STEAM PROCESSED-FLAKED GRAINS FOR DAIRY CALVES

by

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STATEMENT BY AUTHOR

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Continued)

ABSTRACT

Two trials were conducted to determine the effect of steam processing and flaking (SPF) grains for calf starters.

In each trial sixty Holstein calves, three days of age, were allotted to give groups equalized for six: (A) steam rolled milo; (B) SPF milo; (C) steam rolled barley; (D) SPF barley; (E) SPF milo and barley plus 20% alfalfa pellets. The feeding regime on an individual basis was whole milk 8% initial body weight, starter and alfalfa hay <u>ad libitum</u> except group (E) received no additional hay.

In Trial I calves were weaned at 35 days of age, and in Trial II at 24 days. Each treatment in Trial I contained 6 males and 6 females and in Trial II 3 males and 9 female calves.

Differences in daily gains were not significant (P .05) in either trial. Steam flaking milo (B) significantly (P .05) improved feed efficiency over steam rolling by 9% and 11% in Trials I and II, respectively. Differences were not significant between barley treatments, but ration (E) was 27% more efficient than (A). Feed requirements, excluding milk, per pound of gain in order of treatment were

Trial I: 2.83; 2.57; 2.42; 2.36; 2.25 and Trial II: 3.33; 2.96; 2.63; 2.51; 2.47. Steam processing and flaking markedly improved the utilization of milo.

INTRODUCTION

Raising dairy calves is a matter of considerable economic importance in every dairy enterprise. An important phase in the expense occurs during the first few weeks of life when the calf, receiving costly feeds in the form of milk and/or a milk substitute also requires considerable individual attention. Therefore, it is to the dairyman's advantage in reducing feed and labor costs to encourage the early consumption of dry feeds and weaning of calves as early as possible.

The stomach of the newborn calf however, is analogous in function to that of a monogastric animal. It is not until the reticulum and rumen or fermentation compartments develop that the calf can readily utilize feeds other than milk or its by-products. The earlier in life a calf consumes solid foods, the sooner the transition of the digestive system to that of a functional adult ruminant begins.

Much attention therefore has been given to the formulation of special grain mixtures termed "calf starters" to be fed with limited amounts of milk. The feeding regimen whereby milk intake is limited is to encourage the earliest possible consumption and exchange of the calf starter for milk at three to six weeks of age, in contrast to milk feeding periods of 8 to 12 weeks.

This method of raising calves has proven successful and is widely adopted, however, some calves do not make the adjustment to dry feeding as well as others, especially at the earlier weaning ages.

Attempts to improve the acceptance and utilization of calf starters by grinding, pelleting, and steaming have generally met with limited success. These limitations are largely due to the inability of the calf to fully utilize sucrose, maltose, starch and/or vegetable proteins during the first four to six weeks of life.

Recent studies by the University of Arizona Animal Science Department have shown that a new method of steam processing and flaking of milo and barley increases their digestibility, resulting in improved gains and feed efficiency of feed lot steers. It is indicated that this treatment renders the starch fraction of the grain more available to the rumen microorganisms and/or enzyme action.

Methods of processing that might render grains more susceptible to microbial attack or enzymatic degradation may be of particular value in preparing feeds for young dairy calves. The research reported in this thesis was conducted to determine the value of steam processing and flaking grains for dairy calves.

REVIEW OF THE LITERATURE

Warner and Flatt (67) have observed that the transition of the monogastric type stomach of the new born calf to the ruminant or "adult" form is a dramatic change occurring primarily within the first 8 to 16 weeks of life. They state that the reticulo-rumen or fermentation compartments in the calf at birth, only constituted about 38 percent of total stomach volume. In contrast, by 8 weeks of age these organs have expanded to 60 percent of stomach capacity and have further increased to 67 percent at 16 weeks of age. This trend continues until the reticulo-rumen makes up about 87 percent of the stomach volume in the adult ruminant.

Warner, Flatt and Loosli (66) demonstrated that this transformation is not a simple enlargement of the organ as the animal grows but is markedly affected by the type of diet. In calves fed milk, grain and hay, the capacity of the reticulo-rumen at 13 weeks of age was found to be almost 4 times larger when compared to calves receiving only milk. They also observed considerable rumen papillary development in the calves receiving milk and dry feeds. In contrast, the papillae remained rudimentary in calves fed only milk or given nylon bristles as the only solid material. These workers were the first to suggest that chemical entities in the feed or the end products of rumen fermentation were probably responsible for development of the rumen papillae.

Flatt, Warner and Loosli (12) reported that the extension of the reticulo-rumen was at about the same rate as body growth in milk fed calves but occurred at a much faster rate in calves receiving milk plus dry feeds. They further noted that papillary growth in the rumen was closely related to dry matter intake.

More recently, Tamate, et al. (61) observed that the reticulo-rumen capacity of calves fed milk, grain and hay was about twice as large at 4 weeks of age as compared to calves fed only milk. In addition, papillae length was about 5 times greater at eight weeks in calves fed milk and dry feeds than at 12 weeks in milk fed calves. The introduction of milk or volatile fatty acids, but not plastic sponges, into the rumen, stimulated papillary growth over milk fed calves but not as well as dry feeds. In contrast, plastic sponges placed in the rumen promoted tissue growth but failed to elicit papillary development.

The effect of dry feeds on rumen papillary development was dramatically demonstrated by Harrison, et al. (21) who could find no papillary growth in calves fed milk to 27 weeks of age. The most striking effect, however, was the disappearance of papillae in calves at 38 weeks of age that had been changed from a diet of milk and dry feed to milk only, at 16 weeks. They also observed that papillae length, at 16 weeks of age, was about 33 percent greater in calves receiving a concentrate to hay ratio of 9:1, versus a ratio of 1:9, and suggested this effect was probably due to a higher energy intake.

Stobo, Roy and Gaston (56) also found that the weight of reticulo-rumen tissue and the length and density of rumen papillae, increased with increasing ratios of grain to hay. In addition, these workers noted that the development of the papillae was associated with the performance of the calves.

Noller, Dickson and Hill (42) observed that calves, weaned at 21 days of age, consumed very little hay when grain was also offered, free choice to 70 days of age. The rumens of these calves showed only moderate papillary development and evidence of rumen plaques and erosion of the rumen mucosa. These effects were not seen in the well developed rumens of calves fed a grain mixture containing ground hay.

Tamate, et al. (60) reported much shorter papillae in calves fed all concentrate rations as opposed to rations of concentrate plus hay. The authors concluded that some hay is necessary for optimal epithelial growth. In a later study, Tamate, et al. (62) fed large amounts of volatile fatty acids and observed histological changes in rumen papillae identical to calves on natural food stuffs but considerably different from calves fed only milk.

Sander et al. (53) demonstrated that the order of effectiveness of volatile fatty acids in stimulating rumen papillary growth was butyrate, propionate and acetate. However, the exact levels or ratios required for maximum papillae development have not been determined.

According to McCarthy and Kesler (34) the shift towards a functional rumen begins as early as one week of age and can be considered similar to that of a mature animal by six weeks of age. They found that *in vitro* cellulose digestion by rumen contents was 25 to 40 percent by one week and these values essentially doubled at 15 weeks. Rumen volatile fatty acid production peaked at 7 weeks and then plateaued.

Lengemann and Allen (30) reported that in calves fed limited amounts of milk and dry feeds, that the rumen acid levels and cellulose digestion could not be distinguished from the adult at between six and seven weeks of age. In contrast, calves fed more liberal amounts of milk did not reach the same values until one to two weeks later.

Martin et al. (32) fed newborn calves purified diets and milk, or milk only and monitored the blood for levels of ketones and volatile fatty acids. Immediately before each feeding, concentrations of blood constituents were similar for all calves. After feeding, however, a marked increase in ketones and volatile fatty acid values occurred in the blood of calves fed solid foods but not in the milk-fed calves. The values increased with increasing age in calves fed the solid foods. These workers concluded that at 3 weeks of age, calves can absorb considerable amounts of volatile fatty acid.

In a series of experiments Sutton, McGilliard and Jacobson (57) demonstrated that the absorptive capacity and metabolic activity of rumen mucosa is low at birth and does not change significantly for several months when only milk is fed. However, when solid feeds were introduced into the diet at four days of age, there was a marked increase in papillary development and absorption. In calves sacrificed at 16 weeks of age, Sutton et al. (58) observed that the *in vitro* uptake and metabolism of volatile fatty acids by rumen mucosa was, in decending order, butyrate, propionate and acetate. In calves fed milk, hay and grain, 88 percent of the butyrate was converted to ketones, in contrast to only 29 percent for milk-fed calves.

