May 24, 1963

To the Graduate Council:

I am submitting herewith a thesis written by Julius E. Thigpen entitled "The Comparative Nutritive Value of Liquid and Dry Milk for Dairy Calves." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Dairying.

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33

THE COMPARATIVE NUTRITIVE VALUE OF LIQUID AND DRY MILK FOR DAIRY CALVES

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Julius E. Thigpen

June 1963

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ACKNOWLEDGMENT

The author wishes to express his sincere appreciation to Dr. Eric W. Swanson for suggesting this study and for his timely advice during the experiment. The author also acknowledges the assistance of Miss Virginia L. Guy for typing the manuscript.

CHAPTER I

INTRODUCTION

In recent years there has been a gradual change from the use of whole milk to milk replacers or dried skimmed milk because they are more economical and less labor is required in feeding them. Feeding liquid milk to calves is a chore and a possible source of infection, so it is desirable to limit the milk drinking or suckling period to a short time. Calves will eat considerable concentrate feed if they are not drinking milk after five weeks of age. However, calves fed liquid milk beyond this age seem to grow more efficiently than those fed only dry feed. Dry feed consumed goes to the rumen of the calf where it is fermented. Liquid milk by-passes the rumen and goes directly to the abomasum, where protein and fat digestion begin. It is possible that the rumen fermentation lowers the nutritive value of the milk solids when fed dry rather than in the liquid form. It is important to determine whether or not the nutritive value is changed by the method of feeding and to evaluate feeding methods in the light of such knowledge. Little has been done in comparing the forms of feeding dried skimmilk.

The purpose of this study was to compare the nutritive value of dried skimmilk fed in the liquid form with the same type of milk fed dry in the concentrate ration with equal energy intakes for both groups.

CHAPTER II

REVIEW OF LITERATURE

Calves can be weaned early if they will consume enough dry feed to meet their dietary needs. However, feeding large amounts of grain may cut down their utilization of the roughage fed. The calf digests milk differently than it digests grain or hay. Enzymes secreted in the true stomach and intestines of the calf break down the nutrients in milk or milk replacers to products that the body can use. Olson (37) stated that these same enzymes cannot break down cellulose, the most common carbohydrate found in plants. Microorganisms in the rumen must first ferment these carbohydrates before the calf can utilize them effectively. The young calf's rumen is small and does not contain these organisms, therefore, very little cellulose digestion occurs before the thirteenth day. Cellulose decomposition increases as the calves grow older and as the ration changes to all hay (37). Cereal grains contain large amounts of starch, a carbohydrate that is more readily broken down than cellulose. Rumen microorganisms prefer to attack the starch rather than the less available cellulose.

Savage and McCay (47) observed that milk fed to calves passed directly into the fourth stomach. They fed colored water to ruminants and observed that this water distributed itself in all four stomachs.

Wise and Anderson (58) found that unthrifty appearance in dairy calves may be due to the deviation from "nature's way" of feeding. Their contention was that when calves drink from pails, the milk is forced into the rumen where it undergoes abnormal decomposition causing physiological disturbances. Wise and Anderson (58) slaughtered calves after the last

feed had been colored with coal tar dye to determine whether or not milk went into the rumen or abomasum. They were careful in killing to prevent possible transfer of milk from one section to another. The calves were slaughtered at ten to fourteen days of age. Thirty-seven per cent of calves fed from open pails had milk in their rumen. Two per cent of the calves fed by nipple had milk in the rumen.

Anatomical Changes in the Calf

Among all vertebrates different organ systems enlarge at somewhat different rates in proportion to the whole body. This is especially important in ruminants since the internal organs must assume different positions as the rumen develops.

Burt and Bell (8) showed that the adequate utilization of dry food by the calf depends upon the development of the rumen and its microbial-population. The development is linked with and depends upon the ingestion of increasing quantities of dry food. Therefore, the calf's development is especially subject to its diet.

Savage and McCay (47) stated that the rumen at birth occupies an unimportant position in the anterior, upper left part of the abdominal cavity. At about two months of age it has increased in size and sunk down within the body cavity. The reticulum and omasum are very small at birth and develop rapidly. As the rumen develops, it pushes both the omasum and abomasum to the right and dorsally. At birth the abomasum occupies a considerable volume of the abdominal cavity. It extends back from the diaphragm to the seventh vertebrae and rests on the floor of the abdominal cavity. At one month of age it has undergone a relative diminution and extends only to the third vertebrae. In the adult it

continues to lie on the abdominal floor. These anatomical changes are of interest in understanding nutrition of the calf. The type of diet at different ages affects the development of these organs and the degree of utilization of nutrients.

Actions of the Esophageal Groove

Schalk and Amadon (48) found that when water was drunk, it entered the rumen and did not follow the esophageal groove into the abomasum. The ruminoreticular ingesta passes into the omasum only when it is reduced to a fine state. They found the esophageal groove seldom functioned in mature animals except under special conditions. By gastric fistulae they were able to feel the groove as it functioned and observed that milk was conducted directly to the true stomach if it were drunk slowly; but if consumed rapidly from a pail, it tended to pass into the rumen. When the abomasum was filled with milk, the milk went to the rumen; but when calves were fed from nipples, milk did not enter the rumen. All evidence indicates that the methods of feeding calves may be of considerable importance (13).

Wise (57) showed that milk, either from nursing or drunk from a pail, caused the groove to contract and to function as a passage from cordia to omasum. Filling the rumen with milk via a fistula did not affect the tonicity of the groove, indicating that the reflex does not originate at the distal end of the esophagus. Water has an effect on the very young calf but not after one month of age. The act of sucking stimulated closure of the esophageal groove as evidenced by its response to calves sucking a clean nipple. Both sucking and milk itself stimulate the groove.

Psychic Responses

Fright preceding feeding may cause the esophageal groove not to respond, but it does not work in all calves (57). Sight of milk at feeding causes the muscularis of the groove to contract strongly. As the calf becomes older, the response wanes. Elevation of the head had no affect. Milk went to the usual place whether the head was lowered or raised.

Growth of the Rumen

Preston (41) stated that the development of the rumen in the calf is governed not so much by the age as by the rate at which the calf learns to eat solid foods. Studies by Burt and Bell (8) showed that when calves were fed only milk, the development of rumen functions were largely suppressed and that the propionic and butyric acids, normally produced by the microbial digestion of dry food on the rumen, can produce development of the rumen mucosa in the absence of any intake of dry food. In calves weaned at three weeks, feeding large amounts of milk substitutes produced an effect which was still present at eighty-eight days of age. This indicated that feeding in very early life may be permanently detrimental.

Noller (35) divided seventy-eight Holstein calves into eleven groups. They were weaned at twenty-one days of age and fed various levels of hay incorporated into the starter to determine the best levels of feeding hay in concentrate and effects on rumen development. He found that calves grew best on 15 per cent hay in starter. Also incorporating coarse ground hay into the starter was a means of forcing younger calves to eat more hay. This is an important factor in initiating and stimulating rumen development.

