March 14, 1960

To the Graduate Council:

I am submitting herewith a thesis written by Myles Carpenter entitled "A Study of the Provision of Trace Minerals for Suckling 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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A STUDY OF THE PROVISION OF TRACE MINERALS FOR SUCKLING CALVES

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

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by

Myles Carpenter

March 1960

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CHAPTER I

INTRODUCTION

The minerals iron, copper, manganese, and magnesium are not provided in optimum amounts by milk alone for rapidly growing calves. Since the calf eats very little hay or grain for the first three or four weeks, trace minerals are frequently included in milk-replacer formulas to insure an adequate intake. It has not been shown that it is essential to add these minerals to the milk. It is possible that addition of these minerals to the starter ration alone would be sufficient for calves raised on the limited milk feeding plan. If trace minerals could be omitted from the milk replacer, this would simplify the formula and might result in greater stability of vitamin A, or other essential nutrients, in the formula.

Whole milk, the young calf's natural food, is generally too expensive as a feed for calves. However, most nutritionists agree that for normal growth a certain amount of milk should be fed (42). Many experiments have been conducted to find more economical and efficient methods of raising dairy calves. Much progress has been made in developing a milk replacer which would be practical for the average dairyman to use. Feeding minimum amounts of marketable whole milk and getting the calf to eat hay and grain at an early age has been emphasized in more recent work. Hay and grain products

are generally richer in the trace minerals than is milk.

The purpose of this investigation was to determine the need for adding trace minerals to the normal feeds of calves raised by a limited milk feeding plan, and to determine whether such minerals should be added in the milk, in the concentrate or in both.

CHAPTER II

REVIEW OF LITERATURE

Trace minerals in milk. Although milk contains all reported essential minerals, their concentration is inadequate when growing animals are forced to exist on a diet of milk alone (24). With this in mind, milk could not be considered a perfect food. The major minerals, phosphorus, calcium, sodium, and chlorine are present in adequate amounts in milk and will not be discussed since only the essential trace minerals are the main subject of this study. These trace minerals include, iron, copper, manganese, iodine, cobalt, magnesium and zinc.

In an economical calf raising program colostrum could be fed to new-born calves for a period of six to nine days. This is assuming that extra colostrum is stored and used as needed. Only limited data are available regarding the level of trace minerals in bovine colostrum. In a review by Archibald (2) it was reported that colostrum has a higher percentage of all trace minerals than does normal milk. The level of trace minerals in colostrum and normal milk as reported by Archibald is presented in Table I.

Today most calves are raised on a limited milk feeding plan. After five to ten days the young calf is fed in place of whole milk a milk substitute, generally a powder of skimmilk and other milk products which is reconstituted in water. Skimmilk powder is

TABLE I

CONCENTRATION OF TRACE MINERALS IN COLOSTRUM AND NORMAL MILK*

Mineral	Colostrum	Normal milk
	ppm	
Cobalt	.0036	.001
Copper	.50	.13
Iodine	.12	.04
Iron	1.30	.45
Manganese	.14	.03
Zinc	5.7	3.7

*Archibald, J. G., Trace Elements in Milk: A Review, Part II. Dairy Science Abstract, 20:800. 1958.

also low in trace minerals. However, pound for pound skimmilk would have a higher percentage of trace minerals than normal milk because the minerals are water-soluble and no minerals would be lost in the fat which is removed in separation.

Archibald (2) reported that there is some relationship between the trace minerals in feed and the trace minerals found in milk. The cobalt in milk can be increased by adding a cobalt supplement to feed. Iodine in milk can be increased to a great degree by adding it to feed which the cow consumes. Iodine is generally higher in milk from animals raised in coastal areas. Manganese may be increased in milk by feeding a manganese supplement. Zinc may be slightly increased in the same manner. Iron and copper show no such response, although diets low in copper reduce the amount normally present.