Evidence of early rumen activity was observed by Swanson and Harris (59) who noted that of 12 Jersey and 14 Holstein calves fed milk, grain and hay, 9 calves were ruminating between 5 and 10 days of age, 18 by 14 days and 25 by 28 days. Eleven of the Holstein calves were ruminating by 14 days of age. The appearance of rumen contents of sacrificed calves indicated that rumination accompanied or preceded development of normal rumen fermentation and function.

Gilliland, Bush and Friend (18) observed rumination in 24 Holstein calves by 11 days of age, fed a milk and calf starter diet only. However, these workers reported considerable variation among calves in the time spent in this activity.

The role of solid foods in stimulating rumen development and rumination in calves at an early age has motivated researchers to investigate feeding regimens and rations that would permit the earliest possible exchange of dry feeds for milk.

As early as 1924, Mead, Regan and Bartlett (35) introduced the first dry meal mixture, popularly termed a "calf starter" to be fed in conjunction with limited amounts of whole milk. The starter mixture included corn meal, oat process meal and wheat bran. They advocated feeding milk for 30 days at usual levels and then gradually reducing the amounts fed until weaning between 40 and 50 days after which the calves were continued only on starter, hay and water. The authors noted a slight reduction in growth rate at weaning but reported the calves appeared healthful and vigorous. This plan called the dry "calf starter" method marked an epoch in feeding dairy calves, because it did away with extensive periods (4 to 6 months) of feeding large amounts of milk (over 600 pounds) and concentrate gruels. Accordingly, labor and feed costs were reduced. In its simplicity, both the feeding regimen and the calf starter are similar to those currently being recommended for raising dairy calves.

In subsequent investigations during the next several years by Bender and Bartlett (3), Russel, Morrison and Ebling (52), and Jones, Brandt and Wilson (26) the milk feeding period was reduced to as low as 30 days of age and total amounts of milk fed varied between 180 to 350 pounds. Attempts to improve calf starters primarily involved the addition of up to 40% skim milk or other animal protein supplements as noted in work by Knott, Hodgson and Ellington (28) and Berry (4).

The dry calf starter feeding regimen for raising dairy calves was criticized in 1935 by Savage and Crawford (54). They observed that in many studies calves fed limited amounts of milk gained only 1.2 to 1.3 pounds per day to 6 months of age, which was lower than the standard recommended by Eckles (10) of 1.44 pounds. They concluded that a more complete starter was needed for normal growth of calves weaned earlier than 50 to 60 days of age. These workers were the first to recommend a special starter popularly termed a "complex starter" which consisted of a simple starter fortified with skim milk, fish meal, minerals and cod-liver oil. They reported that Holstein calves fed 350 pounds of milk to 7 weeks of age gained an average of 1.56 pounds daily to 4 months of age, and 1.73 pounds to 6 months of age.

The trend in formulation of complex starters continued until some contained 16 or more ingredients as described in a 1942 review by Savage and McCay (55). It was not until about 1950 that workers again focused their attention on formulating the simplified type of calf starters originally pioneered by Mead, et al. (35) in 1924.

Gardner (14) demonstrated that calves of the five dairy breeds could be weaned satisfactorily using a simple calf starter formulated entirely from ingredients of plant origin. The calves each received 370 pounds of milk through 8 to 10 weeks of age plus either a simple or semi-complex calf starter limited to 4.5 pounds daily with hay free choice over the 16 week study. He reported that calves on the simple and complex starters exceeded Ragsdale's (50) growth standard for dairy calves by 14 and 10 percent respectively, but that differences in average daily gain and feed efficiency were not significant.

Similar findings were reported by Murley et al. (39) who fed Jersey calves either simple or complex starters containing 18% protein at a rate of 3 pounds daily plus hay over a 112 day trial period. In addition, each calf received only about 120 pounds of milk with daily amounts gradually reduced to weaning at 35 days of age. The authors found no significant differences between starters in either feed consumption or animal performance. Average daily gains were .95 and .98 pounds for calves fed the simple or complex starter, respectively. These gains are slightly less than the generally recommended rate of one pound daily for normal growth of dairy calves to 3 months of age. However, they are quite acceptable considering the very limited amounts of milk and calf starter fed.

Harrison et al. (20) fed Holstein heifer calves either 350 pounds of milk for 7 weeks or 250 pounds for five weeks in combination with a simple or complex calf starter. Consumption of the starters was limited to 4 pounds daily plus hay. The authors reported a significantly higher gain of 1.20 pounds daily for 350 pound milk group compared to 1.12 pounds for the 250 pound group over the 7 week study. Starter consumption was significantly greater for calves receiving 250 pounds of milk, but total feed costs were less. No differences were observed in the performance of calves fed either the simple or complex starter.

In a series of trials, Clark and Whiting (8) fed Holstein calves a simplified starter and hay free choice. Milk was fed at the rate of 6 pounds daily for 24 and 28 days or 8 pounds per day for 28 days. Average daily gains accordingly were 1.45, 1.52, and 1.58 pounds to 112 days of age. These workers stated that the differences in milk intake did not influence weight gains when the total gain was related to the birth weights.

Pardue et al. (46) reported the successful weaning of Holstein and Jersey calves at 24 days of age when fed 180 pounds of whole milk at 10 percent body weight. Average daily gains during the 87 day trial were 1.54 and 1.41 pounds respectively for calves fed a simple starter with and without dried skim milk. The authors noted that differences in growth rate, feed consumption, or nitrogen retention were not significant between treatments. They concluded that the addition of dried milk products to calf starters is not a requisite to early weaning.

Gardner (15) compared a simplified mesh and pelleted calf starter containing 18% plant protein to a complex commercial pellet having 24% protein from plant and animal sources. Holstein calves were fed about 95 pounds of whole milk and 285 pounds of skim milk at the rate of 10% body weight with gradual weaning at 42 days of age. He found that up to 200 pounds body weight, the calves consumed significantly more of the simple mesh and pelleted starters than the complex commercial starter. Average daily gains respectively were 1.36, 1.34, and 1.21 pounds. He concluded that the formulation of complex starters containing plant and animal proteins to obtain a more favorable amino-acid balance, did not appear to be of practical importance.

Brown and Lassiter (6) investigated the effect of feeding three protein levels, 14, 16, and 18 percent, and three protein-to-energy rations, 1:46, 1:48, and 1:50, in pelleted calf starters containing 25% alfalfa hay. Holstein calves were fed 228 pounds of milk and Guernseys, 169 pounds for the first 40 days of the 84 day trial. Results of this study showed little difference in average daily gains of 1.12, 1.02, and 1.10 pounds related to protein levels, respectively. In contrast, the protein-to-energy ratio appeared to influence growth rates at all protein levels, particularly after weaning. As the ratio increased 1:46, 1:48 and 1:50, post-weaning gains decreased, averaging 1.52, 1.51 and 1.28 pounds per day, respectively. These workers concluded that for optimum growth and feed efficiency, the protein-to-energy ratio should not exceed 1:46. However, there was apparently no real difference in daily gains until the ratio exceeded 1:48.

In a more recent study of protein levels in calf starters, Gardner (16) fed three complete starter rations containing 20% alfalfa hay and either 12, 15 or 16% crude protein (8.5, 11.3 and 13.5% digestible), to Holstein calves weaned at 42 days of age. Average daily gains related to starter protein content were 1.23, 1.21 and 1.32 pounds, respectively, up to 200 pounds body weight. There were no significant differences in body growth, feed consumption or ration digestibility among treatment groups. He further noted that digestible calorie utilization for weight gains apparently was not affected by the level of digestible protein in the rations. Later, after investigating similar starters containing 11 and 12% protein, Gardner and Maqsood (17) have suggested 12% crude protein (8.8% digestible) as a minimum in formulating simplified high energy calf starters.

The National Research Council (40) recommends a diet containing approximately 23% crude protein for growing calves weighing about 95 to 136 pounds, and 15% crude protein from 139 to 200 pounds body weight. These requirements appear to be higher than actual needs. However, some degree of caution should probably be exercised in formulating calf starters with minimum protein levels, as noted above by Gardner (16) when calves are to be weaned at a very early age.

Brown, et al. (5) fed starters to calves from birth to 82 days of age containing 6.7%, 15.2%, and 15.1% crude protein with urea supplying 54.2% of the nitrogen in the latter starter. All groups of calves grew at comparable rates during the 6 week milk feeding period. After weaning the urea supplemented group and the 15.2% conventional protein group showed no significant differences in growth rate, feed consumption, or feed efficiency but these values were significantly less for the low protein starter group. The results show that the microorganism population of the rumen is developed sufficiently by 4 to 6 weeks of age to be capable of obtaining a portion of the nitrogen requirements for the young calf from urea. Moreover, this study suggests that the length of the milk feeding period is important in determining protein levels for calf starters.

