 5%, 3% and 2% for the fourth, fifth, sixth and seventh week, respectively. Starter intake was limited to four pounds for the Jerseys and five pounds for the Holsteins. Alfalfa-brome hay was fed ad libitum. All starters contained the same ingredients, with the protein concentrate varied in each to give the desired crude protein levels of 24.3%, 20.2%, 16.6% and 12.2%. There were no significant differences in average daily gain, increase in height or heart girth and starter intake. But with regard to efficiency, the 16.2% crude protein rations were superior to 24.3% or 20.2% crude protein rations. The digestibility data showed no significant differences in average daily nitrogen retention. However, nitrogen digestion was lowest for the 12.2% crude protein ration.

In a similar second trial they compared a wider range of crude protein levels. These were 23.7%, 20.0%, 16.2%, 13.0% and 8.5%. Results proved the 16.2% crude protein ration to be superior with regard to gain and efficiency, and the 8.5% ration was inferior with regard to the same criteria. The 8.5% crude protein ration also resulted in the reduced nitrogen retention and had the lowest crude protein digestion coefficient.

General observations of both digestion trials were that dry matter and crude protein digestion coefficients decreased with age, while nitrogen retentions increased.

Using the same hay and milk feeding practices of Brown et al. (1958), Everett et al. (1958) compared protein levels of 6.3%, 8.6%, 10.1%, 12.2% and 14.2%. Up to six weeks of age the protein percent of the rations had no effect, due to the amount of milk common to all diets. Hereafter, however, an increase in consumption, gain, and efficiency was noticed for each increase in protein content of the diet. Digestion data showed that crude protein digestibility increased with the protein content of the diet and that calves on the 14.2% crude protein ration retained significantly more nitrogen than those on the 6.3% crude protein ration.

More recently, Brown and Lassiter (1962) using Holstein and Guernsey calves compared 14%, 16% and 18% crude protein rations. In this trial milk was fed for 40 days to total 228 pounds for the Holsteins and 169 pounds for the Guernseys. Alfalfa hay was added to the grain ration and the entire mixture was pelleted. The results of growth studies indicated no difference in body weight gains, however, the 14% crude protein ration was more efficient than the other rations.

In the previously cited studies milk was fed during a major portion of the trials which probably influenced the amount of protein required in the grain ration.

Whitelaw et al. (1961a) removed some of the influence of milk by weaning their calves at three weeks of age. However, they did not begin their trial until the calves reached 11 weeks of age. The experiment lasted only 10 days, five of which the calves were on digestion trials. Using ten parts of corn-oats-ground barley-groundnut meal and one part dried hay, they formulated rations to contain 14.9%, 16.9%, 19.4% and 21.4% crude protein on a dry matter basis. These rations were fed at the rate of 8% of metabolic weight. Dry matter and nitrogen digestibility increased with increasing levels of dietary protein. In the nitrogen balance studies the 19.4% and the 21.6% crude protein rations yielded greater nitrogen retention than the 14.9% or 16.9% crude protein rations. When nitrogen retention was expressed as percent of dietary protein, there were no significant differences even though the values tended to be lowest at the higher levels of protein intake.

In a second trial 11.6%, 18.8%, 20.4% and 22.6% crude protein levels were compared. Again nitrogen retention was maximum for the two high groups, and digestibility of dry matter and nitrogen increased with protein level.

Data from both trials indicate the 20.4% or 19.4% crude protein on a dry matter basis is the minimum for maximum nitrogen retention. When 19.4% crude protein is converted to an air dry basis it becomes 16.3% crude protein, which agrees very closely with the minimum values given by the previous workers.

Results of protein research with sheep are comparable to the results given thus far for dairy calves. Hinds et al. (1961) found that a 11.6% crude protein ration produced better gains than did a 15.62% or 19.62% crude protein ration. However, this trial was conducted after lambs were weaned at nine weeks of age.

Jones and Hogue (1960) compared two protein levels for older lambs weighing about 70 pounds. The 11.2% digestible protein ration, on a dry matter basis, resulted in greater feed consumption and greater gains than the 8.4% digestible protein rations. Using ewe lambs from 70 to 100 pounds Griffith et al. (1959) found a 12.7% crude protein ration to be superior to a 10.9% crude protein ration and equally as effective as a 14.7% or 16.0% crude protein ration.

Recent research regarding protein level for mature ruminants is minimal. Lassiter et al. (1957) found that 10.3% or 11.9% crude protein met the requirements for the milk production, body weight and nitrogen retention of lactating dairy cows. Hale et al. (1959) found similar minimum values when an 11.5% crude protein ration yielded 15% more gain than an 8.6% crude protein ration fed to beef cattle.

Although there is some variation among experiments, the trend toward lower protein requirements as the ruminant developes is clearly displayed.

Protein Quality in Ruminant Rations

Where crude protein requirements are highest for young calves, protein quality requirements are also expected to be the greatest (Morrison, 1956).

Holter (1956) compared two 16% calf rations; one with soybean oil meal as the protein source and one with linseed oil meal, soybean oil meal, alfalfa meal, dried skimmilk, and dried distillers soluable as the protein source. No difference in gains of the calves fed the two rations was observed. The results may have been influenced by feeding 350 pounds of milk. Large amounts of milk were also fed by Lambert et al. (1955) and Hibbs et al. (1953) and neither group noticed any difference between a simple or complex starter.

Murley et al. (1958), however, limited milk feeding through 35 days of age and achieved no extra weight or height increase from feeding a complex starter.

Weaning the calves at 24 days of age, Pardue and Jacobson (1961) found no significant difference in daily gain, height or circumference when comparing 16.5% rations which contained either soybean oil meal or dried skim milk as the protein source. Pardue et al. (1962) in a similar trial replaced some of the soybean oil meal with dried skim milk, but no improvement of growth was noted. However, the dried skim milk ration did increase dry matter digestibility, but had no affect on digestible crude protein or digestible energy. It was also noticed that nitrogen retention for all groups was higher at 12 than at 8 weeks.

Preston et al. (1960) fed a milk replacer to calves until 20 days of age, and compared a corn-oats-groundnut meal ration to a corn-oats-groundnut meal-fish meal ration. In the simple ration the groundnut meal provided 50% of the total nitrogen, whereas, in the second ration 19% of the groundnut meal nitrogen was replaced by fish meal nitrogen. The groundnut plus fish meal ration was superior in efficiency and wither height increase.

Benefits from fish meal supplementation were also noted by Whitelaw et al. (1961b) when fed to six 80-day old calves in a 3 x 3 latin square design. The protein concentrates added to the corn-oats-grass meal ration were: groundnut meal, heated groundnut meal, and peruvian fish meal. All rations were near 16.5% crude protein. No difference in dry matter digestibility occurred, but the live weight gain and nitrogen retention were highest for the fish meal and poorest for the groundnut meal.

Variation in plant protein sources appears to have little effect upon the value of calf starters. Loosli et al. (1952), however, illustrated that differences exist in efficiency of utilization of plant protein concentrates when fed to dairy cows.

Brundage and Sweetman (1963) compared a commercial ration against a simple grain mix with plant and animal protein sources added. The former yielded more milk while the latter resulted in greater body weight gains.

Loosli (1956) found no difference in fat corrected milk production between rations containing either urea or corn distiller dried grains as a nitrogen source.

No significant differences in milk production or weight gains were noticed when Loosli et al. (1963) compared simple rations to progressively complex rations, or to rations in which urea made up a portion of the nitrogen.

Some work has been done with urea additions to calf starters. Reid (1953) claims that calves as young as two months of age can utilize some urea.

Loosli and McCay (1943) conducted some of the initial research with urea in calf rations. Whole milk was fed from birth to 2 months and then gradually decreased until 4 months when it was removed. The low ration diet was 4.4% crude protein. The high diet was the same ration with enough urea added to make a 16.2% crude protein equivalent ration. All calves gained at the same rate until 2 months of age. Hereafter, the low protein group gained at a decreasing rate and practically ceased to grow approximately two weeks after milk feeding ceased. On the other hand, at four months of age the calves on the urea ration were 75 to 90% of normal weight.

Brown et al. (1956) conducted a similar trial, but reduced milk feeding after 21 days and weaned all calves at 47 days of age. Two conventional rations were formulated; one at 6.7% crude protein and one at 15.2% crude protein. A second 15.2% crude protein ration was formulated such that 54.2% of the ration nitrogen was supplied by urea. There were no differences between the two 15.2% crude protein rations with regard to gain, height, circumference, feed efficiency, nitrogen retention, and coefficients for digestibility of dry matter or crude protein. The 6.7% crude protein ration was inferior in all the criteria mentioned.

In a more recent trial Brown et al. (1960) compared corn-oat-starch-urea rations which had crude protein equivalent levels of 6.5%, 9.4%, 12.1% and 15.3%. Milk was fed at the rate of 8% of body weight for the first three weeks and reduced two percentage points each week thereafter ceasing at 6 weeks of age.

All calves performed equally up to 3 weeks of age; thereafter gains, height, circumference and feed intake all increased with protein percent up to 12.1%. No significant difference existed between the 12.1% group and the 15.3% group. Generally, crude protein and dry matter digestion and nitrogen retention increased with crude protein percent.