Trace minerals in feedstuffs. The only other source of trace minerals among the natural feeds used in calf raising is forages, such as hay and silage or pasture, and common grains used to prepare concentrate feeds or starters. The National Research Council (47) has published data which give the trace mineral level in various forages and grain. As a general rule hay crops are higher in copper, cobalt, iron and magnesium than are the grain crops. Grains contain a higher level of iodine. With the exception of corn the grain and hay crops have about the same level of manganese. Corn is very low in manganese. The zinc level is fairly constant in all

crops. Table II shows the trace mineral level in several representative forages and grains. Also the level of trace minerals in soybean oil meal and wheat bran is shown as published by Morrison (46).

Nutritional role of the trace minerals. The need of calves for these trace minerals has been studied by several investigators (8, 28, 36, 57). It is known that iron is an essential constituent of hemoglobin. Iron is also a constituent of the chromatin substance of the body cells and is probably concerned in the oxidation-reduction processes occurring within the organism (24). Knoop et al. (34) reported that calves on an exclusive milk diet developed anemia at about 120 days of age, as evidenced by unthriftiness, retarded growth, and low hemoglobin concentration. It was found that the addition of iron alone to the ration did not prevent anemia. Several other minerals were added to a milk ration, and it was found that a combination of iron and copper would prevent anemia. Copper seemed to act as a catalyst in the formation of hemoglobin according to Elvehjem et al. as reported by Herman (24). Knoop et al. (34) prevented anemia in calves by feeding 400 mg. of iron and 40 mg. of copper daily.

Matrone et al. (41) studied the iron and copper requirements of calves on purified diets. They found that calves receiving no supplemental iron became anemic and gained less than those on 30 mg. and 60 mg. intake of iron daily. Thirty or 60 mg. of iron daily were sufficient either to maintain normal red-cell volumes and

TABLE II

TRACE MINERAL CONTENT OF REPRESENTATIVE FORAGES AND GRASSES

Mineral	Alfalfa and light grass hay	Alfalfa hay	Corn	Oats	Soybean meal	Wheat bran
	mg. per lb.					
Copper	5.8	6.2	1.3	3.0	7.5	5.3
Iron	104.0	108.0	14.0	36.0	72.0	126.0
Iodine		.055	.152			
Manganese	17.7	23.5	2.7	19.5	13.6	51.0
Magnesium	1300.0	1450.0	770.0	860.0	1180.0	2700.0
Zinc		7.7	8.9			
Cobalt	.068	.060	.010	.029		

hemoglobin or to increase the hemoglobin of anemic calves from an average of 5.4 g. to 8.0 g. per 100 ml. during 16-20 weeks. There was no difference in hemoglobin between the 30 and 60 mg. intake levels. The percentage of iron utilized was 60 per cent of the 30 mg. and 30 per cent of the 60 mg. level. Without supplemental copper, serum copper decreased, but an intake of 6 mg. of copper daily maintained it at a normal level. Bennetts et al. as reported by Matrone (41) stated that a daily intake of 60 mg. of copper prevented anemia in grazing cattle in Western Australia and maintained normal hemoglobin and copper concentrations in blood.

Thomas et al. (71) fed 100 mg. of iron per day to calves that were moderately anemic. This caused an increase in the number of their red blood cells and hemoglobin levels. Iron alone or iron in combination with copper, cobalt, and manganese cured the anemic condition in these young calves; whereas, copper, cobalt, and manganese fed alone had no curative properties.

The role of magnesium in nutrition is not very well understood. Magnesium deficiency may result in tetany (27). Huffman and Robinson (27) observed tetany in calves showing normal blood calcium values. Later Duncan and Huffman (18) proposed that the tetany was being caused by "hypomagnesemia." The blood values reported for magnesium by these workers showed a marked lowering when calves were fed a milk diet. Moore et al. (45) found that calves which had low blood magnesium developed gross lesions in the endocardium and blood vessels.