In a trial conducted to determine the effect of incorporating high levels of hay in calf starters, Hibbs, Conrad and Pounden (23) fed Jersey and Holstein calves milk to 7 weeks of age, plus a simple starter containing 13.6% crude protein and 60% legume grass hay. Average daily gains respectively were .68 and 1.07 pounds for the Jersey and Holstein calves to 12 weeks of age. They noted that these gains were slightly less than the recommended Ragsdale growth standard and that considerable variation occurred among animals. However, considering the high level of forced hay intake, the average gains obtained are probably acceptable, but it is doubtful that calves weaned at earlier ages would perform well on such low energy starters.

Van Dyk and Waldern (65) used week-old Holstein calves fitted with rumen fistulas to determine the value of including hay in a starter fed to calves weaned at 5 weeks of age. They found that at 9 weeks of age, calves receiving a pelleted starter containing 20% alfalfa hay had greater development of the rumen mucosa and higher rumen levels of volatile fatty acids, compared to calves fed the starter without hay or with chopped hay, free choice. Calves fed milk, starter and chopped hay to 9 weeks of age had less rumen papillae development, than calves weaned at 5 weeks of age. These researchers concluded that the addition of some hay to all starters was beneficial to rumen development but that feeding milk beyond 5 weeks of age retarded rumen development and maturation.

Noller, et al. (42) have reported the successful weaning of Holstein calves at 21 days of age fed 70 pounds of milk and 77 pounds of liquid milk replacer. A calf starter containing skim milk and about 19% crude protein was fed free choice with loose hay or as a complete ration containing 32% ground alfalfa hay. Average daily gains of 1.00 to 1.12 pounds between treatment groups was not significant. However, the calves fed starter and hay free choice consumed an average of only 15 pounds of hay compared to 56 pounds per calf when hay was incorporated into the starter. These workers observed that the starter containing hay was consumed more readily after weaning, promoted more development of the rumen and resulted in less digestive upsets. They also noted that the early weaned calves showed less fleshing than normal, but all appeared very thrifty.

Attempts to rear calves exclusively on dry feeds after two weeks of age have generally been unsuccessful according to Preston (49). There has apparently only been one report of calves being raised satisfactorily on an all-solid feed diet after only 8 days of liquid feeding by Mochrie and Murley (37). One group of calves received liquid milk replacer to 28 days of age, and two other groups were fed liquid replacer to 8 and 15 days of age and thereafter pelleted milk replacer to 28 days. A calf starter and hay were fed free choice after 8 days of age. The average daily gains according to the liquid feeding periods were .86, .70, .91 pounds, respectively at 63 days of age. The authors made no remarks relative to the health or thriftiness of the animals or if any difficulties in weaning were encountered.

More recently Bush, et al. (7) fed liquid and pelleted milk replacers to calves through 35 days of age after receiving whole milk to 10, 17, and 28 days of age. A semi-complex calf starter composed of only plant ingredients was fed _ad libitum_ throughout the eight week trial. General thriftiness, health, starter consumption and average daily gains of .93, 1.04, and 1.07 pounds for all calves in order of the whole milk feeding periods above were not significant. Consumption of the milk replacer pellet and weight gains were more consistent for calves fed whole milk to 17 rather than 10 days of age, but no differences were observed among calves fed the liquid or pelleted milk replacer to 17 days of age.

Various attempts have been made by researchers to improve the palatability and utilization of dry feeds or calf starters by cud-inoculations or by incorporating enzymes, vitamins, flavor extracts and various other condiments into starters and by grinding, pelleting and/or steaming, etc. But despite some degree of success, the results in general have been disappointing.

Pounden and Hibbs (48) observed very little difference in the performance of Jersey calves inoculated orally with cuds taken from the mouths of adult animals. Milk was fed to 7 weeks of age plus a simple calf starter and hay. Calves receiving the inoculations exhibited smoother hair coats and lacked the "pot bellied" appearance seen in the uninoculated calves, but there was little difference in growth at 6 months of age.

Conrad and Hibbs (9) reported a slight improvement in the digestibility of dry matter by Jersey calves given weekly cud inoculations to 6 weeks of age and weaned from milk at 7 weeks. Cellulose digestibility was 64.4% for the inoculated calves and 61.3% for the uninoculated calves.

In an attempt to stimulate greater rumen function in calves weaned at 21 days of age, Noller, et al. (42)

administered cud-inoculations at intervals between 14 and 42 days of age. They observed that cud-inoculations improved the general appearance of the calves and condition of the feces, and increased starter intake. However, these authors concluded that the benefits were short-term and therefore the practice was probably of little practical value.

Yang, Bush and Odell (69) fed a simple calf starter, with and without a commercial bacterial-enzyme preparation, to Holstein calves weaned at 24 days of age. There was no significant difference among treatment groups in weight gains, feed consumption or general health of the calves. From these and previously reviewed studies it would appear that the microbiological population in the rumen of the young calf is sufficiently developed, even at an early weaning age, to preclude the practical application of rumen inoculations.

Hibbs, Pounden and Conrad (22) were unable to obtain any advantage from the addition of a vitamin B12 supplement to a simple starter fed to Jersey calves up to 12 weeks of age. This finding agrees with the observations of Lengemann and Allen (30) who observed that the vitamin content of the rumen solids of the calf at 6 weeks of age could not be distinguished from the adult.

Recognizing the role of volatile fatty acids in rumen development, Gilliland, et al. (18) fed Holstein calves, weaned at 28 days, a calf starter containing the sodium, potassium and calcium salts of propionate and butyrate in equal amounts on a molar basis. The starter had no significant effect on weight gains, feed consumption or rumen development when fed to calves up to 39 days of age. These observations are in accord with those of McCarthy and Kesler (34) who reported a peak in volatile fatty acid production at 7 weeks of age in calves fed dry feeds. Apparently the consumption of solid foods at an early age results in sufficient volatile fatty acid production for maximum rumen development.

Wing (68) examined the effect of adding a commercial flavoring material to a calf starter. He reported a significant increase in starter intake and preference of calves for the flavored starter, particularly between 31 and 60 days of age. Milk was fed at 9% of body weight to 60 days. The use of this flavoring material in starters for earlier weaned calves has apparently not been reported.

Norton and Eaton (43) observed a measurable increase in palatability of a complex starter when the molasses content was increased from 5 to 12.5%. The calves consumed 49% more of the starter containing 12.5% molasses at 10 weeks of age.

The addition of either molasses, sucrose or dextrose at a level of 8% to simple calf starters was reported by Atai and Harshbarger (2) to have increased starter consumption and weight gains significantly in calves weaned at 5 weeks of age. The average daily gain in 84 days was 1.33 pounds for the controls and 1.46 pounds for calves fed the sweetened starters with starter consumptions of 182 and 210 pounds, respectively. The difference in growth occurred primarily after weaning. There were no differences observed between sweetened starter treatments.

Grinding, rolling, crushing, cooking and steaming grains is often used to facilitate mixing various grains together, to enhance palatability and/or to improve the utilization of certain grains by livestock. Riggs (51) reported that grinding grains tended to increase gains and decrease feed requirements compared to whole grain, and that dry rolling or crushing has little or no advantage over grinding.

According to Morrison (38) such preparation is usually profitable only for certain grains or for those classes of livestock which fail to chew the grains thoroughly. For example, he states that after a few weeks of age calves chew corn or oats thoroughly up to about 6 or 9 months of age, hence there is no advantage in grinding these grains for them. In contrast, such hard cereal grains as barley, wheat and milo should always be ground. He further notes that calf starters are more palatable when the grains are ground coarse instead of fine.

Otis (45) reported that calves fed shelled corn began eating grain sooner and had an average daily gain of 1.74 pounds versus 1.59 pounds for calves fed ground corn in a 133 day trial. In contrast calves fed ground kafir grain had better feed efficiency and an average daily gain of 1.58 pounds compared to 1.44 pounds for calves fed the hard whole grain.

For dairy calves, Kildee (27) suggested feeding cracked corn for the first 30 days followed by whole shelled corn. He also stated that whole oats were better than ground oats for young calves.

Fain and Jarnagin (11) reported that calves fed shelled corn had only slightly greater feed consumption and average daily gains than calves fed ground corn.