Using growing Guernsey heifers which weighed more than 300 pounds, Campbell et al. (1963) found no difference in gain when urea replaced soybean oil meal in a corn-soybean oil meal-alfalfa meal ration.

The use of urea in mature ruminant feeding is a common practice. In some cases, methionine has been added to improve the quality of urea containing rations.

Noble et al. (1955) added methionine to 11% crude protein sheep ration which contained urea or soybean oil meal as the nitrogen source. The addition of methionine improved gains in both cases, however, these were significant in only the soybean oil meal group. Gallup et al. (1952) reported small nonsignificant improvement in nitrogen utilization when methionine was added to a urea containing ration fed to feeder lambs.

Feeding ewe lambs from 70 to 100 pounds in body weight Griffith et al. (1959) found that a 10.9% crude protein barley-oats-soybean oil meal ration was inadequate compared to 12.7%, 14.7% and 16.0% crude protein ration. However, it was superior to all when supplemented with DL-methionine. Contrary to this Hinds et al. (1961) observed no improvement from adding methionine to sheep rations. However, slight improvement in gain and efficiency was noticed when lysine was added in combination with methionine.

Gossett et al. (1962) observed no improvement in gain when adding lysine and methionine to protein supplements for beef steers, but improvements in efficiency were noticed. They also produced this same situation when 5 or 10 gm. of lysine per day were added to a 64% crude protein concentrate.

Feeding 10 gm. of L-lysine hydrochloride improved efficiency when Hale et al. (1959) added it to an 8.6% crude protein beef ration. However, when it was added to an 11.5% ration it improved both gains and efficiency.

Sherman et al. (1959) also added 900 gm. of L-lysine hydrochloride per ton to a corn-alfalfa meal urea ration for fattening lambs. The lysine supplemented group gained .43 lb. per day, while controls gained only .32 lb. per day.

Lysine addition, in some cases, have been shown to be of no benefit when added to sheep rations (Harbers et al., 1961; Meacham et al., 1961) or beef cattle rations (Kolari et al., 1961).

The Effect of Protein Nutrition on Blood Urea

There are several factors that effect the value of protein for ruminants other than quality. They are solubility, degree of denaturation, particle size, nitrogenous compounds, protein level, and digestibility. All except digestibility affect rumen ammonia production. The ammonia is absorbed into the portal system and converted to urea in the liver. This urea is partly returned to the rumen via the saliva (Lewis, 1957). Houpt (1959) has also shown that urea is returned to the rumen via diffusion. Lewis (1957) points out that wastage of nitrogen by these pathways is reflected by the urea level in the peripheral blood.

Lewis (1957) and Perkins (1960) have shown a high relationship between protein level and blood urea concentrations. Everett et al. (1958) observed that calves on a 14.2% and 12.2% crude protein ration had higher blood urea levels than did calves on a 6.3% crude protein ration.

Brown et al. (1956, 1960) noticed that additions of urea to rations in order to increase the nitrogen resulted in high blood urea concentrations.

Packett and Groves (1963) produced only moderate changes in blood urea when urea was added to the ration, but when ten to twenty grams of urea were placed in the rumen, a definite elevation in blood urea occurred.

At a constant protein level of about 16.5%, Whitelaw et al. (1961b) noticed lower blood urea levels as a result of using fish meal rather than groundnut meal as a protein supplement. The authors postulated that the fish meal was superior in amino acid balance or was less soluble than the groundnut meal. Nitrogen retention values were inversally related to blood urea levels, but the relationship was not significant.

Effect of Diet on Plasma or Serum Protein

In addition to blood urea, plasma or serum protein levels are expected to reflect the protein welfare of the non-ruminant. Longnecker and Hause (1959) demonstrated that plasma amino acid changes in the adult dog, after feeding, were directly dependent upon the amino acid composition of the diet. On the other hand, Perkins (1960) found no difference in blood total amino acid nitrogen between groups of dairy cattle fed high or low protein rations.

With regard to plasma protein, Brown *et al.* (1956) found no difference due to protein levels or nitrogen sources fed to dairy calves. Bedrak *et al.* (1957), however, noticed some trends in relationship between extremely low protein levels and serum protein values for hereford heifers.

Brown *et al.* (1958) while comparing ration that varied from 12.2% crude protein to 24.3% crude protein observed that the 12.2% crude protein group had the highest serum protein, even though it had the lowest digestion coefficients for crude protein.

Observing the chick, Leveille *et al.* (1960) noticed that serum protein levels were significantly depressed on low protein diets and that albumin levels followed the same trend. Similarly Wright *et al.* (1962) were able to lower or increase the plasma protein in ewes by dropping or raising the protein in the ration. These workers also noticed that this change was primarily due to albumin level changes.

Cahilly *et al.* (1963) were able to depress albumin levels by feeding a lysine deficient ration to swine. This is in agreement with other trials which increased albumin levels with additions of lysine (Cahilly *et al.*, 1960; Brooks *et al.*, 1961).

EXPERIMENTAL PROCEDURE

Assignment, Management, and Feeding

For this thesis two experiments were conducted. In Experiment I, thirty-two male and female Holstein calves from the Michigan State University and the Southern Michigan Prison dairy herds were divided into four groups of eight calves each. The calves were assigned to their respective groups by filling all groups simultaneously as calves became available over a ten week period.

Forty male and female Holstein calves from the University and Prison dairy herds and from surrounding dairy farms were used in Experiment II. The calves were divided into five groups of eight calves each. Three bull or steer calves from each of the five groups in Experiment II that were born on or near January 6, 1963 or on or near January 20, 1963 were designated to be used in digestion trials. This was done to facilitate the simultaneous procurement of digestion data from several calves of the same age with a limited number of digestion crates.

The remaining five calves per group in Experiment II were assigned to growth studies in such a manner that the average birth weight of the groups would be as nearly equal as possible. The last three of these five calves to be assigned were designated to be used for blood studies.

All calves in both experiments were separated from their dams between two and four days of age and placed on experiment where they remained for eighty-four days.

The calves were retained in individual free stalls, bedded with dry wood shavings.

Bucket milk feeding was begun twenty-four hours after the calf had been removed from the cow. Whole milk was fed at a rate of 9% of body weight the first week, 6% of body weight the second week, and 3% of body weight the third week. At the end of the third week each calf was weaned. All calves received less than 125 pounds of milk.

All starters were fed in the pelleted form from approximately 3 days of age. The calf feeder encouraged each calf to eat the pellets by placing a small amount in the calf's mouth after feeding milk. This was continued until pellet consumption became voluntary. Hereafter, the pellets were fed ad. lib. Water was available at all times.

Preparation and Composition of Rations

No hay was fed to the calves except that which was incorporated into the starter pellet. The following percentages of ingredients were common to all rations in both experiments: 20% ground alfalfa-brome hay, 45% ground shelled corn, 7.225% liquid cane molasses, 1.0% trace mineral salt, 1.0% dicalcium phosphate, 0.70% aurofac-2A, and 0.075% vitamin A and D supplement. The remaining 25% of each ration was made up of dried beet pulp and the main nitrogen source of the particular ration. These last two ingredients were blended so as to give the desired nitrogen level in each ration.

In Experiment I all rations were mixed to approximately 13% crude protein and varied only with regard to the main nitrogen source. The ration numbers and the respective nitrogen sources were: #36, urea; #37, soybean oil meal; #38, fish meal; and #39, fish meal and soybean oil meal. Soybean oil meal and fish meal supplied equal amounts of nitrogen in ration #39.

With regard to Experiment II, the rations varied in crude protein percent as well as nitrogen source. At approximately 17.5% crude protein, the ration numbers and the respective nitrogen sources were: #41, urea; #42, soybean oil meal; and #43, fish meal. At approximately 22%, the ration numbers and respective nitrogen sources were: #44, soybean oil meal; and #45, fish meal. The complete composition for all rations is given in Table 26 of the appendix. The proximate analysis of the rations are given in Table 27 of the appendix.

Procurement of Performance Data

In Experiment I growth was observed by measuring body weight, heart girth circumference, and wither height. These criteria were measured as each calf was placed on experiment and at weekly intervals thereafter. Daily milk and pellet consumption were also recorded.

The criteria for performance in Experiment II was the same as that observed in Experiment I. In addition to these, blood studies were conducted on three of the five animals in each group. The initial blood sample was taken from each calf at one week of experimental age, and the remaining samples were taken at two week intervals thereafter, up through eleven weeks of age.

Forty to fifty milliliters of blood were drawn from the jugular vein three to four hours after the morning feeding. The collection vials were heparinized prior to bleeding to prevent coagulation. The blood was centrifuged within one-half hour after collection at two-thousand rpm for twenty-five minutes.

The plasma was then aspirated from the centrifuged sample and frozen.

Another phase of Experiment II was to determine the digestible energy, digestible dry matter, digestible nitrogen, and the determination of retainable nitrogen of the five rations when fed to growing male Holstein calves.

Three male calves from each of the five groups were fed and raised in the same manner as all calves in Experiment II, up to five weeks of experimental age. At this time they were placed in digestion crates, where they remained for eight days. The first three days were used for an adjustment period, and fecal and urine collections were taken on the remaining five days.

Pellets were fed once daily. Orts were removed and weighed prior to each feeding. Composite samples of fresh pellets and orts were saved daily for later analysis.