Harrison and Warner (21) reported on the effects of milk-fed and milk, hay and grain-fed calves on rumen capacity at sixteen, twenty-eight and forty-eight weeks of age. The milk-hay-grain group had greater capacity, but differences between the two groups became less with age.

Godfrey (19) reported on three groups of calves in which Group A received only milk, B received milk and access to pasture and C received pasture alone. Results showed that the volume of the rumen contents increased with age, whereas the volume of the abomasum contents tended to remain constant. The rumen liquor of milk-fed calves with free access to pasture reached a constant level at five weeks. In calves on an all-milk diet, the development of adult levels of volatile fatty acids were delayed until roughage became available. Rumen pH showed a steady increase from birth to seventeen weeks of age.

Bentley and Klosterman (4) reported that to obtain a high level of microbial activity in the rumen, it appears that the microflora and microfauna require sources of nitrogen, energy and minerals plus a less well-defined group of nutrients or certain rumen factors. Good-quality feeds are good sources of growth factors for microorganisms. This suggests the using of the rumen growth factor content of a feed as an additional measure of its nutritive value. Besides the volatile fatty acids, certain amino acids have been found to have growth factor activity in the artificial rumen.

Williams and Jensen (10, 55) fed calves dried rumen contents to speed up the establishment of bacteria and to get calves to ruminate early, but they did not get an increase in growth rates.

Pounden and Hibbs (40) found that placing microorganisms from the rumen of mature stock into the posterior of the calves mouths assisted

in the establishment of protozoa in the rumen of calves eating hay alone or both hay and grain.

Growth of the Stomach

Wardrop and Coombe (54) slaughtered lambs at weekly intervals from birth to sixteen weeks of age and observed that each organ of the stomach increased in weight with age, reaching approximately adult proportions by eight weeks of age. The rumen had the fastest rate of growth, followed by the reticulum, omasum and abomasum. This work was duplicated by Godfrey (20) with fifty-four calves slaughtered between birth and seventeen weeks of age. Tamate (51) reported papillary growth in the rumen was stimulated by administration of at least forty-three milliliters of C_3 or C_4 volatile fatty acids. Feeding of hay, starter and milk resulted in forestomach development. Becker (2) stated that the stomach is sterile at birth as concerns both bacteria and protozoa, but the abomasum is developed and ready to function at birth.

Milk Substitutes to Replace Fluid Milk

Among the early substitutes for whole milk in feeding were skim-milk and linseed oil (47). The common ingredients of the earliest calf meals were wheat flour, flaxseed meal, cocoanut meal, ground beans and peas, cottonseed meal, tapioca, starch and salt. These rations were low in vitamin A. The fat-soluble vitamin A tends to be lower in fetal blood than that of the mother. The calf is born with small amounts of vitamin A in the liver and must be fed vitamin A in the feed.

Studies by Wallace et al. (53) involving 185 Holstein calves were carried out to formulate substitute mixtures which would satisfactorily

replace fluid whole milk in the rations after ten to fourteen days of age. They obtained normal rates of growth from large amounts of dried skimmilk. However, calves raised on the substitutes were rather rougher in appearance from the third to the seventh week of age than calves on whole milk. Their rates of growth were somewhat lower on the dry skimmilk than on whole milk, but the differences were overcome by the time the calves were four to six months of age.

Carbohydrates to Include in the Young Calf Diet

Preston et al. (28, 36, 42) fed various solutions of carbohydrates to calves and measured the concentration of glucose in the blood. The digestion of a particular carbohydrate would be manifested, within an hour or so of feeding, in an increase in the concentration of blood glucose. Their results showed lactose and glucose produced a rapid rise in blood glucose in the week-old calf. Maltose and cane sugar had only a very slight effect. Dextrin and starch had none. The calf has high lactose activity at birth but has low or negligible activity of starch-splitting enzymes amylase, sucrase and maltase. Hydrolyzing power of these latter enzymes did not become appreciable until the calf reached four to six weeks of age.

Starch is the cheapest and most commonly used source of energy in livestock feeds, but it cannot be utilized by the young calf according to Noller and Shaw (34, 49). Its presence in large amounts in the milk substitute is bad since it passes through the gut undigested and forms a source of food for bacteria in the bowel. The resultant increased bacterial activity is frequently the cause of scours. Calves three to

four weeks old can digest about 90 per cent of the starch in their ration. As the calf gets older, larger amounts of starch can be fed.

Pardue (39) reports that dried skimmilk is the best source of protein for calves, but it provides only a small benefit over a vegetable source of protein. Dried skimmilk fed in solid form passes directly to the rumen first and there it is fermented and possibly digested by bacteria and other microorganisms.

The calf has enzymes to hydrolyze lactose, casein and fat since these are the principle constituents of whole milk (43). There is very little evidence concerning the activity of other enzymes in the digestive tract of the young calf and much that is known is obtained indirectly from feeding trials. Best results are obtained when we include in milk substitutes only those ingredients for which the calf possesses the corresponding enzymes.

Methods of Feeding Dried Skimmed Milk

Bechdel and Rupel (1, 46) reported that powdered skimmilk fed dry to calves in their grain ration was the cheapest and most satisfactory method of feeding milk if it were to be continued for a period of more than two months. Other stated advantages of feeding milk in the dry form were: sell more whole milk, beef cattlemen do not have to maintain as many cows, less labor is required in feeding, may speed up the development of the rumen by using more roughages, helps in synthesizing essential amino acids and also certain vitamins.

Preston (42) reported that solid foods such as dry milk enter the rumen first where they are fermented and mixed with rumen liquids which may lower their nutritive value. This may be done by bacteria utilizing

or breaking down the protein of milk while in the rumen (48). Even if milk undergoes decomposition in the rumen, the extent to which the products may be absorbed is a moot point. Another disadvantage of feeding milk dry is that when it enters the rumen, there may be a tendency for it to form a hard curd. Dickey et al. (12) stated that it takes longer for hard curds to liquify and escape from the abomasum.

Advantages of liquid milk are: farmers have some amount of unsalable milk from treated cows and newly calved cows; better growth rates are obtained in the first few weeks by using liquid milk; it is simpler not to have to buy and use milk substitutes; liquid milk goes directly to the true stomach, giving a higher percentage digestibility; liquid feeding is a more natural way of feeding; and the calf is fed a higher quality of protein (42).

The main disadvantages of feeding liquid milk are that it is more expensive and more labor is involved in feeding.

Characteristics of Proteins

Properties of proteins. Maynard and Loosli (27) stated that proteins are complex substances, colloidal in nature and of high molecular weight. All proteins are not of equal value and their functions differ within the same species, and species differ in their protein make-up. Heating improves some proteins but its effects are harmful on others. Proteins are amphoteric in nature. They differ in regard to their solubility in water and various solutions.