McCandlish (33) allowed calves a free choice selection of either whole or ground corn or oats along with several other feed ingredients in self feeders. He observed that the young calves preferred the whole corn and oats to the ground grains. Also, the calves showed a particular dislike for gluten meal.

Hilton, Wilbur and Hienton (24) fed calves a grain mixture of whole grains and the same mixture ground to a medium degree of fineness. No significant differences in growth were observed to 6 months of age although the calves consumed approximately one-fourth of a pound more of the ground mixture daily. These results may have been influenced by the milk feeding regimen of 10 pounds daily to 4 months of age.

Norton and Eaton (43) found that calves up to 10 weeks of age consumed almost 4 times more starter containing cracked corn than one with ground corn. On the other hand, there was little difference in the palatability of a starter containing rolled oats and one with crushed oats.

Pelleting of grains has received much attention in recent years and many calf starters are prepared in this manner. Newmann and Savage (41) reported that pelleting two calf starters decreased their consumption and reduced calf gains compared to the same starters fed as a meal. The authors noted that the three-sixteenth inch diameter pellets were quite hard and less palatable to calves from 2 to 6 weeks of age.

Lassiter, et al. (29) fed starters prepared in three forms: all meal, all pellet (3/16 inch diameter) and equal parts meal and pellet to calves up to 72 days of age. When calves were limited to one type of starter the physical texture had no significant effect on growth or feed consumption. But when the three starters were offered together on a free choice basis the calves significantly consumed more of the all pellet starter. Consumption of the meal starter was the lowest but without molasses it may have contained considerable fine material.

More recently Gardner (15) reported that calves exhibit a dislike for finely ground feeds unless they are pelleted. He observed, however, that pelleting appeared to reduce the total digestibility nutrients with the exception of nitrogen - free extract, in which case digestibility was enhanced. He concluded that the primary advantage in pelleting is to reduce feed wastage largely caused by the refusal of calves to consume fine material.

For many years it was believed that cooking or steaming feed greatly increased its value. According to Morrison (38) such preparation does not increase the digestibility and in some instances there is a decrease.

Yang, et al. (69) fed calf starters containing corn and oats steam rolled at 190°F to Holstein calves weaned at 24 days of age. They reported no significant difference in feed consumption or average daily gains among calves fed the steam treated or dry rolled starter rations to 16 weeks of age.

Recent studies by University of Arizona researchers have shown a new method involving the moist heat treatment and flaking of cereal grains to be beneficial in the performance of feed lot cattle. According to Hale, et al. (19) the "steam-process flaking" method consists of raising the moisture content of the grain to approximately 18% by steaming for about 20 minutes at atmospheric pressure, having the grain enter the rollers at 205 to 212°F, and rolling a flat flake. These workers found that steers fed steam-processed flaked milo or barley gained .26 and .22 pounds more per day and had a daily increase in feed intake of 1.0 and 1.7 pounds, respectively compared to steers fed the same grains dry rolled.

Matsushima (31) observed similar results when corn was steamed for 12 minutes at 200°F before flaking. He reported feed efficiency with steers was increased by 10% and that fewer animals went off feed.

In vitro studies indicate that steam processing and flaking of grains improves both the rate of fermentation and enzymatic starch digestion. Moreover, they demonstrate that the degree of flaking ranging from a poor to an excellent flat flake is apparently critical relative to the beneficial results obtained.

Mehen (36), Husted, et al. (25) and Hale, et al. (19) reported steam processed flaked milo was significantly more digestible than dry rolled milo. The primary fraction affected was the nitrogen free extract which is considered to be the starch component of grain. Mehen (36) found no significant differences between the digestibilities of any fraction of dry rolled and steam processed flaked barley.

Trei, Hale and Theurer (64) using an artificial rumen system, reported that without flaking, the steam processing of barley effected no change in gas production but that steam processing of milo decreased gas production. In contrast, when steam processed barley and milo were flaked, gas production increased and continued to increase markedly with the flatness of the flake. Gas production was 48% and 30% greater for steam-processed flaked barley and milo, respectively than for the same grains dry rolled.

In vitro work by Osman, et al. (44) using pancreatic enzymes also showed that flaking greatly improved starch digestion of steam-processed grains. Steaming without flaking decreased starch digestion of both barley and milo. On the other hand, a maximum increase in starch digestion of 126% for barley and 173% for milo was noted in going from a dry rolled flake to a steam processed excellent flat flake. The rate of digestion increased as the steam-processed flake became thinner.

Theurer, Trei and Hale (63) using a rumen cell suspension technique, measured volatile fatty (VFA) acid production from barley and milo processed by different methods. Total VFA production increased from a dry roll to a steam-processed flat flake by 700 and 650 micromoles of

VFA per gram of dry matter incubated for barley and milo, respectively. Accordingly the level of acetate decreased in relation to the propionate and butyrate levels.

These studies show that steam processing and flaking of barley and milo increased their susceptibility to degradation by rumen microorganisms and/or enzymatic action resulting in greater starch digestion and volatile fatty acid production. The value of steam processed flaked grains for dairy calves has not been determined. It is suggested this treatment of grains may improve their acceptance and utilization by dairy calves thereby enhancing rumen development, early weaning and body growth.

EXPERIMENTAL PROCEDURE

One hundred and twenty Holstein male and female calves from the University Dairy Herd were used in two trials of 60 calves each. The calves suckled their dams for the first three days after birth and were then penned and fed individually.

Whole milk was fed at a rate of 8% of body weight determined at the start of the experiment. The total amount was fed in equal portions twice daily from open pails. If diarrhea occurred the milk allowance was temporarily reduced as necessary. The calves were weaned abruptly in Trial I at 35 days of age, and in Trial II at 24 days of age. Except for age at weaning, the calves in both trials were handled in the same manner.

Each calf was allotted at random to one of the following calf starter treatment groups:

A. Steam rolled milo

B. Steam processed flaked milo

C. Steam rolled barley

D. Steam processed flaked barley

E. Steam processed flaked milo and barley plus 20% alfalfa hay pellets.

Each treatment group containing 12 calves was equalized for sex. In Trial I each group contained 6 males and 6 females. In Trial II each group contained 9 females and 3 males.

The composition of the experimental calf starters is given in Tables 1 and 2. The calculated total digestible nutrient values for the grains were: steam rolled milo 70%, steam processed flaked milo 77%, and steam rolled and/or steam processed flaked barley 78%. The alfalfa hay contained 12.2% protein and 55% total digestible nutrients. All calculations and data relative to dry feed intake are based on 90% dry matter.

The milo and barley were processed according to the University of Arizona steam processing method of flaking grains (1). In this method an oversized tempering chamber is filled with grains and subjected to low pressure and high moisture steam for approximately 20 to 25 minutes. The temperature of the grain is raised to between 205 to 210 degrees fahrenheit and is rolled at this temperature. The process becomes continuous when the grain starts to flow by gravity through the roller mill and the dry grain is introduced into the top of the chamber. The moisture content of the milo is approximately 18 percent from the rollers and the corresponding value for barley is 15 percent. The roller mill is adjusted to a cold roller spacing

TABLE 1

Calf Starter Composition[1]

Ingredients	A-B	C-D	E
		%	
Milo	74.40		30.45
Barley		76.90	30.45
Cottonseed oil meal	15.10	12.50	
Soybean oil meal			9.00
Molasses	8.00	8.00	8.00
Alfalfa hay pellets			20.00
Salt	0.50	0.50	0.50
Dicalcium phosphate	0.80	0.90	1.10
Ground limestone	0.70	0.70	
Aurofac 10	0.50	0.50	0.50

[1]Vitamin A (10,000 IU/gm) 40 grams added per 100 pounds of ration

TABLE 2

Calculated Analysis

Nutrient	Ration (%)			
	A	B	C-D	E[1]
Total Digestible Nutrients	66.36	71.58	72.55	69.36
Protein	13.58	13.58	13.51	13.57
Phosphorus	0.49	0.49	0.48	0.46
Calcium	0.56	0.56	0.58	0.66

[1]Includes values for 20% alfalfa hay pellets

of 0.002 inches.

The difference between the steam rolled and the steam processed flaked grains was the rate at which the rollers were fed. A slow rate of feeding the grains into the roller mill produced the steam-processed flaked milo with an average weight per bushel of 25 pounds on an air dry matter basis and the flaked barley with an average weight of 23 pounds. A faster feeding of the grains into the rollers produced the steam rolled milo and barley with an average weight per bushel, on an air dry basis, of 36 and 33 pounds, respectively.