Fecal collections were taken daily, weighed, and stored in large polyethylene containers. Thymol crystals were added to these storage vessels along with each fecal collection to prevent mold growth. At the end of the collection period, the accumulated collections were thoroughly mixed, and one composite sample was taken from each vessel. The wet samples were immediately analyzed for nitrogen. Energy was determined after the sample had been dried.

Urine was collected in polyethylene pails daily. Ten milliliters of concentrated hydrochloric acid and twenty milliliters of toluene were added to the empty pails before each daily collection commenced. Two percent of each daily urine excretion was saved and added to a composite sample bottle. These accumulated samples were retained in a refrigerator until the end of the five day collection period and were then immediately analyzed for nitrogen content.

After the collection period the calves were returned to the calf barn and cared for in the same manner as the other calves in the experiment. These same calves were returned to the digestion crates on the eighth week of experiment and again on the eleventh week of experiment. All practices were exactly the same in these two periods as in the first period, except for the adjustment period which was shortened from three to two days.

Analytical Procedures

All rations underwent proximate analysis according to procedures outlined in A.O.A.C. (1955). Dry matter of all rations, except for those pellets fed in the digestion trial, was determined by drying two gram samples for five hours at 100 degrees centigrade.

Blood plasma samples were analyzed for protein and urea nitrogen content. The frozen plasma samples were thawed overnight in a refrigerator and analyzed for protein by the following colorimetric technique developed by Lowry (1951). One milliliter of each plasma sample was diluted 400 times, and one milliliter of the diluted plasma was pipetted into a test tube. Five milliliters of alkaline copper solution were added to the diluted sample, and the contents of the test tube were immediately mixed and allowed to stand for ten minutes. The alkaline copper solution consisted of 1.0 milliliter of 2% sodium tartarate, 1.0 milliliter of 1% copper sulfate pentahydrate, and 100 milliliters of 2% sodium carbonate in 0.1 Normal sodium hydroxide. Folin Ciocalteu Phenol reagent (0.5 milliliter) was added to the test tube, and the contents were again thoroughly mixed. After standing for thirty minutes, the absorbance was read in a Beckman B-2 spectrophotometer at a wave length of 760 mu.

Versatol, a serum standard produced by General Diagnostics, was diluted to different concentrations and used as standards in protein determinations.

The plasma urea was determined by a colorimetric method developed by Brown (1959). One milliliter of each unknown plasma was mixed with 7.0 milliliters of water. Zinc sulfate heptahydrate (1.0 milliliter of a 10% solution) was added to the samples and thoroughly mixed. One milliliter of approximately 0.5 Normal sodium hydroxide was added and again the contents were immediately mixed. After standing for at least 15 minutes the mixtures were centrifuged at 2000 rpm for 25 minutes. A 2.0 milliliter aliquot of each filtrate was transferred to clean test tubes and 2 milliliters of p-dimethlaminobenzaldehyde-sulfuric acid color reagent were added and thoroughly mixed. After standing for 10 minutes the absorbance of the solutions was read at 440 mu in the Beckman spectrophotometer. Standard urea solutions were prepared by varying the concentration of reagent grade urea in distilled water.

With regard to the digestion trial, dry matter for the pellets and orts was determined by drying approximately 200 gram samples at 80 degrees centigrade for 72 hours. Fecal samples were dried for 96 hours at 80 degrees centigrade.

The nitrogen content of the urine, wet feces, and the dried pellets was determined by the improved Kjeldahl method as prescribed by A.O.A.C. (1955).

The energy values of the dried feces and the dried pellets were determined in a standard bomb calorimeter.

Statistical Treatment of the Data

The methods employed in statistical analysis of the data are those described by Snedecor (1956).

In Experiment I, beginning body weight, daily weight gain, increase in wither height, increase in heart girth, starter consumption, milk consumption and feed conversion were analyzed by single classification analysis of variance. Feed conversion or feed consumed per pound of gain and daily weight gain were also analyzed by covariance to adjust for differences in initial body weight.

The data of Experiment II were divided so that the protein quality could be analyzed at each protein level *per se*. The growth data were subjected to the same analyses employed in Experiment I.

Additionally, the growth data from both experiments were combined and analyzed so that any interactions or differences in protein level could be exposed. This attempt to examine protein levels may be somewhat misleading since performance differences between experiments might be due to environmental factors other than crude protein level *per se*.

Because of the unbalanced nature of the combined experiments it was necessary that the combined data be analyzed as two separate 2 x 3 factorial experiments. In one case the soybean oil meal and fish meal as nitrogen sources, were one factor, while 13%, 17.5% and 22% crude protein were the other factor. In the other case, 13% and 17.5% crude protein were one factor, and urea, soybean oil meal, and fish meal as nitrogen sources were the other factor. These factorial arrangements are diagrammed in Figure 1.

Increase in wither height, increase in chest circumference, starter intake, and milk consumption underwent analysis of variance, while feed conversion was analyzed by covariance to correct for variation due to differences in initial weight. Daily gain was adjusted by covariance for initial weight and starter intake.

The blood composition data of Experiment II were also analyzed as two separate experiments. First of all, the data from all calves on the 17.5% crude protein rations were analyzed as a 3 x 6 factorial design. The three nitrogen sources were one factor and the six different ages at bleeding were the other factor. Secondly, the data were analyzed as a 2 x 2 x 6 factorial to expose differences in composition due to nitrogen source, crude protein levels, or ages of bleeding. These arrangements are diagrammed in Figure 2.

The digestion data followed the same type of analysis, except that the three collecting ages replaced the six bleeding ages.

Wherever analysis of variance exposed a significant main effect or interaction, the means of these significantly different values were compared by The New Multiple Range Test developed by Duncan (1955).

Figure 1. Arrangement of the combined and factorialized starter groups for analysis of growth data

Combined

Source	13% C.P.	17.5% C.P.	22% C.P.
urea	#36	#41	-
soybean oil meal	#37	#42	#44
fish meal	#38	#43	#45

U, S, F x 13, 17.5 factorial

Source	13% C.P.	17.5% C.P.
urea	#36	#41
soybean oil meal	#37	#42
fish meal	#38	#43

S, F x 13, 17.5, 22 factorial

Source	13% C.P.	17.5% C.P.	22% C.P.
soybean oil meal	#37	#42	#44
fish meal	#38	#43	#45

Figure 2. Arrangement of the blood composition data for factorial analysis

U, S, F x age factorial at 17.5% C.P.

Protein source	Age (wks) 1	3	5	7	9	11
urea	#41	#41	#41	#41	#41	#41
soybean oil meal	#42	#42	#42	#42	#42	#42
fish meal	#43	#43	#43	#43	#43	#43

S, F x 17.5, 22 x age factorial

Protein source	Age (wks)	% C.P. 17.5	22
Soybean oil meal	1	#42	#44
	3	#42	#44
	5	#42	#44
	7	#42	#44
	9	#42	#44
	11	#42	#44
Fish meal	1	#43	#45
	3	#43	#45
	5	#43	#45
	7	#43	#45
	9	#43	#45
	11	#43	#45

RESULTS AND DISCUSSION

Experiment I

As mentioned in the introduction, the main purpose of this study was to determine the importance of protein source in calf starters. Urea, soybean oil meal, and fish meal were chosen not only because they are practical nitrogen sources, but also because they cover a wide range of protein quality. The term protein quality generally refers to the degree to which a feed stuff provides the proper level and balance of amino acids which are necessary in the diet for optimum maintenance and growth. Unfortunately, no essential amino acid requirements have ever been determined for dairy calves.

Using swine research as a guide for amino acid requirements, the literature shows that tryptophan, methionine-cyctine, lysine, and isoleucine are the amino acids most commonly deficient in the rations which mainly consist of corn. Since urea adds no amino acids to the ration it does not improve the protein quality of the basic corn ration. Soybean oil meal contains each of these critical amino acids, and thus improves the protein quality of the ration. Fish meal contains a greater quantity of these amino acids than does soybean oil meal and therefore should further improve protein quality (Pfander and Tribble, 1957).

The combination of fish meal and soybean meal is expected to provide the highest protein quality because of the wide spectrum of amino acids contained in the mixture.

The crude protein percent of the rations was to be set at the level where protein quality would have it's greatest effect. According to the research done by Brown et al. (1958), Everett et al. (1958), Brown and Lassiter (1962), and Whitelaw et al. (1961a), the optimum crude protein level for calf starters is near the range of 14% to 16%. In addition to this, the results of several swine studies indicated that lysine (Catron et al., 1953; Pond et al., 1953; Acker et al., 1959; Nielson et al., 1959; Chance et al., 1960; Magruder et al., 1961; Becker et al., 1963) and isoleucine (Meade and Teter, 1956) are generally limiting in low protein diets, but not in high protein diets. Additionally, Kifer and Young (1961) noticed no protein quality effect when protein was fed in excess of the pigs requirement. Therefore, if protein quality differences are to be exposed, it will probably be done at crude protein levels just below the calf's minimum protein requirement. With this background in mind the crude protein level of 13% was chosen for Experiment I.

The results of Experiment I expressed in Table 1 indicate no significant differences among groups with regard to growth rate or feed consumption, even though starter intake was highest for the urea group. Feed conversion improved from urea to soybean oil meal to fish meal, however these differences were not significant at the 5% level of probability.