Effect of heat on proteins. There are two processes for drying milk, spray and roller (45). The spray is used mostly on milk for human consumption, whereas the roller process is used mostly for livestock feeds.

Heat from both has the same effect on milk. The higher the heat, the greater the effect. Roy (44) stated that high heat causes denaturation of some of the soluble proteins.

Effect of rumen on proteins. There is no protein absorption from the rumen, but there is evidence of protein digestion in the rumen. As bacteria and other microorganisms multiply, they synthesize protein to construct their own bodies obtaining raw materials from the ingested food. Some bacteria utilize amides, ammonium salts, nitrates and protein itself. Bacterial protein formed in the rumen is digested later in the stomach and intestine to amino acids.

McDonald (29) found that when 94 per cent of the total nitrogen in a sheep's ration was fed as zein, 40 per cent of it was used by rumen organisms to synthesize their own protein. This percentage may be higher with rations of natural feeds.

Further studies (27) have shown that this microbial protein is of high biological value which means that through the intervention of microorganisms in the rumen, rations of poor quality proteins are enhanced in quality for body use. This action by bacteria on milk may not be the same since milk proteins are already high in quality. This microbial action may result in losses when amino acids in feeds are broken down to ammonia or to acids having carbon chains not suitable for amino acid synthesis in the body. Whether this loss is a substantial one under any condition is uncertain.

Digestibility of protein. Digestion occurs as a result of enzymatic action in the stomach and intestines. The lability of proteins may be reflected in lower nutritive value in certain feeds after prolonged

storage depending on moisture content and other conditions. Nitrogenous compounds excreted in the feces consist in part of undigested or unabsorbed food nitrogen and another fraction called metabolic fecal nitrogen. Metabolic nitrogen is made up of residues from the bile, digestive juices, epithelial cells from the alimentary tract with the food residue passing through it and bacterial residues. Nitrogen in bacterial residues may be considered to have come originally, in part, from the food (27).

From in vitro digestion studies by Nakamo (32), using trypsin and pancreatin, the indications were that the ratio of amino nitrogen to total nitrogen was 5 per cent greater in cow's milk with added sucrose than in milk without added sucrose.

Dickey (12) used seven pairs of rats to determine the coefficient of digestibility of protein of hard and soft curd milk. He completed three-day preliminary and seven-day digestion trials and found little difference in the digestibility of the two milks.

Trout et al. (52) stated that about 8 per cent of reconstituted dried skimmilk settled out. Liquid milk did not settle out.

Bruggemann (7, 24) reported that crude protein digestion increased as the percentage of protein increased, but decreased with an increase in age.

Nevens and Shaw (33) compared forty-five samples each of fresh whole milk and evaporated milk for digestibility coefficients of protein and found 92.3 per cent digestible for whole milk and 88.4 per cent for evaporated milk.

Fairbanks and Mitchell (16) compared nitrogen metabolism for raw liquid skimmilk and skimmilk powders and found average coefficients of

true digestibility in feces to be 94.8 per cent for raw skim and 92.7 per cent for dry powder. The analysis of the individual data showed that the proteins of liquid skimmilk were significantly more digestible than the proteins of dry milk. The biological value of proteins was lowered about 8 per cent by drying. This decline in biological value was due to partial destruction of cystine, the amino acid limiting biological value in the roller process.

Fink (18) reported that drying either causes destruction of a growth promoting substance or the production of a growth inhibitor. The incidence of liver necrosis in rats was higher on dry skimmed milk than on fresh milk.

Comparison of different levels of proteins in feeds. Cunningham et al. (1) estimated protein and energy requirements for calves as 65.3 milligrams of nitrogen and 44.7 digestible calories per kilogram body weight per day for maintenance and 3.22 grams of nitrogen and 2.68 digestible calories per hundred grams gain in weight. The best level of protein intake was 24.0 per cent of total calorie intake or 19.4 per cent of the dry matter intake. Optimum energy efficiency measured by weight gain was obtained at intakes below eighty digestible calories per kilogram per day. Above this level of intake each additional digestible calorie did not result in the predicted increment in body weight.

Brown et al. (6) reported on eighty calves reared from two to eighty-four days on starters containing 8.5 to 24.3 per cent crude protein fed with hay. He found the optimum level was 16.6 per cent crude protein. Low levels of 8.5 per cent did not support normal growth.

With high quality protein the protein level required may be substantially lower than that currently found in many milk replacers.

Bush and Schuh (9) compared levels of 15, 20 and 25 per cent protein in milk substitutes. All starters contained 25 per cent dry skimmed milk. Higher levels of protein gave higher gains. Nitrogen retention was influenced by age as well as by live weight. Apparent digestibility of nitrogen decreased with increase in age.

Lassiter et al. (25) studied the optimum protein levels of milk replacers in forty-eight two-day-old male calves. Levels of 15.2, 18.7, 24.1 and 30.9 per cent were studied. All calves had a 16 per cent starter and hay. There were non-significant differences between the groups, but gains from 15.2 per cent were lower than from the others. Coefficients of protein digestibility decreased as the protein content of the replacers decreased.

The Use of Skimmilk in the Ration

Elting and LaMaster (15) reported that the addition of skimmilk powder to the ration of very young calves prevented the severe setback in growth immediately following the milk weaning period.

Bell (3) fed 150 Holstein calves colostrum for two days then converted over entirely to milk substitute which contained 40 to 50 per cent dried skimmed milk and the growth of the calves equaled or exceeded the Beltsville growth standard (26).

Berry (5) reported that the addition of dried skimmilk to meal mixture resulted in improved weight gains. However, the addition of a large percentage of dried skimmilk powder to the grain ration of calves after they had a good start on milk incurred more expense than the results would justify.

Miller and Clifton (30) stated that it appears that calves will grow just as well and be just as healthy when milk replacers are fed by a simplified procedure in which all calves of a breed are given the same amount for a specified period of time and abruptly weaned. This would reduce labor requirements in raising calves.

Williams and Knodt (56) conducted an experiment using five groups of calves. Four groups were fed dry skimmilk and one group (controls) received whole milk. Growth of group one was poor due to scouring and two sick calves. There were non-significant differences between the other four groups. Groups 2, 3 and 4 (dry milk) were more economical than group 5 which used whole milk.

Wallace et al. (53) experimented with 185 calves on several mixtures of dried skimmilk and whey at 50 to 80 per cent after ten to fourteen days of age. Normal growth was obtained with the mixtures, but it was not as good as in the controls which were on whole milk. In general, calves raised on dried skimmilk substitutes were rougher in appearance from three to seven weeks of age. The average growth rates were lower on substitutes during the first month, but the differences were largely overcome at four to six months of age.