Thomas et al. (70) investigated a calf's need for magnesium when being fed a semisynthetic milk diet. Milks containing approximately 0.001, 0.006, 0.011, and 0.022 per cent magnesium were used. They were fed at the rate of 12 lb. per cwt. and furnished approximately 0.06, 0.33, 0.60, and 1.2 g. of magnesium per cwt. per day. Eight calves fed the lowest level of intake had a markedly reduced rate of body weight gain, greatly reduced serum magnesium levels, and died in convulsions at 43 to 80 days of age. At autopsy, numerous small hemorrhages were found in the pericardium, endocardium, pericardial sac and the auricular valves. The intermediate levels allowed the calves to live but they grew at subnormal rates. Serum magnesium levels were maintained for the first one or two months and then gradually declined. The upper level of magnesium intake allowed the most rapid growth, and serum magnesium was maintained at normal levels for as long as seven months.

Huffman and Duncan (26) reported that there appeared to be a relationship between metabolism of magnesium and the availability of vitamin D. These workers reported that the ash and mineral values of the bones indicated better calcium and phosphorus utilization due to the ingestion of magnesium supplements. Thus, magnesium has an antirachitic value. Becker, as reported by Huffman and Duncan (26) reported that certain magnesium compounds prevented or cured osteomalcia in cattle.

Among the early symptoms of a magnesium deficiency in calves

are irritability, nervousness, and anorexia (18). The animal apparently temporarily blinded, will run into obstacles, or becoming confused will turn in circles until its balance is completely destroyed. As the convulsions become more violent, the calf may fall on its side with the legs alternately rigidly extended and contracted. There is frothing at the mouth and profuse salivation. Young calves seem to be able to withstand several such convulsions but older calves usually succumb to the first attack. To the average observer it is practically impossible to distinguish between the form of tetany in calves which is associated with hypocalcemia and the tetany which is associated with hypomagnesemia. Blood samples must be analyzed to distinguish between the two (18).

Low magnesium tetany generally does not occur if a calf's ration includes roughage. Huffman, et al. (25) investigated the feeding of magnesium carbonate and magnesium oxide supplements while feeding whole milk. They found that 15 to 20 mg. of magnesium as magnesium oxide per pound of body weight maintained plasma magnesium values and prevented tetany. They also found that eight to ten mg. of magnesium per pound of body weight maintained the magnesium plasma levels. Thomas (69) also concluded that magnesium in hay and grain was utilized more efficiently than magnesium supplied as magnesium sulfate.

Manganese occurs in the body in traces and appears to be necessary for normal reproduction in rats. Daniels and Everson (14)

found a high mortality in the young born from rats on a low manganese diet. Titus et al. (72) reported that manganese added to a milk plus iron diet resulted in hemoglobin regeneration. Thus, it appears that manganese is associated with iron and copper in hemoglobin formation. However, the exact role of manganese is not known.

There is a possibility that the organisms responsible for digestion in the rumen may need a certain amount of manganese for best results since it is known that manganese exerts an influence upon the growth of certain organisms (57). Most hays have 20 or more parts of manganese per million. The grains are lower with corn being expecially low. The amount of manganese needed by calves has not been determined accurately. Indiana workers (1) found that the growth rate of heifers was depressed and sexual maturity was delayed on a ration having only six to eight parts of manganese per million.

A deficiency of iodine causes metabolism disturbances and hypertrophy of the thyroid gland. Only very small traces of iodine are needed by animals (46). The exact requirements for livestock are unknown but a deficiency of iodine is not a problem in most areas of the United States. Iodine is easily transmitted from the feed to the milk, according to Maynard (43), and unless the soil is deficient in iodine, the feed will contain enough. Supplemental iodine is generally added with salt (53). In Wisconsin, iodized salt containing 0.015 per cent of iodine incorporated at a one per cent level in the grain portions of livestock rations has been entirely effective in preventing goiter of calves (48).