Dry feed was offered to the calves when placed on experiment at 4 days of age. The experimental starters and loose alfalfa hay were offered ad libitum, except the calves fed the complete starter ration in group E did not receive additional hay. Small amounts of starter and hay were fed initially and then gradually increased according to the calves appetite to offer fresh feed to the animals daily. All feed was weighed and recorded. Feed refused was weighed-back and examined for possible selectivity of ingredients. Fresh water in a pail was offered from the beginning of the experiment and changed daily.

Calf weights were taken at 3 days of age, at weaning, and biweekly thereafter except for additional weighings as needed to identify the termination weight of

200 pounds. Body dimensions were observed at 3 days of age, at weaning, and at 200 pounds. Measurements included height at the withers, length from the withers to the pin bones and the heart girth.

Measures of treatment effects included the pre-weaning and post-weaning rate of gain, feed consumption, feed efficiency, skeletal growth and the general health of the calves.

Analysis of variance and Ducans multiple range test (13) were used to locate differences among treatment means.

RESULTS AND DISCUSSION

In presenting the results the data are given for two phases of the growth period: first, the pre-weaning period; and second, the post-weaning period. The results are then summarized for each of the complete trial periods.

Pre-Weaning Period

Data related to the pre-weaning periods in Trial I, 1 to 35 days and Trial II, 1 to 24 days are summarized in Table 3 with the exception that body measurements are listed in Appendix Table (12). No statistically significant ($P>.05$) differences were noted in average daily gains among treatment groups in either trial. The average initial weight for all calves in each trial was 89 pounds and the average total gain during the pre-weaning period was 22.4 and 11.9 pounds for calves on Trials I and II respectively. Accordingly average weaning weights were 111 and 101 pounds for calves weaned at 35 and 24 days of age.

Calves fed the flaked milo (B) and flaked barley (D) calf starters and the complete starter ration (E) had slightly better gains compared to calves fed the steam rolled milo (A) and rolled barley (C) in Trial I. Calves fed the steam rolled milo had the lowest pre-weaning gains in both trials.

TABLE 3

SUMMARY OF DATA FOR PRE-WEANING PERIODS IN TRIAL I (1-35 days) AND TRIAL II (1-24 days)

Treatment	Initial Weight	Milk Intake	Average Daily Gain	Average Total Feed Intake Starter[1]	Hay
			(lb.)		
(Trial I)					
A	91	248	0.52	22.1	2.9
B	87	243	0.65	20.1	4.6
C	90	254	0.57	17.4	3.9
D	87	244	0.71	17.4	4.0
E	89	249	0.75	17.0	3.0
(Trial II)					
A	90	171	0.45	10.0	4.0
B	92	175	0.49	10.0	3.0
C	88	169	0.50	9.4	3.8
D	86	165	0.49	7.0	2.8
E	90	173	0.54	7.0	1.0

[1]Represents concentrate portion of ration only.

A. Steam rolled milo
B. Steam processed flaked milo
C. Steam rolled barley
D. Steam processed flaked barley
E. Steam processed flaked milo and barley

Differences in starter intake were greater among individuals within treatments than between treatments as shown in Appendix Tables (13, 14). Calves weaned at 35 days of age consumed an average of 248 pounds of milk compared to 171 pounds for calves weaned at 24 days. All calf starters appeared to be accepted equally well at weaning. However, calves fed the complete starter ration (E) were reluctant to consume the alfalfa pellets especially during the first four weeks of age as noted in Trial II.

It is generally recommended that calves be consuming at least 3/4 to 1 pound of starter daily for successful weaning. Early in Trial I it was noted that several calves were consuming less than one-half pound of the various starter treatments at weaning on the 35th day.

In an attempt to enhance starter consumption at weaning the milk feeding schedule was adjusted to reduce the amount of milk fed by one-half on the 34th day and to one pound per feeding on the 35th day. However, this reduction in the milk allowance failed to cause any appreciable increase in starter consumption among the next 12 calves weaned. Some calves apparently will eat very little dry food when milk is being fed and will go hungry between feedings when the milk allowance is reduced. It appeared that gradual weaning could further delay the change over to dry feed resulting in a possible check in the growth rate.

Subsequently all calves except for 12 were weaned abruptly regardless of the amount of starter being consumed. Calves weaned abruptly quickly realized by the second feeding that no additional milk was forthcoming and starter intake rapidly increased and no weaning difficulties were encountered. When calves are thrifty the practice of continuing milk feeding until starter consumption reaches a minimum level is not recommended as long as calves are consuming some dry feed.

Diarrhea and other digestive upsets were minimal in both trials but occurred less frequently among calves weaned at 24 days since some digestive upsets among calves in Trial I occurred during the later part of the milk feeding period. It is often suggested that one of the benefits of early weaning is that the occurrence of digestive upsets and diarrhea are less likely than when milk feeding is continued for prolonged periods.

Two calves receiving the flaked milo (B) and rolled barley (C) starters died within the first 15 days of life in each trial. A third calf in Trial II receiving the complete ration (E) died at 65 days of age. Since the cause of the deaths could not be attributed to the experimental treatments the calves were replaced.

Post-Weaning Period

No statistical differences ($P > .05$) were observed in average daily gains during the post-weaning period as shown in Table 4.

Daily gains were slightly lower for calves fed the flaked milo (B) compared to rolled milo (A) in Trial II. Calves receiving the rolled (C) and flaked (D) barley treatments had higher daily gains than calves fed the other treatment starters in both trials. Although calves in Trial I showed more uniform daily gains among treatments it appears in general that differences in milk intake had little if any influence on average daily gains in the post-weaning periods.

Differences in total feed required per pound of gain were not significant ($P > .05$) in Trial I but were statistically significant ($P < .05$) in Trial II. In probability this difference was due to the greater variability in hay consumption and longer milk feeding period in Trial I.

In Trial II calves fed the flaked milo starter (B) required less feed per pound of gain than calves receiving the rolled milo (A). On the other hand calves fed the rolled (C) or flaked barley (D) or the complete starter (E) were more efficient in feed conversion than calves fed the milo rations.

When considering only the calf starters or concentrate portion of the rations without the hay, differences

TABLE 4

SUMMARY OF DATA FOR POST-WEANING PERIODS IN TRIAL I AND TRIAL II

Treatment	Average Total Feed Intake Starter[1]	Hay	Average Daily Gain	Total Feed per lb. Gain	Starter[1] per lb. Gain
	(lb.)				
(Trial I)					
A	264	25	1.56	3.12	2.84a
B	240	36	1.57	2.92	2.55b
C	222	27	1.67	2.71	2.41bc
D	228	21	1.62	2.77	2.54b
E	194	38	1.54	2.71	2.27c
(Trial II)					
A	314	46	1.48	3.55a	3.10a
B	274	46	1.43	3.18b	2.72b
C	253	35	1.60	2.81c	2.48c
D	244	41	1.65	2.72c	2.33c
E	227	40	1.61	2.68c	2.27c

[1]Represents concentrate portion of ration only.

[a,b,c]Figures within the same trial and column with differing superscripts were significantly ($P < .05$) different.

A. Steam rolled milo
B. Steam processed flaked milo
C. Steam rolled barley
D. Steam processed flaked barley
E. Steam processed flaked milo and barley

in feed efficiency were significant in both trials. Calves receiving the steam rolled milo (A) consumed more starter per pound of gain than calves fed the steam flaked milo (B) and other calf starters. In contrast, calves given the complete flaked milo and barley ration (E) were the most efficient in feed conversion, but this difference was not significant at all treatment levels.

Data relative to the crude protein and total digestible nutrients (TDN) consumed during the post-weaning period are reported in Table 5.

Recent studies (6, 16, 17) have suggested that the protein requirements recommended in current feeding standards (38, 40) for dairy calves are much higher than actual needs. The level of crude protein in the calf starter rations in this study average approximately 13.6 percent. Comparable rations formulated according to the requirements given by the National Research Council (NRC) (40) for normal growth of dairy calves between 110 and 200 pounds would conservatively have contained 18 to 20% crude protein. The total protein intake at all treatment levels therefore was considerably less than the recommended amounts but weight gains and feed efficiency suggest protein intake was not a limiting factor according to NRC growth standards.

TABLE 5

SUMMARY OF DATA FOR CRUDE PROTEIN AND TOTAL DIGESTIBLE NUTRIENT (TDN) CONSUMPTION IN POST-WEANING PERIODS TRIAL I AND TRIAL II

Treatment	Average Daily Protein Intake	Average Total TDN Intake Starter[1]	Hay	TDN/ lb. Gain Total Feed	TDN/ lb. Gain Starter[1]
	(lb.)				
(Trial I)					
A	0.650	174	13.9	2.03	1.88
B	0.615	172	19.6	2.03	1.83
C	0.609	162	14.9	1.92	1.76
D	0.611	166	11.6	1.98	1.85
E	0.563	142	20.9	1.90	1.66
(Trial II)					
A	0.710	207	25.2	2.30a	2.05a
B	0.613	197	25.4	2.21a	1.96ab
C	0.603	184	19.0	1.99b	1.81bc
D	0.597	178	22.4	1.92b	1.70c
E	0.584	165	22.4	1.88b	1.66c

[1]Represents concentrate portion of ration only.