Kondyrev (23) reported on sixty-seven calves on 80 per cent dried skimmed milk, vitamins and antibiotics fed 300 kilograms as compared to calves fed 300 kilograms of whole milk. The average daily weight gains of experimental calves were superior to those of controls.

Ellington and Knott (14, 22) reported work with the use of dried skimmed milk and by a gradual change over to it obtained good results.

Studies with Liquid and Dry Feeding of Milk

Bechdel (1) investigated whether to feed milk in liquid or dry form. He found that one pound of dry milk must be reconstituted in nine pounds of water to have equal value to fresh skimmilk (46). In utilizing thirty-five calves fed dry rations from thirty-four to one-hundred and fifteen days of age, he reports that group one, which contained twelve calves, gained 1.36 pounds per day to six months and was 95.7 per cent normal in size as compared to the control group on liquid milk.

Orth and Drews (38) reported a study of three groups of calves fed fresh skimmilk, reconstituted skimmilk and whole milk. They were fed vitamins A and D with skimmilk. Satisfactory results and an economic return were claimed for the skimmilk-vitamin A and D groups, but the best weight gains were obtained from the whole milk group.

Rupel and Bohstedt (46) conducted calf feeding trials with dried skimmilk compared to fresh skimmilk. Fluid skimmilk resulted in 1.61 pounds daily gain as compared to 1.4 pounds per day for dried skimmilk. The dried skimmilk group produced strong, well-grown heifers. Calves fed a liberal allowance of skimmilk up to sixteen pounds per head per day made gains slightly larger than those fed only half as much. The protein content was adjusted between lots by altering the grain so both would be balanced between protein and carbohydrates. Calves two-months of age grew just as well on dried skimmilk and grain mixed as the lot fed the material mixed with water until the calves were six-months old.

Muller and Bittner (31) compared fresh and dried skimmilk for thirty-four albino rats. Diets containing 89.3 per cent barley and

either 5.1 per cent dried skimmilk or an equivalent amount of fresh skimmilk were compared in feeding trials lasting four to twenty days. The nitrogen retention was significantly greater (10 per cent) when the fresh skimmilk was fed.

Farkas (17) studied the effects of dried skimmilk to replace liquid skimmilk in the diets of twenty pigs weighing thirty-four kilograms at the beginning of the experiment. Weight gains and food utilization were comparable to those obtained with good quality liquid skimmilk.

Summary of the Review of Literature

This review of literature has shown that the rumen of the young calf undergoes certain changes in early life that are influenced by the ingredients in the ration.

The nutritive value of dried skimmilk is lowered by the heating of the proteins in drying. Other factors that may affect the nutritive value is that dried skimmilk enters the rumen when fed in dry form where it is fermented by bacteria. This may lower the digestibility of the protein in dry milk. The extent that the protein may be absorbed is a moot point. Dried skimmilk is one of the most satisfactory methods of supplying protein for the young calf as evidenced by satisfactory growth from calves fed dry milk alone. However, feeding liquid whole milk results in faster growth but at a higher cost.

CHAPTER III

EXPERIMENTAL METHODS

General Description

Five groups utilizing thirty-five calves were used to detect the level of protein at which liquid milk would show the greatest difference in growth response, if there were one, compared with the feeding of dry milk in the concentrate ration. To detect a difference in growth response, calves were weighed and measured weekly. Feed was weighed and refusals were weighed daily. After this first phase was completed a level of 11 per cent protein was decided on for further comparisons. Calves were used in five more groups to determine differences in protein utilization as affected by type of milk fed. Male calves from each group were used in metabolism trials to help detect differences between the ration effects.

Source and Selection of Calves for the Experiment

The calves used in the experiment were obtained from the University of Tennessee Dairy herd at Knoxville, Tennessee. Only Holsteins were used because they are more vigorous and would give a better growth response. Eighty-two seven-day-old Holstein calves of both sexes were used to determine the comparative nutritive value of reconstituted liquid milk and dry milk fed in equal amounts, with special attention to protein and digestibility. The calves were placed on the experimental rations as they became available over a two-year period from the fall of 1961 until the spring of 1963.

Feeding Schedules

First twenty-eight days. All calves were fed alike to twenty-eight days of age. The calves were separated from their dams at approximately forty-eight hours after birth. They were fed colostrum or whole milk for the first week at the rate of nine pounds per day. Days seven and eight were used as a transition period to reconstituted skimmilk. From nine to fourteen days of age they were fed liquid milk at the rate of ten pounds per day; from fifteen to twenty-one days they were fed twelve pounds per day and from twenty-two to twenty-eight days of age they were fed fourteen pounds per day. Dry milk was reconstituted at the rate of one pound of milk in nine pounds of water at approximately 100°F. In addition, the calves were fed a 20 per cent protein basal starter and a grass-legume hay ad libitum.

From twenty-nine to ninety-one days. At twenty-eight days of age each calf was assigned to one of the experimental rations. The calves in the first phase of the experiment were each fed two pounds of starter daily from twenty-nine to forty-two days of age; from forty-three to forty-nine days they were fed three pounds daily; from fifty to seventy days they were fed four pounds daily; from seventy-one to seventy-seven days they were fed five pounds daily; from seventy-eight to eighty-four days they were fed 5.4 pounds daily and from eighty-five to ninety-one days they were fed 5.6 pounds daily. The calves on the first phase of the experiment were fed hay ad libitum.

The calves in the second phase of the experiment had hay ground and mixed in the starter and were each fed approximately the same schedule as above except for the dry milk groups (8, 10) which were fed

as follows: from twenty-nine to thrity-five days of age they were each fed 2.2 pounds daily; from thirty-six to forty-two days they were fed 3.4 pounds daily; from forty-three to forty-nine days they were fed four pounds daily; from fifty to fifty-six days they were fed 4.6 pounds daily; from fifty-seven to sixty-three days they were fed 5.2 pounds daily; from sixty-four to seventy days they were fed 5.8 pounds daily; from seventy-one to seventy-seven days they were fed six pounds daily; from seventy-eight to ninety-one days they were fed 6.8 pounds daily. Allowances were made as necessary to allow equal energy intakes between the dry and liquid groups. The liquid milk groups, 4, 6, 9 and 11, were each fed 2.8, 4.2, 5.6, 6.3, 7.0, 7.7, 7.7, 8.4 and 9.1 pounds of dry milk daily in successive weeks from twenty-eight to ninety-one days of age.

From ninety-two to one-hundred and five days. At ninety-two days of age all calves were put on a high protein starter and fed four pounds daily with alfalfa hay ad libitum to observe post-experimental effects of the rations.