Table 1. Effect of source of protein on mean growth, feed consumption, and feed conversion at the 13% crude protein level

	Starter Groups			
	urea	SBOM	fish meal	SBOM & fish meal
	36	37	38	39
Growth[a]				
Initial weight (lb.)	86.5	87.4	91.8	84.9
Daily gain (lb.)	1.08	1.02	1.05	1.09
Increase in height at withers (in.)	3.21	3.56	3.53	4.03
Increase in heart girth (in.)	7.63	7.16	7.06	7.84
Feed consumption[a]				
Milk (lb.)	109.9	110.9	117.6	106.8
Starter (lb.)	258	244	240	255
Feed conversion[a]				
(lb. feed/lb. gain)	2.92	2.85	2.74	2.82

[a]No significant differences among groups.

The failure of Experiment I to produce any significant performance differences may have been caused by an overall protein deficiency in all calves, which was brought about through a combination of early weaning and low crude protein level in the ration. It was suspected that the protein deficiency retarded normal growth to the extent of masking any effects resulting from differences in protein quality.

Experiment II

To avoid possible protein deficiencies in Experiment II, approximately 17.5% and 22% crude protein levels were used. As pointed out in the experimental procedure, the results of Experiment II were analyzed separately according to protein level.

Growth, feed consumption, and feed conversion results Table 2 contains the growth, feed consumption, and feed conversion data from Experiment II at the 17.5% crude protein level. The actual daily gain values were higher for the urea group than for the soybean oil meal or the fish meal groups. However these values as well as those corrected for initial body weight were not significantly different. There were no significant differences among groups for any of the remaining criteria, even though heart girth increase appeared to improve with protein quality and starter consumption responded inversely.

The data from the 22% crude protein level are shown in Table 3. Fish meal was superior to soybean oil meal with regard to daily gain, heart girth increase and feed conversion, but none of these or the other criteria were significantly different. The failure of protein source to affect gains in these experiments reflects the results obtained by Holter (1956), Lambert et al. (1955), Hibbs et al. (1953), Pardue and Jacobson (1961), Pardue et al. (1962), and Preston et al. (1960), all who found protein source not to be an important factor for improving body weight gains.

Table 2. Effect of source of protein on mean growth, feed consumption and feed conversion at the 17.5% crude protein level

	Starter Groups		
	urea 41	SBOM 42	fish meal 43
Growth[a]			
Initial weight (lb.)	93.6	90.0	90.4
Daily gain (lb.)	1.17	1.14	1.07
Increase in height at the withers (in.)	4.30	4.26	4.30
Increase in heart girth (in.)	7.20	7.40	7.80
Feed consumption[a]			
Milk (lb.)	123	117	119
Starter (lb.)	272	241	233
Feed conversion[a]			
(lb. feed/lb. gain)	2.83	2.52	2.61

[a]No significant differences among groups.

In order to examine the effect of protein level on calf performance, the factorial arrangements explained in the experimental procedure were employed.

Investigation of the average daily weight gains by an urea, soybean oil meal, fish meal X 13%, 17.5% factorial comparison (hereafter designated U, S, F x 13, 17.5 factorial) as shown in Table 4

Table 3. Effect of source of protein on mean growth, feed consumption and feed conversion at the 22% crude protein level

	Starter Groups	
	SBOM 44	fish meal 45
Growth[a]		
Initial weight (lb.)	90.4	93.2
Daily gain (lb.)	1.21	1.36
Increase in height at the withers (in.)	4.80	3.80
Increase in heart girth (in.)	8.30	9.30
Feed consumption[a]		
Milk (lb.)	113	121
Starter (lb.)	246	246
Feed conversion[a]		
(lb. feed/lb. gain)	2.44	2.16

[a]No significant differences among groups.

shows no significant differences among sources, levels, or interaction when the actual data are used. However, when the data are analyzed by covariance to adjust for starter intake an interaction does exist, where fish meal at the 17.5% crude protein level is superior to urea at 13% and 17.5% crude protein. Body weight gains adjusted for starter intake, however, is merely an expression of feed conversion and should not be confused with actual weight gains.

Table 4. Mean daily weight gains at 13% and 17.5% crude protein

Nitrogen source[a]	% Crude protein 13[b]	% Crude protein 17.5[b]	average
	Actual(adjusted)[d]	Actual(adjusted)[d]	Actual(adj)[c]
	(lb.)		
Urea	1.08(0.98)[d]	1.17(0.99)[d]	1.11(1.03)
Soybean oil meal	1.02(1.06)	1.14(1.11)	1.07(1.10)
Fish meal	1.04(1.05)	1.07(1.15)[d]	1.06(1.11)
Average	1.05	1.13	

[a]No significant difference among groups.

[b]Approximate.

[c]Adjusted for starter intake.

[d]1.15 is significantly greater than 0.98 and 0.99 ($P<0.05$).

Analysis of covariance to adjust for initial body weight exposed no significant differences in weight gain, therefore the mean gain values were not adjusted.

The soybean oil meal, fish meal x 13%, 17.5%, 22% factorial (hereafter called the S, F x 13, 17.5, 22 factorial) comparison of average daily weight gains is shown in Table 5. The analysis of the actual data and the data adjusted for differences in initial body weight shows that the 22% crude protein level was significantly superior ($P<0.05$) to the 13% crude protein level. When the data

Table 5. Mean daily weight gains at 13%, 17.5%, and 22% crude protein

Nitrogen source[a]	% Crude protein 13[b]	17.5[b]	22[b]	average
	(lb.)			
Soybean oil meal	1.02	1.14	1.21	1.11
Fish meal	1.05	1.07	1.36	1.14
Average(actual)	1.03[B]	1.11[AB]	1.29[A]	
Average(adjusted)[c]	1.03**	1.14**	1.27**	
Average(adjusted)[d]	1.04[B]	1.12[AB]	1.27[A]	

[a]No significant differences among groups.

[b]Approximate.

[c]Adjusted for starter intake.

[d]Adjusted for initial weight.

**Significantly different ($P<0.01$).
Values with the same large superscript represent a homogeneous group ($P<0.05$).

are adjusted for starter intake the crude protein levels are all significantly different ($P<0.01$); the daily gains improving with each level of crude protein. Here again the intake corrected values simply reflect efficiency. The difference in gain due to protein source was not significant for the actual data. This confirms the results obtained earlier in the analysis of each crude protein level for differences in sources.

The results of this S, F x 13, 17.5, 22 factorial comparison do not agree with results obtained by Brown and Lassiter (1952) and the first trial conducted by Brown et al. (1958). In both cases these workers noticed no effect of protein level on body weight gains. Additionally, in a second trial, Brown et al. (1958) found that a 16.2% crude protein ration was superior to 20.0% and 23.7% crude protein rations. One possible explanation that can be given for the difference in results is that milk was fed through the seventh week by Brown et al. (1958), and their calves were not as dependent upon the protein in the ration during the fourth, fifth, sixth, and seventh week. The calves in this trial were weaned at three weeks of age and were solely dependent on the pellet rations hereafter, in which case the high protein rations would be of greater value to the calves. Brown et al. (1958) also point out that calves fed the 16.2% crude protein ration consumed more starter than the other groups, and the 16.2% ration had what they considered to be an optimum protein-energy ratio.

Investigation of the increase in wither height with a U, S, F x 13, 17.5 factorial comparison, as shown in Table 6, indicates a highly significant advantage of the 17.5% crude protein level over the 13% crude protein level.

This protein level effect on wither height in Table 6 was repeated in the S, F x 13, 17.5, 22 factorial comparison, as can be seen in Table 7. However, it was not significant in this factorial.

Table 6. Mean increase in wither height (in.) at 13% and 17.5% crude protein

Nitrogen source[a]	% Crude protein 13[b]	17.5[b]	average
	(lb.)		
Urea	3.21	4.30	3.25
Soybean oil meal	3.56	4.26	3.91
Fish meal	3.53	4.30	3.91
Average	3.43**	4.29**	

[a]No significant difference among groups.

[b]Approximate.

**Significantly different ($P<0.01$).

Table 7. Average increase in wither height (in.) at 13%, 17.5%, and 22% crude protein

Nitrogen source[a]	% Crude protein 13[b]	17.5[b]	22[b]	average
	(lb.)			
Soybean oil meal	3.56	4.26	4.80	4.21
Fish meal	3.53	4.30	3.80	3.88
Average	3.55	4.28	4.30	

[a]No significant difference among groups.

[b]Approximate.

There was no protein source effect in either factorial investigation of wither height.

When increase in heart girth, milk consumption and starter intake data were analyzed by the two factorial comparisons, no significant differences among crude protein levels were exposed. These average values are shown in Table 8.

Table 8. Average values for increase in heart girth, milk consumption, and starter intake for each crude protein level

Criteria	% Crude protein		
	13	17.5	22
Increase in heart girth (in.)[a]	7.3	7.4	8.8
Milk consumption (lb.)[a]	112	119	117
Starter intake (lb.)[a]	247	249	246

[a]No significant differences among groups.

The last criteria of growth performance to be considered is feed conversion, which was measured as pounds of starter consumed per pound of gain. The U, S, F x 13, 17.5 factorial arrangement exposed no significant differences among actual values or values adjusted for initial body weight. However, the efficiency appeared to improve with protein quality and with protein level as can be seen in Table 9.