Zinc is another trace mineral which is found in both animal and plant tissues. Experiments (65) with rats fed highly purified diets, freed as thoroughly as possible from zinc, have shown that traces of this mineral are necessary for good growth and also for normal hair development. Gilbert (23) stated that the rate of absorption of carbohydrates and proteins from the gastrointestinal tract is influenced by the concentration of zinc in the diet. Zinc has also been found in the pancreas and in all commercial preparations of insulin even though there is no relationship between zinc and insulin activity (60). Livers of young animals have much more zinc than those of adults, suggesting a storage of the element in the young animals before birth (23). It seems possible that a young calf would not become deficient in zinc before it was old enough to consume grain and hay which provides ample zinc (47).

In the past few years it has been discovered through careful investigations that a deficiency of cobalt causes slow growth of cattle, sheep, and goats in certain areas of the world (29). Keener, et al., (29) found that cobalt deficiency was about twice as common among calves and heifers as milking cows. A young calf's need for cobalt is perhaps no greater than a grown cow's need, but an older animal eats a greater variety of feeds and will have more chances of consuming the required cobalt. Milk is known to be very low in cobalt (47) and if a calf is raised for several months on a milk diet, there is likely to be a deficiency of cobalt in its body.

Cobalt is required by the bacteria in the rumen; however, nonruminants require traces of cobalt, because vitamin B_{12} contains cobalt. They reported that a cobalt deficiency did not appear to affect nonruminants. Thus, one would question if young calves would need cobalt since they do not have a functioning rumen for some time after birth. However, with the limited milk feeding plan and the encouragement of roughage consumption at an early age the dairy calf begins ruminating at a very early age (67). Cattle or sheep suffering from cobalt deficiency lose their appetite, become unthrifty and emaciated, and may have a depraved appetite, especially a desire to chew hair or gnaw wood. A deficiency of cobalt has been known to cause anemia even though cobalt is not a part of the hemoglobin. The feeding of excess cobalt will cause an increase in the level of hemoglobin and red cells (29). Cobalt fed at a high level will cause a toxic effect. Ely et al. (19) found that if over 40 mg. per 100 lb. body weight were fed daily toxic effects were manifested in dairy calves. Keener et al. (29) found that growing dairy animals could consume 50 mg. daily per 100 lb. body weight without harmful effects. A deficiency of cobalt can be corrected very efficiently and easily by adding a small quantity of cobalt sulfate or cobalt carbonate to the concentrate being fed. Dickey (16) reported that the addition of one teaspoon of cobalt sulfate to one ton of the grain mixture corrected the cobalt deficiency symptoms. Most roughages, unless grown on cobalt deficient soils, furnish sufficient cobalt for the

animals which consume them. Legume forage generally has more cobalt than does grass forage (47). A salt mixture containing one ounce of cobalt carbonate per 100 lb. will generally prevent cobalt deficiency symptoms (4).

Substitution of skimmilk for whole milk. Workers in calf nutrition have been striving to formulate a method to replace whole milk efficiently in the ration of young dairy calves since the earliest studies. In 1909 Savage and Tailby (59) showed that whole milk could be replaced by skimmilk, skimmilk powder and a "calf meal." Skimmilk and skimmilk powder gave better results than the "calf meal." Average daily gains were 1.53, 1.23, and 1.10 lb. respectively. Hay consumption for these groups averaged 360.6, 370.4, and 324.8 lb. respectively, to five months. The larger gains of the skimmilk-fed calves can be partly attributed to the greater amount of hay consumption than the meal-fed calves. These workers concluded that skimmilk, although not equal to whole milk in nutritional value, was superior to all other feeds. The gross chemical analysis of skimmilk showed that it contained all the proteins, sugar, minerals, and water soluble vitamins found in whole milk (37). It lacked the fat-soluble vitamins and fat.

Today, reconstituted skimmilk is used extensively in raising dairy calves. Williams and Bechdel (74) tried feeding skimmilk powder and other synthetic rations in dry form. Their experiences showed that liquid milk replacers proved better for calves than solid

diets fed dry or as a slurry. Other workers (33, 58, 64) have obtained very good results from feeding reconstituted skimmilk as a part of the young calf's ration.