Feed and Growth Data

Feed consumption and growth responses were measured from seven to one-hundred and five days of age. Complete feed intakes were recorded by weighing all feed offered and refused daily. Growth responses were determined by weights and measurements taken every seven days. The calves were kept in individual feeding pens and were watered and fed twice daily. Blood samples were taken about 4 p.m. at biweekly intervals from all calves from twenty-one to one-hundred and five days of age. Samples were analyzed for protein and non-protein nitrogen. Total blood nitrogen was determined by using two milliliters of plasma in the

regular Kjeldahl procedure for protein analyses. Non-protein nitrogen analyses were made by using two milliliters of plasma, sixteen milliliters of water, one milliliter of tungstate, one milliliter of hydrochloric acid and collecting the filtrate. Then five milliliters of the filtrate were used to determine the non-protein nitrogen by adding one milliliter of (1-1) dilute acid mixture, two glass beads and boiling gently to evaporate. Then cool and add thrity-five milliliters of water and fifteen milliliters of Nessler's solution, mix and let stand for ten minutes. The color intensity was read in an Evelyn colorimeter tube using a 515 filter.

Rations Used

The rations were mixed at the University of Tennessee Dairy farm. The ingredients are shown in Tables I and II for the first and second phases of the experiment, respectively.

At twenty-eight days of age each calf was assigned to one of the experimental rations. The groups, starters and beginning weights for the first and second phases of the experiment are presented in Tables III and IV, respectively.

Digestion and Balance Experiments

Selecting calves for trials. Four male calves from each of the groups 7, 8 and 10, three calves from group 9, and five calves from group 11 were put in metabolism crates at seventy to seventy-seven days of age to determine digestibility and nitrogen balances from the rations. The calves were allowed a three-day preliminary period before actual data were recorded. Collection periods were seven days. Calves were weighed before and after the trials.

TABLE I

FORMULAS OF THE STARTERS FED TO GROUPS 2, 3, 4, 5 AND 6 FROM 28 TO 91 DAYS OF AGE ON FIRST PHASE OF EXPERIMENT

Ingredients	Groups				
	2*	3	4	5	6
	--------(lbs per 1000 lbs)---------				
Corn meal	900	525	660	675	900
Corn starch	70	255	310	55	70
Dried skimmilk	-	200	-	250	-
Salt	10	5	10	5	10
Dicalcium phosphate	10	5	10	5	10
Vitamin A and D and antibiotics**	10	10	10	10	10

*Basal group without milk.

**Vitamins A and D = 20,000 and 2,500 units per gram of supplement and 2 grams of aureomycin per pound to all rations.

TABLE II

FORMULAS OF THE STARTERS FED TO GROUPS 7, 8, 9, 10 AND 11 FROM 28 TO 91 DAYS OF AGE IN SECOND PHASE OF EXPERIMENT

Ingredients	Groups				
	7	8	9	10	11
	--------(lbs per 1000 lbs)---------				
Corn meal	600	205	350	205	280
Corn starch	170	370	425	370	445
Dried skimmilk	-	200	-*	200	-*
Ground hay	200	200	200	200	250
Salt	10	10	10	10	10
Dicalcium phosphate	10	5	5	5	5
Vitamin A and D antibiotics	10	10	10	10	10

* Starters 9 and 11 were supplemented with reconstituted skimmilk to supply 20 per cent of the dry matter intake.

TABLE III

ALLOCATION OF CALVES ON STARTERS AND INITIAL WEIGHTS FOR FIRST PHASE OF THE STUDY

Group	Calves	Feed Description Starter	Concentrate and Milk Protein	7-day Weights	28-day Weights
	(no)		(%)	-----(lbs)-----	
2	7	Basal and hay*	8	93.6	117.6
3	7	Dry milk, 20%	11	92.1	112.3
4	7	Liquid milk	11	92.4	116.1
5	7	Dry milk, 25%	14	91.3	110.4
6	7	Liquid milk	14	93.0	118.1

*Fed hay ad libitum with all formulas.

TABLE IV

ALLOCATION OF CALVES ON STARTERS AND INITIAL WEIGHTS FOR SECOND PHASE OF THE STUDY

Group	Calves	Feed Description Starter	Concentrate and Milk Protein	7-day Weights	28-day Weights
	(no)		(%)	-----(lbs)-----	
7	8	Basal and hay*	8	95.9	114.6
8	8	Dry milk, 20%	11	100.1	120.3
9	8	Liquid milk	11	101.6	123.1
10	11	Dry milk, 20%	11	91.2	101.5
11	12	Liquid milk	11	91.3	102.8

*20 per cent hay ground and mixed with all starters.

Collection and sampling of feces. A clean weighed pan was placed at the rear of the crate and adjusted so that the feces would drop directly into the pan. The feces were emptied and weighed daily. A thoroughly mixed aliquot sample was taken to the laboratory and frozen. After the end of the collection period a well-mixed composite sample was made of all collections. From this fresh composite ten grams were used for determinations of total nitrogen. A sample of the composite was dried at 60°C and then allowed to stand for several days in the laboratory to equilibrate to a steady moisture content. Air-dry samples were ground in a Wiley mill in preparation for proximate analyses.

Collection and sampling of urine. A funnel was placed under a square, wire mesh covered hole in the floor of the crate to direct the urine into gallon collection jars. Each day a thoroughly mixed urine sample representing 5 per cent of the total was transferred to a composite collection jug containing five milliliters of acid and one milliliter of toluene kept in a 40°F refrigerator. At the end of the collection period the composite sample was transferred to an appropriate volumetric flask and brought to volume. Nitrogen determinations were made on a volume-dilution basis.

Analyses of feeds. As the feeds were mixed a composite sample of each batch was obtained. This composite sample was ground in a Wiley mill and subjected to routine feed analyses.

Analyses for Significance

Apparent digestibility coefficients and nitrogen balance values were analyzed for statistical significance as outlined by Snedecor (50).

Total feed consumption, weight gains and blood protein levels were analyzed by analyses of variance (50) to determine the significance of differences between the responses to dry and liquid milk. The analyses of variance for all differences are found in the appendix under Tables I to VII.

CHAPTER IV

RESULTS

In the first phase of this experiment a low protein basal ration and two protein levels supplied by liquid and dry milk were compared. Hay was allowed almost ad libitum in this part of the study. The calves on this phase of the experiment were fed starters 2, 3, 4, 5 and 6. The formulas for these starters are presented in Table III. A summary of growth responses and feed consumption is presented in Table V for the first phase of the experiment. The results indicated that there were significant growth differences when dried skimmilk fed in the concentrate was compared to dry milk reconstituted and fed at equal energy intakes. These differences were found in total gain from twenty-eight to ninety-one days of age, an increase in heart girth from twenty-eight to ninety-one days of age and an increase in wither height from twenty-eight to ninety-one days of age.

Average total protein nitrogen and non-protein nitrogen summaries are presented in Table VI and VII for the first phase of the experiment. Protein nitrogen was obtained by subtracting non-protein nitrogen from total nitrogen. Differences in plasma-protein nitrogen and non-protein nitrogen were due to the type of milk fed, to protein levels or to age and were not statistically significant. Calves in this experiment were allowed free access to a high-quality alfalfa hay which was 23 per cent protein. The calves on the lower levels of protein, especially the basal group, consumed more hay which resulted in smaller differences in protein intake between the milk groups than the starter would indicate. Therefore, the protein level in the blood of the basal group was higher than was required to support normal growth.