Table 9. Mean feed conversion (lb. of starter per lb. of gain) at 13% and 17.5% crude protein

Nitrogen source[a]	% Crude protein[a] 13[b]	17.5[b]	average
	(lb.)		
Urea	2.92	2.83	2.89
Soybean oil meal	2.85	2.52	2.73
Fish meal	2.74	2.61	2.69
Average	2.84	2.66	

[a]No significant difference among groups.

[b]Approximate.

Similarly the S, F x 13, 17.5, 22 factorial analysis showed an insignificant improvement in efficiency as protein quality increased (Table 10). A significant improvement in efficiency occurred with each increase in crude protein level. Both actual values and values corrected for initial body weight followed the same trend, however, the corrected values were all significantly different at the 1.0 percent level.

Here again, the efficiency results like the daily gain results disagree with the observation of Brown et al. (1958) and Brown and Lassiter (1962), but since gain and efficiency are highly related this would be expected, and the reasons given for the differences in gain would apply to the differences observed in efficiency.

Table 10. Mean feed conversion (lb. starter per lb. gain) at 13%, 17.5% and 22% crude protein

Nitrogen source[a]	% Crude protein 13[b]	17.5[b]	22[b]	average
	(lb.)			
Soybean oil meal	2.85	2.52	2.44	2.65
Fish meal	2.74	2.61	2.16	2.54
Average(actual)	2.80^{Aa}	2.56^{Ba}	2.30^{b}	
Average(adjusted)[c]	2.79**	2.56**	2.32**	

[a]No significant differences among groups.

[b]Approximate.

[c]Adjusted covariance for initial body weight.

**Significantly different ($P < 0.01$).
Values with the same large subscript represent a homogeneous group ($P < 0.05$).
Mean with the same small subscript represent a homogeneous group ($P < 0.01$).

Digestion trial results The statistical approach used to analyze the digestibility data are those outlined in the experimental procedure and diagrammed in Figure 2.

The statistical analysis of the coefficients of apparent digestibility of dry matter at 17.5% crude protein using the urea, soybean oil meal, fish meal by age factorial (hereafter denoted by U, S, F x age factorial) exposed a nonsignificant increase in apparent dry matter digestibility at each successive age (Table 11).

Table 11. Mean coefficients of apparent dry matter digestibility at 17.5% crude protein

Nitrogen source[b]	Age (wks.)[b] 5	8	11	average
	(%)			
Urea	72.63	76.72	76.66	75.34
Soybean oil meal	78.47	76.49	81.89	78.95
Fish meal	72.54	74.44	77.80	74.93
Average	74.54	75.88	78.78	

[a]Approximate.

[b]No significant differences among groups.

The soybean oil meal, fish meal by 17.5%, 22% by age factorial (hereafter referred to as the S, F x 17.5, 22 x age factorial) analysis, of the apparent dry matter digestibility coefficients, also exhibits an insignificant increase in value for each age (Table 12). In all cases, the apparent dry matter digestibility coefficient was greater for the soybean oil meal source than for the fish meal source. When the protein levels were combined, this difference was significant at the 5% level.

The coefficients of apparent digestibility of energy followed the same pattern as the apparent dry matter digestibility coefficients, with the values increasing with age and with protein percent. Here

Table 12. Mean coefficients of apparent digestibility of dry matter at 17.5% and 22% crude protein

Nitrogen source	% Crude protein[a] 17.5[b] Age(wks)		Average	22[b] Age(wks)		Average	Average
		(%)					
Soybean oil meal	5	78.47		5	78.92		
	8	76.49	78.95	8	80.74	79.53	79.26*
	11	81.89		11	79.05		
Fish meal	5	72.54		5	76.46		
	8	74.44	74.93	8	78.15	77.88	76.87*
	11	77.80		11	79.02		
Average			76.94			78.72	

Age Averages

Age(wks.)[a] 5	8	11
76.60	77.45	79.44

[a]No significant difference among groups.

[b]Approximate.

*Significantly different ($P<0.05$).

also, the soybean oil meal source had the highest apparent energy digestibility coefficient. These values are shown in Tables 13 and 14, and as indicated none are statistically significant.

Table 13. Mean coefficients of apparent digestibility of energy at 17.5%[a] crude protein

Nitrogen source[b]	Age(wks)[b] 5	8	11	average
	(%)			
Urea	69.46	73.81	73.90	72.39
Soybean oil meal	75.97	73.96	79.80	76.58
Fish meal	71.46	72.14	76.96	73.52
Average	72.29	73.30	76.89	

[a]Approximate.

[b]No significant differences among groups ($P < 0.05$).

Nitrogen digestibility of all rations significantly increased with each successive age (Table 15 and 16). In contrast Brown et al. (1958) found that crude protein digestibility coefficients decreased with age, but this was probably due to the reduction of milk feeding as their trial progressed. The 22% crude protein level had a significantly ($P < 0.05$) higher nitrogen digestibility coefficient than did the 17.5% crude protein level. This confirms the results

Table 14. Mean coefficients of apparent digestibility of energy at 17.5% and 22% crude protein

Nitrogen source	% Crude protein[a] 17.5[b] Age(wks)		Average	22[b] Age(wks)		Average	Average
		(%)					
Soybean oil meal	5	75.97		5	76.61		
	8	73.96	76.58	8	78.65	77.46	77.02
	11	79.80		11	77.12		
Fish meal	5	71.46		5	75.07		
	8	72.14	73.52	8	77.65	77.04	75.28
	11	76.96		11	78.40		
Average			75.05			77.25	

Age Averages

Age(wks.)[a] 5	8	11
74.78	75.60	78.07

[a]No significant differences among groups ($P < 0.05$).

[b]Approximate.

Table 15. Mean nitrogen digestibility coefficients at 17.5%[a] crude protein

Nitrogen source[b]	Age(wks) 5	8	11	average
	(%)			
Urea	62.60	73.43	74.96	70.33
Soybean oil meal	70.26	71.96	78.95	73.72
Fish meal	59.49	65.44	75.20	66.71
Average	64.11^{Bb}	70.27^{Bab}	76.14^{Aa}	

[a]Approximate.

[b]No significant difference among groups ($P<0.05$).

Values with the same large superscript represent a homogeneous group ($P<0.05$).

Values with the same small superscript represent a homogeneous group ($P<0.01$).

obtained by Brown et al. (1958), Everett et al. (1958), Whitelaw et al. (1961a) and Brown et al. (1960), all who noticed that nitrogen digestibility increased with the protein content of the diet. Again the digestibility coefficients were the greatest for the soybean oil meal ration in both factorials, however, these values were not significantly greater.

In order that the nitrogen welfare of the groups might be studied more thoroughly, retainable nitrogen was expressed as a percent of nitrogen intake. Data in Table 17 indicate that calves

Table 16. Mean nitrogen digestibility coefficients at 17.5% and 22% crude protein

Nitrogen source[b]	% Crude protein						Average
	17.5[a]			22[a]			
	Age(wks)		Average	Age(wks)		Average	
	(%)						
Soybean oil meal	5	70.26		5	73.36		
	8	71.96	73.72	8	79.90	77.53	75.63
	11	78.95		11	79.33		
Fish meal	5	59.49		5	67.51		
	8	65.44	66.71	8	76.33	74.15	70.43
	11	75.20		11	78.61		
Average			70.22^{B}			75.84^{A}	

Age Averages		
Age(wks.)		
5	8	11
67.66^{B}	73.40^{AB}	78.02^{A}

[a] Approximate.

[b] No significant difference among groups.

Values with the same large superscript represent a homogeneous group ($P<0.05$).

Table 17. Mean nitrogen retention as percent of nitrogen intake at 17.5% crude protein

Nitrogen source	Age(wks)[b] 5	8	11	average
	(%)			
Urea	17.77	34.09	31.92	27.93[Aab]
Soybean oil meal	16.68	18.22	19.40	18.10[Bb]
Fish meal	24.45	28.59	35.95	29.66[Aa]
Average	19.63	26.97	29.09	

[a]Approximate.

[b]No significant differences among groups ($P < 0.05$).

Values with the same large superscript represent a homogeneous group ($P < 0.05$).

Values with the same small superscript represent a homogeneous group ($P < 0.01$).

on the soybean oil meal ration retained significantly less nitrogen than those on urea ($P < 0.05$) and less than those on fish meal ($P < 0.01$). These results seem unusual since calves fed the soybean oil meal ration had the highest nitrogen digestibility coefficients. However, the dry matter intake during collection averaged over the three ages, for the urea, soybean oil meal, and fish meal groups were 1,714 gm, 1,060 gm and 1,277 gm, respectively. Whether this difference in intake is of the magnitude to affect the digestibility and the retainibility of the nitrogen is questionable. The effect of dry matter intake on nitrogen digestibility has been reported by Kumta and Harper (1962).

Table 18 shows the S, F x 17.5, 22 period factorial where level and source effect were rendered insignificant due to a source level interaction. Calves fed the 17.5% crude protein ration containing fish meal and the 22% crude protein ration containing soybean oil meal retained significantly more nitrogen than those fed the 17.5% crude protein ration containing soybean oil meal ($P < 0.01$).