Supplementation to skimmilk. Many supplements to skimmilk have been proposed by different workers. Mineral supplements have been studied by some investigators (8, 18). Though most of these studies have failed to evaluate conclusively the justification for feeding mineral supplements to calves on a normal diet, the need for certain essential elements has been established. After calves are old enough to consume hay and grain the needed minerals will be supplied by the hay and grain if they are of good quality (46). Further work is needed to determine a young calf's need for trace minerals and the way in which they can be supplied.

Since skimmilk is practically free of fat, one would assume that some form of fat should be supplied to a calf on skimmilk. A dietary need for fat has been shown, but the amount required to make normal gains has not been determined. A low-fat diet has been successful for several investigators (77). Cunningham and Loosli (13) found total lipids in the plasma of all calves were low at one day of age but rose in those calves receiving sources of fat as time progressed. These workers suggested that body storage of essential fatty acids at birth may be adequate to last a calf several months, but dietary fat may be necessary during the first few days and this could be supplied from the colostrum which a baby calf generally

receives.

Supplementing a calf's ration with vitamins has been studied for many years and it is still questionable if vitamins should be added to natural rations. Phillips et al. (53) reported that vitamin A and certain members of the vitamin B complex were effective in preventing and curing nutritional scours. Other workers (20, 50, 51, 52) have conducted similar experiments and reported no benefit from supplementing a ration with extra vitamins. In a study at the University of Tennessee (66) there appeared to be no advantage from adding vitamin A to reconstituted skimmilk. There was no significant difference in blood plasma levels of vitamin A, liver storage of vitamin A or in general health of the calves between the group receiving vitamin A and those not receiving it. The type of ration being fed is of major importance when one is deciding whether to add vitamins. The blood level of vitamin A of the newborn calf is known to be low (42). If colostrum is fed for a few days, vitamin A will be supplied in adequate amounts. If the young calf is put on a skimmilk diet at an early age, vitamin A supplement may be desirable. Whole milk will generally supply adequate amounts of vitamin A. Vitamin D should be added to a calf's ration if the calf is enclosed in a barn without any exposure to sunlight (17). Vitamin D can be obtained from hay, but a young calf will eat very little or no hay. Thomas et al. (68) found that a calf had to eat 1.5 lb. per cwt. of alfalfa or its equivalent as alfalfa silage to avoid rickets. These workers also

found that late cut forages contained more vitamin D than early cut forages.

Another supplement which has received much attention during the past decade is antibiotics. The principle interest concerning antibiotics for young calves has been their effect on growth, feed consumption and efficiency, and diarrhea. In 1950, Bartley et al. (3) reported that an APF concentrate containing aureomycin stimulated the growth rate of dairy calves from birth to 42 days of age. The incidence of calf scours was much lower in the aureomycin-fed calves. Rusoff (56) reported that same year that aureomycin improved the growth rate of calves, but his calves had received an APF concentrate containing vitamin B_{12}. His calves were 14 weeks old when the study began. Aureomycin increased the growth rate of the calves over the control calves 60, 36, and 30 per cent after two, four, and six weeks of the experiment. After 20 weeks there was no difference between the two groups of calves. Loosli and Wallace (40) reported a growth response in young calves with crystalline aureomycin. The aureomycin was fed in a milk substitute at the rate of 10.0 g. per ton. The control calves gained 0.92 lb. and the antibiotic-fed calves gained 1.11 lb. daily for the first 8 weeks. These workers also reported a significant reduction in calf scours.