TABLE V

AVERAGE GROWTH RESPONSES AND FEED CONSUMPTION OF HOLSTEIN CALVES FED DRY AND LIQUID MILK AT TWO PROTEIN LEVELS

	Groups				
	2	3	4	5	6
Per cent protein	8	11	11	14	14
28- to 91-day gain (lb)	88.0	94.0	105.8	93.2	106.2
Gain per day (lb)	1.40	1.49	1.68	1.48	1.69
Increase in heart girth (in)	5.7	6.8	8.2	6.9	8.5
Increase in height (in)	3.6	3.8	4.8	4.5	4.8
Dry skimmilk consumed (lb)	-	44.5	46.1	56.4	58.4
Starter consumed (lb)	214	177.8	173.6	169.3	176.2
Hay consumed (lb)	84.1	78.3	78.2	69.2	79.1
Total feed consumption (lb)	298.1	300.6	297.9	294.9	313.7

TABLE VI

AVERAGE PLASMA PROTEIN NITROGEN OF HOLSTEIN CALVES FED DIFFERENT LEVELS OF PROTEIN AND DRY OR LIQUID MILK

Group	Calves	Starter Protein	Age of Calves in Days						
			21	35	49	63	77	91	105
	(no)	(%)	----------(mg per 100 ml)----------						
Basal	7	8	1029	1051	1007	1044	992	1016	1061
Dry milk	7	11	1029	1040	1033	1044	1052	1039	1076
Liquid milk	7	11	1043	1050	994	1005	1048	1006	1064
Dry milk	7	14	1025	1036	1008	1036	1028	1086	1084
Liquid milk	7	14	1102	1056	1072	1042	1033	1077	1087

TABLE VII

PLASMA NON-PROTEIN NITROGEN OF HOLSTEIN CALVES FED DIFFERENT LEVELS OF PROTEIN AND DRY OR LIQUID MILK

Group	Calves	Starter Protein	Age of Calves in Days						
			21	35	49	63	77	91	105
	(no)	(%)	----------(mg per 100 ml)----------						
Basal	7	8	24.3	21.6	16.2	15.3	15.7	18.1	25.0
Dry milk	7	11	30.1	16.7	19.6	16.7	16.9	16.2	26.4
Liquid milk	7	11	25.9	20.7	14.0	14.4	14.9	16.5	24.3
Dry milk	7	14	21.1	23.7	20.1	18.8	16.0	17.3	21.8
Liquid milk	7	14	24.8	14.0	15.1	19.5	15.3	21.4	26.8

The results of the first experiment indicated that the amounts of protein supplied by starters and ad libitum hay feeding were too high above the critical level for growth to detect a difference between liquid and dry milk. In order to study the milk differences a second phase of the study was designed with five experimental groups. These included a basal 8 per cent protein and four 11 per cent protein groups comparing the feeding of milk fed in the concentrate and reconstituted and fed in the liquid form. Hay was ground and mixed in the ration to keep the protein level constant.

The starters were mixed at the University of Tennessee Dairy farm and were analyzed in the nutrition laboratory for routine analyses. Each time a separate mixture was made it was sampled for analyses. During balance experiments the composition of the specific mix being fed was used to calculate intakes for calves on digestion trials. The chemical analyses of starters used in the second phase of the study are presented in Table VIII.

In the second phase of the experiment there were two trials due to different seasons of the year and availability of calves. Three groups comparing liquid and dry milk with eight calves each were studied. In order to equalize the hay intakes of the dry and liquid milk groups, the percentage of hay in the starter was changed from 20 to 25 per cent for group 11.

A summary of growth responses and feed consumption for calves in both trials in the second phase of the experiment is presented in Table IX. The results indicated significant differences between the trials and between the liquid and dry milk in total gain. However,

TABLE VIII

PROXIMATE CHEMICAL ANALYSES OF EACH STARTER USED IN DIGESTION TRIALS COMPARING DRY AND LIQUID MILK IN 11 PER CENT PROTEIN RATIONS

Rations	Mix No.	Dry Matter	Nitrogen	Crude Protein	Crude Fiber	Ether Extract	Nitrogen Free Extract	Ash
		(%)						
7	1	90.4	1.28	8.00	5.69	2.61	69.9	4.20
	2	89.2	1.42	8.88	7.86	3.10	64.1	5.23
	3	88.7	1.25	7.81	4.26	2.54	70.0	4.11
	4	89.1	1.30	8.13	5.16	2.71	69.3	3.73
8	1	92.9	1.90	11.88	4.50	1.30	70.7	4.51
	2	92.0	1.93	12.06	4.72	1.36	68.7	5.22
	3	92.1	1.91	11.94	5.47	1.55	67.7	5.47
	4	93.3	1.90	11.88	2.89	0.98	73.0	4.55
	5	93.1	1.98	12.38	3.15	0.96	71.8	4.80
9	1	92.6	0.93	5.81	5.50	1.62	76.5	3.15
	2	93.7	0.91	5.69	4.81	1.30	77.5	4.45
	3	94.1	0.92	5.75	4.89	1.63	78.0	3.82
	4	93.0	0.71	4.44	3.51	1.35	81.1	2.65
10	1	92.7	1.77	11.06	3.41	1.05	73.0	4.21
	2	92.6	1.81	11.31	4.22	1.13	71.7	4.32
	3	92.8	1.98	12.35	2.45	0.98	73.0	4.02
11	1	90.7	1.05	6.53	8.28	1.72	70.0	4.26
	2	91.7	0.94	5.86	5.69	1.56	74.7	3.90
	3	91.7	0.76	4.81	2.39	1.07	81.1	2.26

TABLE IX

SUMMARY OF GROWTH AND FEED CONSUMPTION OF HOLSTEIN CALVES FED DRY AND LIQUID MILK

	Starter Number				
	7	8	9	10	11
Ration protein (%)	8	11	11	11	11
Calves (no)	8	8	8	11	12
Increase in heart girth (in)	4.9	6.0	7.0	5.7	6.5
Increase in height (in)	3.1	4.2	4.7	3.3	3.5
Grain fed (lb)	204.8	162.2	172.3	142.9	151.8
Hay fed (lb)	51.2	54.0	43.1	47.7	50.6
Milk fed dry basis (lb)	-	54.0	58.8	47.7	58.8
Total feed consumption (lb)	256.0	270.2	274.2	238.3	261.2
Gains (lb)	59.9	79.3	95.7	63.9	83.9
Average daily gain (lb)	.95	1.26	1.52	1.01	1.33
Feed per pound of gain (lb)	4.27	3.41	2.86	3.73	3.11

non-significant differences were obtained between the dry and liquid milk group in total feed consumption. The ninety-one to one-hundred and five day gains were similar for all groups.