[a,b,c]Figures within the same trial and column with differing superscripts were significantly ($P < .05$) different.

A. Steam rolled milo
B. Steam processed flaked milo
C. Steam rolled barley
D. Steam processed flaked barley
E. Steam processed flaked milo and barley

For example the NRC recommends 340 grams of crude protein per day for calves weighing 165 pounds and gaining 550 grams daily. By contrast, calves fed the complete starter ration (E) in Trial II consumed an average of approximately 265 grams of crude protein per day while gaining 731 grams daily from weaning at 24 days of age to 200 pounds body weight.

During the post-weaning period all calves in Trial I consumed an average of 277 grams of protein daily while gaining 722 grams per day. Calves in Trial II consumed 283 grams of protein and gained 704 grams daily. The lower levels of protein consumed in both trials did not appear to adversely affect feed efficiency. Calves consuming the least amount of crude protein required less feed per pound of gain as noted among calves fed the complete ration (E) in Trial II. However, the digestibility of crude protein in milo is less than in barley. Therefore, the lower average daily gains observed among calves fed the milo compared to the barley rations may indicate that the protein intake was near the minimum level among calves fed the milo rations.

These observations are in agreement with those of Gardner (16) who reported similar growth rates among calves consuming slightly less protein. He observed that calves consumed an average of 238 grams of crude protein while gaining 718 grams per day from weaning to 200 pounds body weight. However, the calves were not weaned until 42 days of age and the length of the milk feeding period has been shown by Brown, et al. (5) to influence the levels of protein required in calf starters. Nevertheless, the protein levels in this study appeared to be satisfactory for calves weaned as early as 24 days of age.

The NRC requirements are related to a given daily feed intake and calf starter consumption is often limited to a maximum of 3 to 5 pounds daily. By imposing restrictions on feed consumption protein requirements may easily be confounded with energy requirements for growth. It would appear that a high level of energy intake and not a high level of protein is the primary need of the young calf to attain maximum growth, especially when weaned at an early age. The levels of protein fed in this study appeared to satisfactorily meet the requirements of calves weaned as early as 24 days of age.

No significant differences were observed in total digestible nutrients (TDN) per pound of gain in Trial I. On the other hand, differences in TDN consumed in Trial II were similar to differences observed in total feed and starter consumption but the TDN differences were not significant between rolled and flaked milo.

An average of 3.03 pounds of total digestible nutrients (TDN) was consumed daily during the post-weaning period by calves fed the complete starter ration in Trial II. The calves gained 1.61 pounds daily for a conversion of 1.9 pounds TDN per pound of gain. Again these values are not consonant with comparative NRC values. According to their recommended requirements a 165 pound calf should gain 1.21 pounds daily if consuming 3.30 pounds of TDN per day which gives a conversion value of 2.75 pounds of TDN per pound of gain.

Although the TDN values are calculated the data suggest that the TDN requirements, apparently are higher than necessary but come closer to meeting actual needs than the recommended protein requirements. It is recognized of course that the NRC recommendation must over estimate rather than under estimate the requirements and that the calves in this study were fed *ad libitum* for maximum growth. The TDN intake on all treatments was less than the recommended amounts except for 3.4 pounds of TDN consumed daily by calves fed the rolled milo starter in Trial II. Gardner (16) also observed lower energy or TDN requirements per pound of gain for calves having similar gains and fed calf starter containing 20% alfalfa hay *ad libitum*.

COMPLETE TRIAL PERIOD

Differences in average daily gains, Table 6, were not statistically significant ($P > .05$) at the end of either trial period. Average daily gains among calves in Trial II weaned at 24 days of age were generally greater than for calves weaned at 35 days in Trial I. This is in contrast to the trend of slightly greater average daily gains observed among calves in Trial I during the pre-weaning and post-weaning periods. However, calves in Trial II required fewer total days to reach the termination weight of 200 pounds and also gained a greater portion of their weight over more days in the post-weaning periods than calves in Trial I. Therefore, differences in milk intake apparently did not influence average daily gains for the complete trial periods which is in agreement with similar observations by Clark and Whiting (8). No differences were observed in the general appearance of the calves at the end of either trial period.

Body dimensions at equal weights differed considerably more between calves within treatments than between treatments, Appendix Table (12). Skeletal development was indicative of the influence of high energy levels on growth

TABLE 6

SUMMARY OF DATA FOR PRE-WEANING AND POST-WEANING PERIODS TRIAL I AND TRIAL II

Treatment	Age to Reach 200 lb	Average Feed Intake[1] Starter	Average Feed Intake[1] Hay	Average Daily Gain	Total[1] Feed/ lb. Gain	Starter[2] lb. Gain
	Days			(lb.)		
(Trial I)						
A	95	286	28.1	1.17	2.83a	2.58a
B	95	260	40.1	1.23	2.57b	2.23b
C	90	239	31.0	1.24	2.42bc	2.14b
D	90	245	25.0	1.27	2.36bc	2.14b
E	91	211	41.0	1.24	2.25c	1.88c
(Trial II)						
A	92	324	49.9	1.22	3.33a	2.89a
B	94	284	49.2	1.19	2.96b	2.53b
C	88	262	38.3	1.30	2.63bc	2.29bc
D	88	251	45.6	1.34	2.51c	2.14c
E	86	234	41.0	1.30	2.47c	2.10c

[1] Excluding milk.

[2] Represents concentrate portion of ration only.

[a,b,c] Figures within the same trial and column with differing superscripts were significantly (P .05) different.

A. Steam rolled milo
B. Steam processed flaked milo
C. Steam rolled barley
D. Steam processed flaked barley
E. Steam processed flaked milo and barley

irrespective of daily protein consumption and there was little difference in measurements among treatment groups. However, calves fed the complete ration with alfalfa pellets had slightly smaller heart girth measurements in both trials which may be related to the lack of bulk in the diet.

Total calf starter and hay consumption was less but feed efficiency was greater for all treatments in Trial I compared to Trial II. Calves in Trial I consumed an average of 248 pounds of starter and 33 pounds of hay compared to 271 pounds of starter and 45 pounds of hay among calves in Trial II. These differences reflect the influence of the length of the milk feeding period and the greater amount of milk consumed by the calves in Trial I. However, the milk feeding period apparently did not influence the significant differences in feed efficiency within Trials.

Calves fed the steam rolled milo starter (A) required significantly (P .5) more feed per pound of gain compared to calves fed the other four starter rations in both trials. Steam processing and flaking the milo grain improved feed efficiency by 9% in Trial I and 11% in Trial II compared to steam rolling. Statistically flaked milo (B) was not different from rolled (C) or flaked (D) barley except in Trial II flaked barley was more efficient.

Flaking did not improve the feed efficiency of barley compared to steam rolling.

These observations agree with results reported by Mehen (36) Husted, et al. (25) and Hale, et al. (19) in studies with steers. They found that steam processed flaked milo was significantly more digestible than rolled milo. However, Mehen (36) observed no differences in the digestibility of rolled or flaked barley. Hale, et al. (19) reported that steam-processing and flaking milo improved feed efficiency, but feed required per pound of gain was not affected by steam-processing and flaking barley.

The combined steam processed and flaked milo and barley treatment (E) was not significantly different in total feed efficiency compared to the rolled (C) or flaked (D) barley calf starters. On the other hand, the combination or complete calf starter significantly (P .05) improved feed efficiency by 21% and 26% compared to rolled milo in Trials I and II, respectively. Accordingly this improvement was 12% and 17% when compared to flaked milo.

When considering only the concentrate portion of the rations the significant differences in feed efficiency among treatments noted above were the same with the exception in Trial I the complete ration was the most efficient. Also, utilization of the complete ration without alfalfa pellets was calculated separately for both trials to be 27% greater than rolled milo and about 13% greater than flaked milo. These results suggest that hay consumption had little effect on the significant differences in feed efficiency among treatments especially in Trial II where hay intake was relatively uniform.