Although aureomycin has been studied more extensively than other antibiotics, terramycin, hygromycin, erythromycin, penicillin, streptomycin, and bacitracin have been fed to calves. Terramycin

has given good results in some experiments (30, 73). Both potassium and procaine penicillin were found to depress growth rate (32). Williams and Knodt (75) reported that the addition of a streptomycin containing animal protein factor supplement to a milk-replacement diet for calves did not increase the rate of gain in body weight or in height at withers. Warner as reported by Reid (55) stated that bacitracin fed at a level of approximately 100 mg. per day resulted in an increase in body weight gains of 7.0 per cent. However, bacitracin fed at levels of 10 to 40 mg. per 100 pounds of body weight daily appeared to be inferior to aureomycin. The results of several experiments suggested that the age of animals or dietary qualities associated with age were related to the amount of response obtained from feeding antibiotics. It appeared that young animals received the most benefit from antibiotics. Bloom and Knodt (6) observed that aureomycin stimulated a greater gain in weight during the first four weeks of life. Since a high incidence of scours is most commonly observed during this period, it is not known to what extent the growth response is indebted to the control of microorganisms causing digestive and other disturbances. Bartley (3) suggested that the increased growth of calves during the first seven weeks is stimulated as a result of antibiotics preventing scours. However, Bloom and Knodt (7) reported an increased rate of gain in treated calves over controls which were not disturbed by diarrhea.

Calf feeding plans. The most popular and economical contemporary plan of feeding calves is the limited milk feeding plan. In this plan skimmilk or reconstituted skimmilk is fed for a period of approximately six to eight weeks. By this time the calf is able to consume enough concentrate and hay to maintain proper growth and health. Many investigators have studied the level at which the milk should be fed and also the length of time to feed it. In 1915, Lindsey (39) reported substituting skimmilk for whole milk after two weeks and continuing skimmilk feeding until the end of four months. Converse (12) successfully raised 136 calves without any whole milk. The calves were given colostrum for three days, then changed immediately to skimmilk and continued on this ration for six months. In 1942, work was begun by Converse (12) to find out how much earlier than six months of age the calves could be weaned from skimmilk. After weaning at 90 days of age proved satisfactory, weaning at 60, 45 and 30 days of age was tried. He found that calves could be weaned at 30 days without any adverse effects. Knodt, et al. (33) fed skimmilk for five weeks and obtained satisfactory results. Berry (5) obtained results which indicated that calves could be weaned from skimmilk at 42 days of age. Conover (11) fed whole milk for two weeks and then changed to reconstituted skimmilk which was fed until the seventh week. The reconstituted milk was gradually reduced and stopped at the eighth week. Skimmilk powder was then fed as 30 per cent of the grain-mix until the calf was four months

of age.

It is generally recommended that the calf be fed milk at the rate of 10 per cent of its body weight daily. McCullough et al. (44) fed milk at the rate of 10, 14, and 18 per cent of body weight. The average daily gains to four months of age for these groups were 1.26, 1.42 and 1.50 lb., respectively. Other experiments have been conducted using much higher levels of feeding, but they did not conform to the limited milk feeding plan. Fraser and Brand (22) reported that a calf could be raised on 600 lb. of milk with weaning taking place at the end of eight weeks. Davis and Cunningham (15) concluded that calves could be raised to five months of age on calf meal and 150 to 300 pounds of whole milk. They fed a milk ration for two weeks and then reduced milk sharply and substituted calf meal. However, the calves did receive a very small quantity of milk until 60 days of age.

In all the limited milk feeding plans grain and hay are offered free choice to the calf at a very early age. As a general rule the calf will begin to eat hay and grain at about two weeks of age or even sooner in some cases. Grain is generally limited to four or five pounds daily. The purpose of limiting grain consumption is to promote consumption of the less expensive hay and to develop the rumen at an early age. It is important that good quality hay be fed to calves. Good quality hay will be consumed in greater quantities and will also provide the calf with needed minerals

and vitamins A and D which the milk and starter may not furnish.

Supplementing calf rations with trace minerals. Jones et al. (28) compared a calf ration supplemented with iron, copper, manganese, cobalt, zinc, and iodine with another ration containing these trace minerals plus calcium, phosphorus, and manganese, certain vitamins and aureomycin.