Table X presents a summary of plasma-protein nitrogen and non-protein nitrogen for the second phase groups. The results from these analyses indicated a significant difference between dry and liquid milk when fed at 11 per cent protein level. Calves fed dry milk had higher plasma nitrogen values during the twenty-eight to ninety-one day comparison with liquid milk. At twenty-one and one-hundred and five days, before and after the comparison, when both groups were fed alike the differences were slightly in favor of the other group.

Male calves from each of the five groups (7, 8, 9, 10 and 11) were placed in metabolism crates to determine the difference in the digestibility of the rations comparing liquid and dry milk with special attention to protein. The results presented in Table XI indicated a significant difference (P=.10) in total nitrogen digestibility between the liquid and dry milk rations.

The average apparent digestibility coefficients for the dry and liquid milk groups are presented in Table XII. The results indicated a significant difference (P = .05) in apparent protein digestibility in favor of the liquid milk group. However, a significant difference was obtained in nitrogen-free extract in favor of the dry milk group.

TABLE X

AVERAGE PLASMA PROTEIN NITROGEN AND NON-PROTEIN NITROGEN OF HOLSTEIN CALVES COMPARING BASAL, DRY MILK AND LIQUID MILK GROUPS

	Group	Protein %	Age of Calves in Days 21	35	49	63	77	91	105
			(mg per 100 ml)						
Protein nitrogen	Basal	8	1001	970	958	993	990	955	1006
Protein nitrogen	Dry milk	11	1030	1041	1009	1052	1038	1054	1048
Protein nitrogen	Liquid milk	11	1070	1018	984	991	983	961	1071
Non-protein nitrogen	Basal	8	26.7	17.4	12.3	12.3	13.0	16.4	21.4
Non-protein nitrogen	Dry milk	11	27.3	22.0	15.3	13.4	13.2	16.2	22.4
Non-protein nitrogen	Liquid milk	11	28.0	16.3	14.6	12.6	12.8	15.1	23.1

TABLE XI

AVERAGE NITROGEN BALANCES FOR HOLSTEIN CALVES COMPARING BASAL, DRY MILK AND LIQUID MILK GROUPS

Group	Intake	Absorbed	Feces	Urine	Total Excreted	Retained Balance	Apparent Digestibility	Retained of Fed	Retained of Digested
	(mg)						(%)		
Basal	28,612	15,780	12,832	2,766	15,598	13,014	51.9	45.0	82.6
Dry milk	38,435	26,078	12,358	4,416	16,774	21,662	67.4	56.2	83.5
Liquid milk	40,743	29,666	11,078	5,527	16,604	24,139	72.7	59.3	81.8

TABLE XII

AVERAGE APPARENT DIGESTIBILITY COEFFICIENTS FOR
8 CALVES EACH FED DRY AND LIQUID MILK RATIONS

Ration	Dry Matter	Ether Extract	Crude Protein	Nitrogen-Free Extract	Crude Fiber	Total Carbohydrates
	(%)					
Dry milk	77.1	49.1	67.6	84.4	9.4	79.4
Liquid milk	74.0	54.1	73.6	78.2	17.2	74.8

CHAPTER V

DISCUSSION

The formulas were mixed at the University of Tennessee Dairy farm, often using a different supply of ingredients for each mix of the rations. It was found as indicated in Table VIII that it was hard to mix rations with a constant composition of chemical factors. The greatest variable in the mixes was the hay. Hay may vary in composition from bale to bale as well as lot to lot. The protein varied from 10 per cent in grass hay to about 23 per cent in some of the alfalfa hay. Therefore, the hay caused quite a variation even though the same number of pounds were used in each mix and an effort was made to select uniform lots of hay for the entire experiment.

The results from the first five groups (first phase) indicate there was a significantly greater rate of gain in response to skimmilk fed as a liquid than to skimmilk fed in the dry form. The reason for the difference undoubtedly was more efficient use of the feed. Differences in total feed consumption between the five groups were not statistically significant. The first five groups were fed hay ad libitum. They consumed enough high quality hay for all to make rapid gains even though the concentrates formulas varied from low to medium. Even the basal group gained 1.4 pounds daily on an 8 per cent protein starter. The 11 per cent protein group fed liquid milk gained just as well as the group fed 14 per cent protein, and the group fed 11 per cent protein containing dry milk gained just as well as those fed 14 per cent protein and dry milk. This would indicate the importance of good quality hay for calves.

The differences between the groups averages of blood protein nitrogen and non-protein nitrogen were non-significant in the first phase of the experiment. This could be explained by the feeding of hay ad libitum which allowed the low protein groups (8 and 11 per cent) to consume more hay than expected. This hay intake gave them almost the same growth level as the 14 per cent group. Nevertheless a difference between liquid and dry milk appeared regardless of the level of protein in the ration.

Protein requirements as estimated by Cunningham (11) were 65.3 milligrams of nitrogen and 44.7 digestible calories per kilogram of body weight per day for maintenance and 3.22 grams of nitrogen and 268 digestible calories per 100 gram gain in weight. Calves in the second phase of the experiment were fed below these estimates in order to detect a greater difference in liquid and dry milk.

In the second phase of the experiment there was again a significant difference in total gain from twenty-eight to ninety-one days of age between liquid and dry milk groups. There was also a significant difference between the two times in the second phase of the experiment. Groups 8 and 9 were larger calves at birth and gained an average of 4.6 pounds more per calf as compared to groups 10 and 11. The calves in groups 8 and 9 were spring calves from older cows. Calves in groups 10 and 11 were mostly from heifers and were fall calves. Groups 10 and 11 were raised under more adverse conditions. However, in these groups a growth difference still occurred between liquid and dry milk.

The growth response in favor of the liquid milk groups could be explained in different ways. The calves fed liquid milk consumed more

total feed, but the difference when analyzed was statistically non-significant. Indications from previous investigations (27, 42 and 48) are in agreement with these results that the digestibility or nutritive value of milk is lowered when fed in the dry form. This is most likely due to the fact that dry milk is fermented in the rumen and there is a possibility that bacteria use this milk somewhat wastefully for their own growth. It has been stated that calves fed dry milk developed more scours (48, 58). In this experiment no difference in the two methods of feeding in the incidence of scours was noted; but the dry milk groups were usually rougher in general appearance. In the first week of the experiment the calves fed liquid milk gained six pounds per calf compared to three pounds per calf by those fed dry milk. This trend continued until ninety-one days of age when the difference had lessened.