All rations were readily consumed with the exception that the flaked milo tended to break up more easily while mixing and being fed, causing considerable fine material and a possible reduction in palatability. New feed was added to the fines in the manger to induce complete consumption of the ration. While this forced feeding was effective it may have slightly reduced feed intake but such an effect was not readily apparent. A new method of pressure cooking grains appears to be as effective as flaking in improving feed efficiency when fed to steers and the grains are more resistant to physical breakdown during mixing and feeding. This method may improve palatability in calf starter rations by reducing fine materials.

Gardner (15, 16) has reported that if calves are given unlimited access to calf starters and good quality alfalfa hay, about 20% of daily dry matter intake will be in the form of hay. By self-selection of rations A, B, C and D the calves in Trial I consumed an average ratio of concentrates and hay within a range of 89:11 to 91:9 and in Trial II from 85:15 to 87:13. The ratio of consumption of the complete ration containing 20% alfalfa pellets was 84:16 and 85:15 which reflects the refusal of the calves to consume the hay pellets during the first few weeks of age. Pelleting the complete ration or preferably coarsely chopping the hay may reduce selectivity.

Failure of the calves to consume more hay may have been due to a lower quality than generally used as reflected in the relatively low crude protein content of 12.2%. Also, since the calves were weaned 7 to 18 days earlier than by Gardner (15), their desire for energy may have increased their appetite for grain throughout the trial period. However, hay consumption by the early weaned calves in Trial II was greater and more uniform among treatments than in Trial I.

The results of this study demonstrate that steam processing and flaking milo markedly improved its utilization by dairy calves weaned from milk at an early age. It is suggested that feed efficiency may further be improved by combining steam processed and flaked milo and barley with hay in a complete calf starter ration.

APPENDIX

APPENDIX

Explanation of Abbreviations

A D G	-	Average Daily Gain
F I	-	Feed Intake
lb.	-	pounds
Start.	-	Starter
T D N	-	Total Digestible Nutrients
Wt.	-	Weight
df	-	degrees of freedom

TABLE 7

ANALYSIS OF VARIANCE FOR AVERAGE DAILY GAIN DURING THE PRE-WEANING, THE POST-WEANING AND THE TOTAL PERIOD. TRIAL I

Source of variation	df	Mean Square Pre-Weaning ADG	Post-Weaning ADG	Total Period ADG
Treatment	4	0.123	0.045	0.014
Error	55	0.059	0.051	0.016

TABLE 8

ANALYSIS OF VARIANCE FOR TOTAL DRY FEED INTAKE PER TOTAL GAIN, AND TOTAL OF STARTER INTAKE PER TOTAL GAIN DURING THE POST-WEANING, AND THE TOTAL PERIODS. TRIAL I

		Mean Square			
		Post-Weaning		Total Period	
Source of variation	df	Total F.I.[1]/ lb. Gain	Start.[2] I./ lb. Gain	Total F.I.[1]/ lb. Gain	Start.[2] I./ lb. Gain
Treatment	4	0.340	0.535	0.580	0.745
Error	55	0.140	0.108	0.090	0.075

[1]Excluding milk

[2]Represents concentrate portion of ration only

TABLE 9

ANALYSIS OF VARIANCE FOR AVERAGE DAILY GAIN DURING THE PRE-WEANING, THE POST-WEANING, AND THE TOTAL TRIAL PERIOD. TRIAL II

Source of variation	df	Mean Square		
		Pre-weaning ADG	Post-weaning ADG	Total Trial Period ADG
Treatment	4	0.015	0.083	0.035
Error	55	0.038	0.043	0.027

TABLE 10

ANALYSIS OF VARIANCE FOR TOTAL DRY FEED INTAKE PER TOTAL GAIN, AND TOTAL STARTER INTAKE PER TOTAL GAIN DURING THE POST-WEANING, AND THE TOTAL TRIAL PERIOD. TRIAL II

Source of variation	df	Mean Square			
		Post-weaning		Total Trial Period	
		F.I.[1]/Gain	Start.[2]/Gain	F.I.[1]/Gain	Start.[2]/Gain
Treatment	4	1.580	1.338	1.530	1.225
Error	55	0.150	0.118	0.180	0.138

[1]Excluding milk

[2]Represents concentrate portion of the ration only

TABLE 11

ANALYSIS OF VARIANCE FOR STARTER TDN CONSUMED PER POUND OF GAIN, DRY FEED TDN CONSUMED PER POUND OF GAIN, DURING THE POST-WEANING PERIOD. TRIAL I (35 DAYS-200 POUNDS) AND TRIAL II (24 DAYS TO 200 POUNDS)

	Mean Square			
	Trial I		Trial II	
Source of variation	Starter[1] TDN per lb. Gain	Feed TDN per lb. Gain	Starter[1] TDN per lb. Gain	Feed TDN per lb. Gain
Treatment	0.085	0.035	0.318	0.515
Error	0.055	0.056	0.059	0.068

[1]Represents concentrate portion of ration only.

TABLE 12

SUMMARY OF SKELETAL MEASUREMENT DATA BY TREATMENT GROUPS IN TRIAL I AND II.

MEASUREMENTS IN INCHES

Treat-ment	INITIAL			WEANING			FINAL		
	Height	Length	Heart Girth	Height	Length	Heart Girth	Height	Length	Heart Girth
(Trial I)									
A	28.81	23.56	32.35	30.48	25.29	34.23	33.52	30.56	41.02
B	28.83	23.27	32.06	30.27	25.15	34.67	34.17	31.13	41.15
C	29.05	24.10	32.69	30.65	25.88	35.04	33.38	31.08	41.13
D	28.79	23.23	31.67	30.44	25.40	34.63	33.52	31.00	41.04
E	29.19	24.10	32.94	30.29	25.92	35.10	33.63	31.15	41.17
(Trial II)									
A	28.77	23.25	31.83	29.69	24.46	33.25	33.44	30.90	41.08
B	29.23	23.52	32.54	29.81	24.58	33.60	33.90	31.06	41.19
C	28.62	23.44	32.35	30.06	24.38	33.33	33.79	31.06	41.17
D	28.54	23.08	31.67	29.98	24.31	33.48	33.77	31.00	41.15
E	29.00	23.42	32.90	30.27	24.79	34.38	33.58	31.02	41.13

TABLE 13

SUMMARY OF DATA FOR EACH CALF DURING THE PRE-WEANING AND POST-WEANING PERIODS. TRIAL I

Birth Wt.	Pre-weaning Milk Intake	Pre-weaning Hay Intake	Pre-weaning Grain Intake	Pre-weaning Weight Gain	Post-weaning Hay Intake	Post-weaning Grain Intake	Post-weaning Weight Gain	Age to 200 lb.
(lb.)								days
Treatment A								
86	241.5	2.3	39.4	14.0	21.0	200.6	100	53
102	263.0	0.9	17.2	-3.0	9.4	276.9	107	62
112	315.0	1.0	27.6	26.0	9.1	218.0	68	39
80	188.0	4.1	4.4	22.0	47.0	326.6	98	80
80	224.0	8.1	17.5	24.0	41.6	285.4	98	60
66	185.0	1.0	10.7	9.0	39.7	336.8	125	87
96	259.0	1.5	27.7	83.0	29.4	267.8	85	49
104	290.5	1.1	22.5	15.0	6.8	244.3	83	50
84	217.5	5.7	10.9	18.0	47.5	318.0	98	80
80	224.0	1.0	15.2	24.0	22.0	274.5	96	71
108	301.0	4.1	31.5	18.0	5.3	175.7	74	37
94	262.5	4.4	41.1	27.0	23.4	247.5	83	46
Treatment B								
88	245.0	8.4	34.3	27.0	5.9	197.3	87	53
100	280.0	9.5	29.2	24.0	27.7	211.1	80	49
90	252.0	4.2	15.2	18.0	65.1	192.0	95	65
92	259.0	0.7	20.9	27.0	45.5	213.8	86	53
62	175.0	4.0	13.9	18.0	50.5	304.4	120	68
102	275.0	8.2	29.0	28.0	12.7	225.0	74	49
78	217.0	6.6	18.1	22.0	41.7	262.0	100	66
96	269.5	0.5	12.4	12.0	25.4	209.3	92	60
80	224.0	0.3	14.5	16.0	36.2	282.3	110	64
82	231.0	5.1	16.6	32.0	34.1	282.4	92	71

TABLE 13 (Continued)