The quantities of trace minerals in elemental form supplied daily in milligrams per 100 lb. of body weight were 200 of iron, 20 of copper, 20 of manganese, 10 of cobalt, 10 of zinc, and 0.19 of iodine. These quantities were approximately 2.5 times the amount of iron, copper, and manganese as fed by Herman (24) to prevent anemia in calves on milk alone. The nutritive value of the basal ration was considered to be approximately optimal. Good quality alfalfa hay and a calf starter were fed ad libitum beginning at one week of age. The starter formula contained 22 per cent crude protein. Although the calves on both of the supplements grew at significantly faster rates than unsupplemented calves on a basal ration, the differences in feed consumption and efficiency of gain were not statistically significant.

Knoop et al. (34) conduted an experiment to determine if milk supplemented with iron and copper could serve as a complete feed for calves. They fed 40 to 60 mg. of copper and 400 to 600 mg. of iron daily in the ration. Toward the end of the 255 day experiment the calves tended to develop rickets. The difference with and

without supplements were not marked in either the number of red cells or the hemoglobin. The iron and copper storage in the livers of calves fed milk alone was found to be 91 and 35 mg., while in calves fed supplements these values were 359 and 550 mg. It is not known if these high values of iron and copper in the liver are desirable.

The National Research Council (48) reported that many manufacturers of feed mixtures are directly adding potassium iodide as a source of iodine. Iodine in mixtures is fairly stable, due to the presence of starches and unsaturated fats. They concluded that a salt mixture containing 0.0076 per cent of iodine, which has been stabilized against loss of the iodine, incorporated into the grain portion of the ration at the one per cent level will be sufficient in supplying the needed iodine.

Thomas et al. (71) supplemented a calf ration with 100 mg. of iron daily and found that anemia could be cured or prevented.

Other reports of supplementing calf rations with only one trace mineral to study the effect it might have upon the well-being of the calf have been made. These studies have been mentioned previously in this review. Investigations in which more than one trace mineral was added to a calf ration are very limited, and merits more attention.

Summary. A review of the literature indicates that calves should be fed trace minerals in order to maintain proper growth. Milk, nature's food for baby calves, contains the essential trace

minerals, iron, copper, cobalt, zinc, iodine, magnesium, and manganese. The amounts are so low; however, that on a whole milk ration there is a deficiency of iron, copper, magnesium and manganese. In today's limited milk feeding plans there is a chance that the calf's ration will be deficient in trace minerals. Investigators have reported that all of these trace minerals play a role in the nutrition of calves. There has been a limited amount of work dealing with the amount of these minerals needed and the way in which they can be supplied to the calf. The possibility of furnishing the essential minerals through forages and concentrates has been only partly explored.

CHAPTER III

EXPERIMENTAL PLAN AND METHODS

Location. This study was conducted at the University of Tennessee Agricultural Experiment Station at Knoxville and the West Tennessee Experiment Station at Jackson. The study began in June, 1958, and ended in January, 1960.

Animals. Jersey and Holstein calves were used in the experiment at Knoxville and only Jerseys at the West Tennessee station. The Jerseys at the West Tennessee station are referred to as W. T. Jerseys and the Jerseys at Knoxville are referred to as U. T. Jerseys. Each calf was assigned to one of four groups at two to four days of age according to its size, alternating to keep the groups as nearly equalized as possible at all times. The four groups were fed plain or mineralized skimmilk and plain or mineralized starter according to the following plan:

Group I. Plain skimmilk and plain starter formula

Group II. Mineralized skimmilk and plain starter formula

Group III. Plain skimmilk and mineralized starter

Group IV. Mineralized skimmilk and mineralized starter

Each group at Knoxville consisted of 12 Holsteins and 10 Jerseys while the groups at Jackson consisted of 14 Jerseys. The U. T. Jersey groups included three to four Guernseys or crossbreeds per group which fit well into the Jersey groups because of their

size.