Another method used to express retained nitrogen was grams of nitrogen retained per day per hundred pounds of body weight. These values are given in Tables 19 and 20, and show the same pattern as the percent nitrogen retained values. Here again, at the 17.5% crude protein level, the value for soybean oil meal was significantly ($P < 0.01$) less than for urea or fish meal. Similarly, this value was less than the 22% crude protein soybean oil meal value ($P < 0.01$) or the 22% crude protein fish meal value ($P < 0.05$). In addition the 22% crude protein fish meal group retained significantly less ($P < 0.01$) nitrogen than the 22% soybean oil meal group.

If the daily dry matter intake values listed in Table 21 are examined, the relationship between nitrogen retention and dry matter intake is easily recognized. Computation of the correlation coefficient of dry matter and percent nitrogen retained using individual observations and disregarding quality, quantity, and age effects gives a coefficient of 0.75.

Table 18. Mean nitrogen retention as percent of nitrogen intake at 17.5% and 22% crude protein

Nitrogen source$_a$	% Crude protein$_a$ 17.5$_b$ Age(wks)		Average	22$_b$ Age(wks)		Average	Average
	(%)						
	5	16.68		5	30.22		
Soybean oil meal	8	18.22	18.10[b]	8	32.56	30.13[a]	24.12
	11	19.40		11	27.60		
	5	24.45		5	16.33		
Fish meal	8	28.59	29.66[a]	8	29.08	22.47[ab]	26.07
	11	35.95		11	22.00		
Average			23.88			26.30	

Age Averages

Age (wks.)$_a$ 5	8	11
21.92	27.12	26.24

[a]No significant difference among groups ($P<0.05$).

[b]Approximate.

Values with the same small subscript represent a homogeneous group ($P<0.05$).

Table 19. Mean grams of nitrogen retained per day per hundred pounds of body weight at 17.5%$_a$ crude protein

Nitrogen source	Age(wks)$_b$ 5	8	11	average
	(gm)			
Urea	5.81	13.28	11.56	10.21[a]
Soybean oil meal	4.53	4.13	4.38	4.35[b]
Fish meal	7.31	8.71	11.51	9.18[a]
Average	5.88	8.71	9.15	

[a]Approximate.

[b]No significant differences among groups.
Values with the same small subscript represent a homogeneous group (P<0.01).

Since this high relationship did exist, percent nitrogen retention was analyzed with covariance to correct for differences in dry matter intake. As a result, none of the significant differences in nitrogen retention in Table 18 remained. Whitelaw *et al.* (1961b) overcame the intake effect by controlling consumption. With this accomplished they noticed an improvement in nitrogen retention when fish meal was included in the ration. Visual observation of the data indicates no relationship between average nitrogen retention and average daily gain of the groups, although both gain and nitrogen retention generally increased as the crude protein percent increased.

Table 20. Mean grams of nitrogen retained per day per hundred pounds of body weight at 17.5% and 22% crude protein

Nitrogen source[a]	% Crude protein[a] 17.5[b] Age(wks)		Average	22[b] Age(wks)		Average	Average
		(gm)					
	5	4.53		5	11.66		
Soybean oil meal	8	4.13	4.35[Bc]	8	13.17	12.04[Aa]	8.19
	11	4.38		11	11.29		
	5	7.31		5	4.69		
Fish meal	8	8.71	9.18[Aab]	8	10.50	7.66[Abc]	8.42
	11	11.51		11	7.78		
Average			6.76			9.85	

Age Averages

Age(wks.)[a] 5	8	11
7.05	9.13	8.74

[a]No significant differences among groups.

[b]Approximate.

Values with the same large superscript represent a homogeneous group ($P < 0.05$).

Values with the same small superscript represent a homogeneous group ($P < 0.01$).

Table 21. Average grams of dry matter consumed per day during collection

Nitrogen source	% Crude protein 17	22
	(gm)	
Soybean oil meal	1,060	1,365
Fish meal	1,277	1,105

Blood plasma studies Whitelaw et al. (1961b) observed an insignificant yet inverse relationship between nitrogen retention and blood urea levels. This was not the case in this experiment since calves fed the 22% crude protein ration containing soybean oil meal had the highest plasma urea nitrogen level as well as the highest nitrogen retention values (Table 22). The only explanation that can be given for the high level of plasma urea nitrogen produced by the soybean oil meal ration at 17.5% crude protein is that solubility and the high nitrogen level of this starter acted together to produce large amounts of rumen ammonia, which after absorption were converted to blood urea in the liver.

Like Lewis (1957), Brown et al. (1960), Perkins (1960), and Everett et al. (1958), a relationship between protein level and plasma urea was observed. However, these urea nitrogen values were not significantly different among levels.

Table 22. Mean plasma urea nitrogen (mg %) at 17.5% and 22% crude protein

Nitrogen source[a]	% Crude protein[a]						Average
	17.5[b]			22[b]			
	Age(wks)		Average	Age(wks)		Average	
	(mg %)						
Soybean oil meal	1	15.8		1	12.7		
	3	8.5		3	10.1		
	5	6.3		5	12.0		
	7	6.7	8.42[b]	7	14.0	13.19[a]	10.80
	9	7.1		9	13.0		
	11	6.0		11	17.2		
Fish meal	1	11.0		1	9.0		
	3	9.1		3	9.1		
	5	10.4		5	5.5		
	7	6.1	7.94[b]	7	9.1	8.43[b]	8.18
	9	4.4		9	10.6		
	11	6.6		11	9.0		
Average			8.18			10.81	

Age Averages

Age(wks.)[a]					
1	3	5	7	9	11
12.15	9.36	8.56	8.23	8.87	9.80

[a]No significant differences among groups.

[b]Approximate.

Values with the same small superscript represent a homogeneous group ($P<0.01$).

The urea rations produced a significantly ($P < 0.01$) greater plasma urea nitrogen level than the soybean oil meal or the fish meal rations at the 17.5% crude protein level (Table 23). This would be expected since the urea in the rations would be readily converted to rumen ammonia. This same phenomenon was also observed by Brown et al. (1956, 1960) who fed rations containing urea, and by Packett and Groves (1963), who added urea to the rumen directly. There was no significant change in plasma urea nitrogen values with regard to age, however both factorials indicate that the urea concentration generally decreased with age, which might suggest the possibility of an increasing number of ammonia utilizing bacteria in the rumen as the calves matured.

The other blood component analyzed was plasma protein. At 17.5% crude protein, the soybean oil meal ration produced significantly lower ($P < 0.05$) plasma protein levels than did the fish meal ration, while the urea ration value was not different from either of the two (Table 24). Similarly, calves fed the soybean oil meal ration at 17.5% crude protein had significantly lower plasma protein values than calves fed the soybean oil meal ration at 22% ($P < 0.01$) or the fish meal ration at 17.5% ($P < 0.05$) crude protein (Table 25). The low plasma protein level of these calves can hardly be blamed on protein quality since calves fed the 17.5% urea ration, which had the lowest protein quality, had higher plasma protein levels. Additionally, calves fed the 22% soybean oil meal ration had the highest

Table 23. Mean plasma urea nitrogen (mg %) at 17.5%[a] crude protein

Age(wks)[a]	Urea	Soybean oil meal	Fish meal	Average
	Nitrogen source			
	(mg %)			
1	11.2	15.8	11.0	12.68
3	14.0	8.5	9.1	10.56
5	13.8	6.3	10.4	10.18
7	12.3	6.7	6.1	8.40
9	13.9	7.1	4.4	8.48
11	12.3	6.0	6.6	8.29
Average	12.9[a]	8.42[b]	7.94[b]	

[a]Approximate.

[b]No significant differences among groups.

Values with the same small superscript represent a homogeneous group ($P < 0.01$).

plasma protein levels. Protein level cannot be considered as the cause since the fish meal groups had a nonsignificant, but higher plasma protein value at 17.5% crude protein than at 22% crude protein. The results reported in the literature are also inconclusive. Brown *et al.* (1956, 1958) found no relationship between the nitrogen level in the ration and the serum protein level in calves, while Bedrack *et al.* (1957) working with hereford heifers, and Wright *et al.* (1962)

Table 24. Mean plasma protein (grams %) of calves fed 17.5%[a] crude protein rations

Age(wks)[b]	Nitrogen source: Urea	Soybean oil meal	Fish meal	Average
	(gm %)			
1	6.22	6.11	6.84	6.39
3	6.47	5.36	5.44	5.76
5	6.07	4.90	6.40	5.80
7	6.04	5.74	6.22	6.01
9	5.42	5.76	5.93	5.71
11	6.11	6.12	6.29	6.18
Average	6.06[AB]	5.67[B]	6.20[A]	

[a]Approximate.

[b]No significant difference among groups.
Values with the same large superscript represent a homogeneous group ($P < 0.05$).

working with ewes, both reported a relationship between protein level in the ration and plasma or serum protein levels.

With regard to age, the first bleeding date, which took place at one week of age, gave the highest plasma protein value, however, this was only significant in the S, F x 17.5, 22 x age factorial. This high value would be expected since the calves were receiving the most milk during this period.