The difference in level of protein the the blood between groups 7 and 9 was not statistically significant, but group 8 which was fed dry milk averaged significantly higher than the others as shown in Table X. The average differences in non-protein nitrogen among the three groups were non-significant. The most logical explanation for the above differences would be due to the time of day (4 p.m.) the blood samples were taken. The liquid milk group apparently had low blood protein in the afternoon because the major portion of their protein had come from milk ingested in the early morning, which may have been digested and used by 4 p.m. in the afternoon. Calves which ate milk apparently had a more constant supply of protein in the blood at all times as all feed went first to the rumen and from there it should leave at a more constant rate. The level of blood protein in the basal

group was low because the starter contained no milk and was low in total protein.

The data from the metabolism trials would partially explain the growth differences between the two methods of feeding dry milk. A significant difference in protein digestibility between the groups was observed. There were non-significant differences in protein percentage retained of that fed and percentage retained of that digested. This would indicate that whatever happened to the protein, happened before the milk was digested because after it was absorbed there were non-significant differences between any of the groups. This could have occurred in the rumen by bacteria fermenting the milk and lowering the nutritive value. How much of the difference in nutritive value can be attributed to this effect is unknown. The dry milk seemed to cause a slight palatability problem because the calves in these groups consumed slightly less feed and were not as thrifty as the group fed liquid milk. Although the differences in feed consumption were not statistically significant, the slightly lower average consumption combined with the lower digestibility must have had a significant growth effect.

Nitrogen-free extract may have been used more efficiently by the calves fed dry milk because of the lower levels of starch in their formulas. There is a possibility that the dry milk in the rumen aided the digestion of nitrogen-free extract. The calves fed liquid milk had a lower percentage of protein in their rumen ingesta, which probably reduced the total utilization of the starchy feeds in their starter.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Eighty-two seven-day old Holstein calves of both sexes were utilized in an experiment to determine the comparative nutritive value of reconstituted liquid skimmilk and skimmilk fed dry with special attention to utilizations of proteins and digestibility of nutrients.

Thirty-five calves were used in the first phase of the experiment to determine the best protein level to compare the two methods of feeding. Starter protein levels fed were 8, 11 and 14 per cent. Calves fed dry skimmilk gained an average of 12.4 pounds less than those fed liquid milk in the nine-week experiment. This difference was statistically significant, P=.05. However, the differences in weight gains between levels of starter protein fed were not statistically significant probably due to feeding of hay ad libitum. The difference between dry and liquid milk occurred regardless of the level of protein in the ration.

The second phase of the experiment utilized forty-seven calves fed a 11 per cent protein ration comparing dry and liquid milk. Calves fed dry skimmilk gained 18.2 pounds less than calves fed liquid milk and this difference was statistically significant, P=.01. A significant difference at P=.01 was also obtained between the two periods in which the second phase of the experiment was conducted.

Blood samples were taken biweekly from twenty-one to one-hundred and five days of age and analyzed for plasma protein nitrogen and non-protein nitrogen. The dry milk caused a significantly higher plasma protein level than that observed in the liquid milk group, which was significant, P=.01. Differences between the non-protein nitrogen levels by groups were non-significant.

There were non-significant differences between total feed consumption by the liquid and dry milk groups, but there was a significant difference, P=.05, between the first and second trials of the second phase.

Twenty male calves seventy to seventy-seven days of age were used for digestion and nitrogen balance studies. Calves fed liquid milk absorbed an average of 3.59 grams more protein per day than the dry milk group, which was significant, P=.10. Apparent protein digestibility coefficients were 73.6 per cent from the liquid milk group, and 67.6 per cent from the dry milk group, the difference being significant P=.05.

Reasons for the superior growth rate of the calves fed liquid milk were not clear from the results of the digestion and balance studies.

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APPENDICES

TABLE I

ANALYSIS OF VARIANCE SUMMARY: PROTEIN LEVELS AND MILK TYPE CALCULATED ON TOTAL GAIN FROM 28 TO 91 DAYS OF AGE

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F Value	F Table P=.01	F Table P=.05
Total	34	8,644	--			
Milk type	2	1,841	920	4.60*	5.39	3.32
Protein level	2	789	395	1.86	5.39	3.32
Error term	30	6,014	200			

TABLE II

ANALYSIS OF VARIANCE SUMMARY: MILK TYPE AND TIME CALCULATED ON TOTAL GAIN FROM 28 TO 91 DAYS OF AGE

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F Value	F Table P=.01	F Table P=.05
Total	38	10,401				
Time	1	1,879	1,879	12.8**	7.31	4.08
Milk type	1	3,240	3,240	22.0**	7.31	4.08
Error term	36	5,282	147			

TABLE III

ANALYSIS OF VARIANCE SUMMARY: APPARENT DIGESTIBILITY COEFFICIENTS OF PROTEIN NITROGEN FOR ALL CALVES ON DRY AND LIQUID MILK CALCULATED ON PER CENT OF NITROGEN DIGESTED

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F Value	F Table P=.01	P=.05	P=.10
Total	15	406	-				
Protein nitrogen	1	93	93	4.15*	8.68	4.54	3.07
Error term	14	313	22.4				

TABLE IV

ANALYSIS OF VARIANCE SUMMARY: LEVEL OF PROTEIN NITROGEN IN BLOOD FOR ALL CALVES IN GROUPS 7, 8 AND 9 CALCULATED ON AVERAGE PER CENT OF NITROGEN FROM 35 TO 91 DAYS OF AGE

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F Value	F Table P=.01	F Table P=.05
Total	119	365,399				
Groups	2	91,271	45,635	19.93**	4.79	3.07
Weeks	4	15,324	3,831	1.67	3.48	2.45
Error term	113	258,804	2,290			

TABLE V

ANALYSIS OF VARIANCE SUMMARY: TOTAL FEED CONSUMPTION FOR ALL CALVES ON DRY AND LIQUID MILK CALCULATED ON TOTAL CONSUMPTION PER CALF

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F Value	P=.01	P=.05
Total	38	34,064	-			
Time	1	3,868	3,868	5.01*	7.31	4.08
Milk type	1	2,420	2,420	3.13	7.31	4.08
Error term	36	27,776	772			

TABLE VI

ANALYSIS OF VARIANCE SUMMARY: APPARENT PROTEIN DIGESTIBILITY COEFFICIENTS FOR CALVES ON DRY AND LIQUID MILK CALCULATED ON PER CENT OF PROTEIN DIGESTED

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F Value	F Table P=.01	F Table P=.05
Total	15	567	-			
Protein	1	144	144	4.77*	8.68	4.54
Error term	14	423	30.2			

TABLE VII

ANALYSIS OF VARIANCE SUMMARY: APPARENT NITROGEN-FREE EXTRACT DIGESTIBILITY COEFFICIENTS FOR CALVES ON DRY AND LIQUID MILK CALCULATED ON PER CENT OF NITROGEN-FREE EXTRACT DIGESTED

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F Value	F Table P=.01	F Table P=.05
Total	15	571	-			
Nitrogen-free extract	1	153	153	5.12*	8.68	4.54
Error term	14	418	29.9			