	Pre-weaning				Post-weaning			
Birth Wt.	Milk Intake	Hay Intake	Grain Intake	Weight Gain	Hay Intake	Grain Intake	Weight Gain	Age to 200 lb.
(lb.)								days
Treatment B (Continued)								
77	217.0	3.6	19.2	35.0	45.4	237.6	93	66
96	269.5	3.8	18.3	13.0	37.1	250.4	101	57
Treatment C								
92	279.0	2.4	6.1	2.0	9.7	294.5	108	65
80	224.0	2.6	21.3	35.0	13.2	240.9	85	61
80	224.0	3.9	16.9	32.0	38.4	193.6	94	56
99	276.5	10.5	23.1	22.0	25.8	167.6	79	37
86	241.5	2.0	26.0	33.0	40.0	176.4	81	42
94	262.5	7.5	28.9	22.0	33.0	201.9	88	43
72	203.0	2.1	14.2	17.0	10.9	253.2	113	59
96	269.5	3.0	9.7	13.0	38.3	232.8	94	64
96	269.5	3.2	19.1	22.0	17.0	233.1	84	55
104	290.5	3.6	12.4	11.0	14.4	251.0	85	59
90	252.0	3.2	17.9	20.0	45.8	179.5	90	48
92	253.0	3.0	13.1	8.0	39.1	238.8	102	71
Treatment D								
98	267.0	0.7	8.9	6.0	17.5	213.6	96	51
80	224.0	2.2	22.0	30.0	3.4	237.4	90	60
90	252.0	6.5	13.0	28.0	20.8	186.9	84	48
92	259.0	6.2	8.8	24.0	29.8	205.1	86	42
82	231.0	2.0	14.8	30.0	48.6	213.3	92	71
78	217.0	5.4	14.5	27.0	13.5	345.9	101	77
75	210.0	0.9	14.9	29.0	28.7	235.3	101	57
98	273.0	6.9	35.1	39.0	3.6	179.8	65	36
84	234.5	2.0	32.3	31.0	8.8	230.1	85	45
76	213.5	3.1	9.8	17.0	21.8	259.3	111	69
95	266.0	4.3	20.8	20.0	15.8	219.6	85	54
100	280.0	7.4	14.2	18.0	41.0	209.9	82	55

TABLE 13 (Continued)

Birth Wt.	Pre-weaning Milk Intake	Pre-weaning Hay Intake	Pre-weaning Grain Intake	Pre-weaning Weight Gain	Post-weaning Hay Intake	Post-weaning Grain Intake	Post-weaning Weight Gain	Age to 200 lb.
(lb.)								days
Treatment E								
100	280.0	3.9	15.4	17.0	4.7	178.9	68	36
90	252.0	1.5	6.1	13.0	35.2	140.6	76	38
90	252.0	0.4	19.5	22.0	53.6	214.2	86	63
96	269.5	2.8	24.4	11.0	42.8	171.4	84	56
103	281.0	1.6	8.2	20.0	33.3	170.0	69	49
88	245.0	5.8	23.0	8.0	49.4	197.8	80	53
88	245.0	2.8	14.8	6.0	44.4	177.6	85	50
84	234.5	2.8	11.0	30.0	20.4	218.5	109	68
92	259.0	3.8	15.3	28.0	40.6	220.2	91	60
72	199.5	1.9	10.6	24.0	48.1	262.4	102	73
70	196.0	2.5	10.2	30.0	39.3	209.4	111	69
100	280.0	8.2	36.5	27.0	43.4	173.4	68	53

TABLE 14

SUMMARY OF DATA FOR EACH CALF DURING THE PRE-WEANING AND POST-WEANING PERIODS. TRIAL II

	Pre-weaning				Post-weaning			
Birth Wt.	Milk Intake	Hay Intake	Grain Intake	Weight Gain	Hay Intake	Grain Intake	Weight Gain	Age to 200 lb.
(lb.)								days
				Treatment A				
78	148.8	1.0	4.8	12.0	54.9	343.3	110	73
84	160.8	15.1	11.0	14.0	50.1	307.8	102	65
88	159.0	2.0	2.5	7.0	54.0	385.2	111	100
86	165.6	5.8	8.7	14.0	29.2	274.2	100	64
82	158.4	10.9	19.0	8.0	64.5	342.2	112	71
102	196.8	5.4	20.9	12.0	24.7	274.7	90	60
76	146.4	1.4	10.0	5.0	46.1	386.7	119	71
82	158.4	0.9	9.2	18.0	56.8	326.0	100	67
80	142.6	0.5	5.6	2.0	55.9	401.6	118	94
100	192.0	1.8	11.0	20.0	19.8	239.4	86	47
96	184.8	1.9	9.8	13.0	80.5	218.2	93	53
122	235.2	1.0	4.2	5.0	13.7	265.5	73	52
				Treatment B				
88	168.0	1.0	13.2	21.0	23.9	209.2	97	50
82	145.4	1.5	8.9	5.0	105.9	354.6	117	97
102	196.8	4.0	11.5	13.0	35.7	265.1	86	67
94	180.0	4.6	10.0	12.0	41.2	222.0	94	60
72	139.2	3.3	11.2	8.0	79.8	347.9	126	88
108	206.4	4.8	4.8	8.0	49.5	258.0	90	61
88	168.0	2.4	7.1	15.0	39.4	284.1	103	64
76	146.4	1.5	5.0	6.0	24.3	341.6	118	108
86	165.6	1.2	16.1	17.0	19.4	213.3	99	57
98	187.2	5.2	13.5	18.0	33.7	271.2	88	54
108	206.4	0.4	3.8	9.0	41.8	195.4	87	62

TABLE 14 (Continued)

	Pre-weaning				Post-weaning			
Birth Wt.	Milk Intake	Hay Intake	Grain Intake	Weight Gain	Hay Intake	Grain Intake	Weight Gain	Age to 200 lb.
(lb.)								days
Treatment B (Continued)								
96	184.8	5.8	21.0	10.0	59.3	315.4	100	72
Treatment C								
68	129.6	4.0	8.9	8.0	23.6	295.2	124	69
88	163.0	3.4	9.2	5.0	24.8	283.9	107	84
84	160.8	2.0	7.1	10.0	14.0	184.4	106	51
90	172.8	4.2	13.3	16.0	26.3	313.4	100	67
88	168.0	1.0	3.2	11.0	31.1	300.4	102	66
88	160.8	10.0	10.9	13.0	23.6	292.1	105	69
84	172.8	2.3	10.0	16.0	53.2	249.0	100	65
90	158.4	4.1	9.4	14.0	28.1	254.2	102	58
82	211.2	1.3	13.0	12.0	52.5	256.9	106	71
110	184.8	6.8	15.0	20.0	47.4	143.7	72	43
96	177.6	4.2	1.5	10.0	36.5	214.2	98	50
92	169.0	1.7	8.1	10.0	52.4	243.5	102	70
Treatment D								
102	196.8	4.3	8.0	15.0	22.5	236.3	87	52
74	141.6	1.8	13.0	14.0	32.8	191.9	116	66
74	141.6	0.7	5.0	6.0	50.5	300.2	124	84
78	148.8	5.0	12.9	12.0	59.7	267.1	116	66
90	172.8	9.3	8.5	12.0	62.7	232.5	102	65
82	158.4	1.1	3.8	7.0	41.9	298.7	111	71
96	184.8	0.3	3.7	10.0	46.9	221.3	100	56
78	148.8	1.3	11.0	16.0	48.6	208.0	98	58
82	158.4	2.0	3.0	9.0	54.4	268.8	109	71
82	158.4	1.8	6.9	10.0	38.3	235.7	114	72
102	196.8	4.6	3.0	10.0	25.0	261.2	88	54
88	168.0	1.1	5.0	21.0	6.0	206.7	91	45

TABLE 14 (Continued)

	Pre-weaning				Post-weaning			
Birth Wt.	Milk Intake	Hay Intake	Grain Intake	Weight Gain	Hay Intake	Grain Intake	Weight Gain	Age to 200 lb.
(lb.)								days
				Treatment E				
82	158.4	1.0	4.7	8.0	67.0	272.4	120	79
94	180.0	0.5	2.0	9.0	66.4	265.5	99	71
98	187.2	1.3	5.2	13.0	51.7	207.0	94	57
82	158.4	0.9	3.8	8.0	38.6	277.0	110	80
86	165.6	2.3	9.3	22.0	36.6	197.4	92	46
112	216.0	1.5	6.2	12.0	34.5	186.5	80	50
90	172.8	1.8	7.3	16.0	20.5	227.6	96	55
88	168.0	1.8	7.2	15.0	24.8	215.3	101	52
82	158.4	3.1	12.5	17.0	53.0	247.0	101	64
86	165.6	1.5	5.8	14.0	14.0	194.0	100	53
85	163.2	0.8	3.2	10.0	17.5	243.6	107	69
94	180.0	1.3	5.2	12.0	44.5	203.4	97	67

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