Table 25. Mean plasma protein (grams %) at 17.5% and 22% crude protein

Nitrogen source[a]	% Crude protein[a]: 17.5[b] Age(wks)		Average	22[b] Age(wks)		Average	Average
		(gm %)					
Soybean oil meal	1	6.11		1	7.65		
	3	5.36		3	6.18		
	5	4.90		5	6.40		
	7	5.74	5.67^{Bb}	7	6.41	6.53^{Aa}	6.10
	9	5.76		9	6.39		
	11	6.12		11	6.13		
Fish meal	1	6.84		1	5.44		
	3	5.44		3	6.13		
	5	6.40		5	5.80		
	7	6.22	6.20^{Aab}	7	6.38	6.15^{Aab}	6.17
	9	5.93		9	6.22		
	11	6.29		11	6.07		
Average		5.93			6.34		

Age Averages

Age(wks.) 1	3	5	7	9	11
6.72^{A}	5.79^{B}	5.88^{B}	6.19^{B}	6.08^{B}	6.16^{B}

[a] No significant differences among groups.

[b] Approximate.

Values with the same large superscript represent a homogeneous group ($P<0.05$).

Values with the same small superscript represent a homogeneous group ($P<0.01$).

The overall examination of this study gives rise to two possible conclusions. First of all the failure of the different nitrogen sources to significantly affect the growth of the calves in these experiments may not be out-of-order. There is a possibility that all rations had an amino acid imbalance. As indicated earlier in the thesis the protein sources were chosen on the basis of quantity of tryptophan, methionine-cystine, lysine, and isoleucine and not on the basis of balance of these critical amino acids. If the amino acid supplementation research with swine is applicable to dairy calves, it is probable that lysine was deficient in the urea and soybean oil meal rations at the 13% crude protein level (Pond et al., 1953; Neilsen et al., 1959; Catron et al., 1953), while methionine was deficient in all soybean oil meal rations (Berry et al., 1962) and tryptophan was lacking in all fish meal rations (Becker et al., 1963; Miner et al., 1955). Noble et al. (1955), Gallup et al. (1952), Hinds et al. (1961), Gossett et al. (1962), Hale et al. (1959), and Sherman et al. (1959) have all produced beneficial results by supplementing ruminant rations with amino acids. Amino acid supplementation of calf starters of the type used here might result in performance approaching that of calves reared on high milk feeding programs. However performance of this type may not be necessary.

The second conclusion that can be drawn is that the starters fed in these trials could not have been lacking protein quality to any great degree, since growth and feed conversion were satisfactory for all groups. It is surprising to see that the calves on the urea rations performed as well as the calves on the soybean oil meal or the fish meal rations at both 13 and 17.5 percent crude protein levels. This study definitely indicates that satisfactory performance can be attained where urea provides a major source of nitrogen in calf starters. Urea supplied 25 percent of the nitrogen in the 13% crude protein ration and 41 percent of the nitrogen in the 17.5% crude protein ration. Brown et al. (1956) also attained satisfactory growth by feeding calf starters in which 54.2 percent of the nitrogen was provided by urea.

A side note on starter intake seems to be in order. Since it was not initially intended to make a detailed study of intake and its impact on performance, this criteria was not pursued to a greater extent. However, this study implies that the palatability of the ration, which in turn affects intake, may be equally as important as protein level or protein quality.

SUMMARY

Seventy-two holstein male and female calves, which were two to four days old, were used in two experiments to determine effect of protein source and protein level on the growth rate and metabolism of young, early weaned dairy calves. All calves were weaned at three weeks and none received more than 125 pounds of milk.

In the first experiment, four groups of eight calves each were assigned to a 13% crude protein pelleted ration which varied in protein (or protein equivalent) source only. No significant differences were observed in growth rate, feed consumption, or feed conversion of calves receiving either urea, soybean oil meal, fish meal, or soybean oil meal-fish meal mixture as a protein source.

Forty calves were used in growth and metabolism studies in the second experiment where starters contained urea, soybean oil meal and fish meal at the 17.5% crude protein level and soybean oil meal and fish meal at the 22% crude protein level. The data of this experiment were analyzed at each crude protein level, and in addition were combined with the data of the first experiment so that a factorial arrangement exposing protein level effects could be employed. Protein quality had no significant affect on growth rate, feed consumption, or feed conversion. The combined data showed that 17.5% crude protein significantly improved daily gain, wither height, and feed conversion over 13% crude protein, and 22% crude protein was

superior to both 13% and 17.5% with regard to daily gain and feed conversion.

Results of the digestion trial in Experiment II indicate that soybean oil meal significantly improved apparent dry matter digestibility over fish meal. Protein source had no apparent effect on nitrogen retention. Apparent nitrogen digestibility was significantly greater for the 22% crude protein level than for the 17.5% crude protein level. The same, but nonsignificant trends, also existed for the apparent dry matter and energy digestibilities and nitrogen retention.

The coefficients of digestion for nitrogen increased with age, while nitrogen retention followed no trends.

The blood composition study in Experiment II indicated that at 17.5% crude protein plasma urea nitrogen was significantly greater for calves fed the urea ration.

There was also a trend toward more satisfactory growth and metabolism response at the higher levels of starter intake.

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APPENDIX

Table 26. Composition of calf starters

Ingredient	#36	#37	#38	#39	#41	#42	#43	#44	#45
	(%)								
Ground shelled corn	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
Ground alfalfa	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Molasses	7.225	7.225	7.225	7.225	7.225	7.225	7.225	7.225	7.225
Beet pulp	23.75	16.45	18.45	17.45	22.35	9.05	11.70	-	3.85
Urea	1.25	-	-	-	2.65	-	-	-	-
Soybean oil meal	-	8.55	-	3.35	-	15.95	-	-	-
Fish meal	-	-	6.55	4.20	-	-	13.3	-	21.5
Dicalcium phosphate	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
TM salt	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Table 26. (Continued)

Ingredient	#36	#37	#38	#39	#41	#42	#43	#44	#45
	(%)								
Vit. A & D supplement[a]	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075
Aurofac 2-A[b]	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70

[a]10,000 I.U. vitamin A and 500 I.U. vitamin D per gram.

[b]Provided 15 mg of chlortetracycline per pound of feed.

Table 27. Proximate analysis of calf starters

Starter	% Expressed as air dry basis						D.M. basis
	Ash	Crude fiber	Ether extract	Water	Protein	N-Free extract	Protein
#36	5.40	12.31	2.08	12.08	12.88	55.25	14.64
#37	5.89	11.03	2.17	11.73	12.81	56.37	14.51
#38	6.22	12.16	3.00	12.27	12.81	53.54	14.60
#39	6.03	11.54	2.63	13.10	12.56	54.23	14.43
#41	5.54	11.10	2.53	10.82	17.75	52.26	19.90
#42	5.56	8.70	2.82	10.43	17.88	54.61	19.96
#43	7.43	8.75	3.92	10.32	17.56	52.02	19.58
#44	5.89	6.80	2.57	10.19	22.13	52.42	24.64
#45	7.97	7.39	5.24	9.99	21.69	47.72	24.09

Table 28. Growth performance criteria of calves in Experiment I and Experiment II

Starter no.	Calf no.	Initial weight	Total gain	Increase height	Increase heart girth	Feed consumption milk	Feed consumption starter	Feed consumed (lb.) per gain (lb.)
		(lb)	(lb)	(in)	(in)	(lb)	(lb)	(lb)
36	743	74	97	2.75	8.50	90.3	267.5	2.76
"	206	79	82	2.50	8.25	99.4	255.4	3.11
"	1	97	114	2.75	8.00	130.9	296.4	2.62
"	210A	86	94	4.00	8.25	108.5	255.9	2.62
"	11	87	117	3.75	9.00	109.2	293.7	2.51
"	263	97	63	2.75	6.50	118.3	222.5	3.53
"	4138	90	109	4.75	9.00	116.4	303.7	2.79
"	7	82	48	2.50	3.50	106.4	167.5	3.45
37	647A	86	68	3.00	7.00	110.5	182.0	2.68
"	742	86	64	3.50	5.00	107.1	199.2	3.11
"	3	96	93	3.50	7.50	124.6	281.3	3.02
"	2	79	91	3.75	8.25	97.3	272.8	2.99

Table 28. (Continued)

Starter no.	Calf no.	Initial weight	Total gain	Increase height	Increase heart girth	Feed consumption milk	Feed consumption starter	Feed consumed (lb.) per gain (lb.)
		(lb)	(lb)	(in)	(in)	(lb)	(lb)	(lb)
37	4130	91	101	4.00	8.00	115.5	236.2	2.36
"	740	87	77	3.25	7.50	109.2	234.1	3.04
"	10	88	112	4.50	8.00	115.5	314.2	2.81
"	746	86	81	3.00	6.00	107.1	228.9	2.83
38	627B	89	85	5.25	9.00	116.9	233.1	2.74
"	158B	99	93	2.50	7.75	123.2	266.0	2.86
"	4132	76	78	3.50	9.00	95.9	224.9	2.88
"	4	106	66	2.50	4.50	138.6	152.7	2.31
"	5	100	140	3.00	11.75	127.4	362.2	2.59
"	8	100	96	3.50	6.00	128.1	254.5	2.65
"	9	88	86	5.50	6.00	113.4	253.7	2.95
"	676A	76	58	2.50	2.50	97.3	170.6	2.94

Table 28. (Continued)

Starter no.	Calf no.	Initial weight	Total gain	Increase height	Increase heart girth	Feed consumption milk	Feed consumption starter	Feed consumed (lb.) per gain (lb.)
		(lb)	(lb)	(in)	(in)	(lb)	(lb)	(lb)
39	264	74	82	4.00	9.50	95.2	207.0	2.52
"	4133	82	64	3.00	7.00	105.0	189.4	2.96
"	6	97	127	5.50	11.00	123.9	333.5	2.63
"	13	102	93	3.50	6.00	130.9	303.0	3.26
"	744	98	114	5.50	9.00	123.2	309.3	2.71
"	745	75	79	3.00	6.00	95.2	201.4	2.55
"	747	76	118	5.25	9.50	85.8	311.5	2.64
"	741	74	56	2.25	4.75	95.2	186.9	3.34
41	275	82	104	5.00	8.00	109.2	258.5	2.49
"	754	90	100	4.00	9.00	110.0	261.7	2.62
"	4225	96	90	4.00	6.00	139.3	280.5	3.12
"	4227	114	66	3.00	5.00	141.4	224.8	3.41

Table 28. (Continued)

Starter no.	Calf no.	Initial weight	Total gain	Increase height	Increase heart girth	Feed consumption milk	Feed consumption starter	Feed consumed (lb.) per gain (lb.)
		(lb)	(lb)	(in)	(in)	(lb)	(lb)	(lb)
41	643C	86	133	5.50	8.00	117.6	335.2	2.52
42	4226	104	122	5.00	11.00	134.5	290.5	2.38
"	276	92	67	3.00	4.50	126.5	169.9	2.54
"	214A	82	109	4.80	8.50	108.8	282.6	2.59
"	756	82	83	4.50	5.00	104.3	216.0	2.60
"	278	90	97	4.00	8.00	113.1	244.4	2.52
43	4203	109	105	2.50	9.00	138.6	230.2	2.19
"	274	72	94	5.00	9.00	108.5	236.7	2.82
"	755	94	80	5.00	5.00	121.1	224.2	2.80
"	279	88	89	4.00	7.00	116.9	238.8	2.68
"	282	89	91	5.00	9.00	109.9	234.2	2.57
44	283	85	102	6.50	8.50	104.3	244.2	2.39

Table 28. (Continued)

Starter no.	Calf no.	Initial weight	Total gain	Increase height	Increase heart girth	Feed consumption milk	Feed consumption starter	Feed consumed (lb.) per gain (lb.)
		(lb)	(lb)	(in)	(in)	(lb)	(lb)	(lb)
44	4197	106	134	6.50	9.00	135.1	307.0	2.29
"	177B	85	111	4.00	11.00	107.1	246.2	2.22
"	280	94	71	4.00	6.00	116.9	203.6	2.87
"	758	82	94	3.00	7.00	101.7	230.3	2.45
45	4208	94	126	4.50	11.50	121.8	262.5	2.08
"	205A	94	98	5.00	9.00	123.9	209.3	2.14
"	281	84	107	3.50	10.00	108.5	235.2	2.20
"	220A	87	135	4.00	9.00	111.3	304.8	2.26
"	204A	107	103	2.00	7.00	140.0	218.2	2.12

Table 29. Apparent coefficients of digestion and nitrogen retention values

Starter no.	Calf no.	pd.	Coefficients			Nitrogen retention	
			Dry matter	Energy	Nitrogen	% of N intake	Gms. per day per 100 lb. B.W.
41	640A	1	72.50	68.90	56.92	17.40	5.99
"	"	2	74.82	72.17	71.76	34.26	15.16
"	"	3	76.63	73.51	75.13	34.94	13.88
"	659B	1	74.26	70.35	64.99	26.61	9.35
"	"	2	75.63	72.03	73.27	30.82	10.85
"	"	3	76.29	73.51	76.26	31.39	10.68
"	698A	1	71.13	69.12	65.86	9.30	2.09
"	"	2	79.72	77.22	75.25	37.21	13.82
"	"	3	77.05	74.69	73.49	29.42	10.11
42	4220	1	78.28	75.92	70.31	8.57	1.64
"	"	2	77.12	74.78	75.52	21.28	4.31
"	"	3	82.28	80.10	79.51	4.27	0.76

Table 29. (Continued)

Starter no.	Calf no.	pd.	Coefficients			Nitrogen retention	
			Dry matter	Energy	Nitrogen	% of N intake	Gms. per day per 100 lb. B.W.
42	166A	1	80.19	77.55	72.31	33.70	10.49
"	"	2	76.86	73.97	73.41	19.24	4.78
"	"	3	83.27	81.49	81.23	23.71	6.26
"	1	1	76.95	74.44	68.16	7.76	1.46
"	"	2	75.49	73.12	66.94	14.15	3.31
"	"	3	80.10	77.81	76.10	30.23	6.12
43	4222	1	72.99	71.41	57.46	18.73	4.28
"	"	2	82.62	77.12	70.89	27.30	6.37
"	"	3	79.25	78.95	76.63	37.89	11.74
"	4238	1	79.77	78.76	69.81	33.89	9.31
"	"	2	79.45	78.78	73.72	38.37	11.16
"	"	3	78.55	77.84	76.63	32.94	8.74

Table 29. (Continued)

Starter no.	Calf no.	pd.	Coefficients: Dry matter	Coefficients: Energy	Coefficients: Nitrogen	Nitrogen retention: % of N intake	Nitrogen retention: Gms. per day per 100 lb. B.W.
43	201B	1[a]	64.85	64.20	51.20	20.74	8.34
"	"	2	61.24	60.51	51.71	20.10	8.24
"	"	3	75.64	74.08	72.35	37.01	14.04
44	187C	1	76.94	75.10	74.28	12.79	3.91
"	"	2	81.51	79.78	80.70	30.61	11.63
"	"	3	77.90	77.18	79.20	28.38	11.63
"	2	1	79.53	76.84	67.65	34.38	12.87
"	"	2	81.36	79.52	79.02	30.08	11.50
"	"	3	79.03	76.94	78.25	21.73	7.67

[a] Calves went off feed during these periods. The values given were estimated according to the methods prescribed by Snedecor (1956).

Table 29. (Continued)

Starter no.	Calf no.	pd.	Coefficients			Nitrogen retention	
			Dry matter	Energy	Nitrogen	% of N intake	Gms. per day per 100 lb. B.W.
44	199B	1	80.29	77.88	78.16	43.50	18.21
"	"	2	79.34	76.66	79.98	37.00	16.39
"	"	3	80.22	77.25	80.53	32.70	14.56
45	194A	1	78.78	76.44	68.14	13.00	3.46
"	"	2	78.68	78.26	77.31	31.26	12.44
"	"	3[a]	80.54	79.39	79.41	21.43	8.14
"	4224	1	72.79	70.80	58.71	19.13	6.11
"	"	2	76.72	75.74	71.02	27.70	11.06
"	"	3	79.72	79.35	78.59	21.56	8.33
"	4239	1	77.82	77.97	75.69	16.83	4.50
"	"	2	79.06	78.96	80.67	28.29	8.00
"	"	3	76.81	76.47	77.82	23.02	6.88

Table 30. Plasma protein and plasma urea nitrogen content of the blood for calves in Experiment II

Starter no.	Calf no.	Plasma protein (g.%) periods						Plasma urea nitrogen (mg.%) periods					
		1	2	3	4	5	6	1	2	3	4	5	6
41	643C	7.10	6.15	6.39	5.40	5.78	5.84	12.6	13.1	13.5	14.1	15.3	12.2
"	4225	5.55	6.62	5.70	6.27	5.95	6.55	11.9	16.5	6.4	9.7	12.3	8.5
"	4227	6.05	6.65	6.14	6.47	4.55	5.97	9.1	12.5	21.6	13.2	14.1	16.1
42	4226	5.44	4.83	5.38	5.68	5.30	5.94	20.3	12.1	9.4	3.7	6.3	8.5
"	278	6.85	6.21	4.50	5.18	6.43	6.34	16.0	3.8	4.8	6.5	6.6	6.2
"	756	6.05	5.07	4.82	6.38	5.57	6.10	11.2	9.6	4.7	10.0	8.5	3.4
43	755	6.30	6.25	6.46	6.38	6.62	6.73	9.6	14.0	6.7	4.8	4.1	12.1
"	282	6.85	4.54	6.50	6.24	5.53	6.10	14.0	7.4	19.6	3.6	5.5	3.5
"	279	7.40	5.55	6.27	6.07	5.67	6.07	9.4	6.0	4.9	10.0	3.6	4.1
44	177B	7.10	5.70	6.71	5.70	5.32	5.48	10.4	10.3	10.3	15.7	13.1	14.9
"	283	7.78	6.43	6.48	6.82	7.25	6.04	12.7	12.4	15.9	18.0	18.2	22.2
"	280	8.10	6.43	6.04	6.73	6.61	6.90	15.1	7.7	9.8	8.3	7.7	14.7

Table 30. (Continued)

Starter no.	Calf no.	Plasma protein (g.%) periods						Plasma urea nitrogen (mg.%) periods					
		1	2	3	4	5	6	1	2	3	4	5	6
45	204A	7.40	7.10	6.02	7.17	6.56	5.78	8.1	13.1	6.1	7.3	10.1	4.5
"	220A	6.70	6.18	6.18	5.97	5.69	5.65	7.6	9.5	4.7	4.1	14.0	12.0
"	281	4.65	5.13	5.23	6.01	6.43	6.80	11.4	6.4	5.8	6.8	8.7	11.5