All calves were allowed to remain with their dams for the first three or four days after birth to insure that the calf received colostrum. The calves were then taken from their dams and placed in individual pens in an enclosed barn. Bedding for the pens consisted of oat straw and wood shavings. They were kept in individual pens for the duration of the experiment to 112 days (16 weeks) of age.

Feed. Colostrum and whole milk were fed the first five days and on the sixth and seventh day the milk was gradually changed to the experimental skimmilk. All calves were taught to take their milk from a nipple pail. The dried skimmilk was reconstituted at 15 per cent in warm water. The amount of skimmilk fed daily was 10 per cent of body weight. The milk feeding schedule was made out on the basis of the birth weight of the calf and the expected growth rate. The maximum daily amount of milk fed to each calf was 9.0 lb. for Jerseys and 12.0 lb. for Holsteins. The Jerseys were weaned at 56 days of age and the Holsteins at 42 days of age.

The special trace mineralized salt used was "Hardy's Trace Mineral Salt" mixed by the Hardy Salt Company, St. Louis, Missouri. To this salt was added three per cent of ferrous sulfate which gave a salt mix containing 0.68 per cent iron, 0.243 per cent manganese, 0.0032 per cent copper, 0.015 per cent cobalt, 0.007 per cent iodine, and 0.005 per cent zinc. The mineralized skimmilk was

prepared by adding the special mineral mixture to non-fat dry milk solids in such a ratio that 1.0 lb. of dried skimmilk contained supplemented minerals equivalent to 22.0 mg. of manganese, 61.6 mg. of iron, 2.9 mg. of copper, 1.36 mg. of cobalt, 0.63 mg. of iodine, and 0.45 mg. of zinc. Aureofac D was added to all milk at a rate equivalent to 50 mg. aureomycin per calf per day.

The mineralized starter formula was so prepared that each pound was supplemented with 11.0 mg. of manganese, 30.8 mg. of iron, 14.5 mg. of copper, 0.68 mg. of cobalt, 0.317 mg. of iodine, and 0.226 mg. of zinc. All starter was pelleted to facilitate accurate consumption weights. All starter was fortified with 2500 units of vitamin A and 400 units of vitamin D per pound. The formulas of the starters used are given in Table III.

The starter was available to the calf at the time it was put into the individual pen. The starter was clean and fresh at all times and was considered palatable. The maximum amount fed per calf was four lb. daily.

Coarse chopped, green alfalfa hay or alfalfa grass mixed hay was available to the calf at all times beginning at the time the calf entered its individual pen. Each calf was given free access to clean water at all times. The water pails were rinsed out daily.

Records. Records were kept of all milk, hay and starter consumption. Each calf was weighed at seven days of age and every seven days thereafter to 112 days. At the time of weighing, height

TABLE III

MINERALIZED AND PLAIN STARTER FORMULAS

Ingredient	Per cent of formula	
	Mineralized	Plain
Corn	35	35
Oats	20	20
Bran	10	10
Linseed oil meal	10	10
Soybean oil meal	17	17
Molasses	5	5
Defluorinated phosphate	1	1
Common salt	0	1
Trace mineral salt	1	0
Vitamin A and D meal	1	1

at withers and heart girth measurements were taken. Height at withers was obtained by using a calibrated rod with a sliding arm on it. A steel tape was used in measuring heart girth. All measurements were made by the men responsible for feeding the calves and were carried out before the evening feeding. The calves were observed each day for any abnormalities and a record was kept of all sickness and treatments.

Blood Analysis. Duplicate blood samples were taken from each calf at one week of age and repeated each two weeks through the 15th week. Heparin was used in one sample as an anticoagulant and the other sample was allowed to coagulate. Cell volume (hematocrit) and hemoglobin were determined on the fresh blood. Cell volume was determined by filling a Wintrobe tube to the zero mark with blood, centrifuging it at 3000 r.p.m. for 30 minutes, and then reading the percentage of packed cells. Hemoglobin was determined by mixing 0.02 cc of blood with 10.0 cc of dilute ammonium hydroxide in a colorimeter tube and reading transmittance in an Evelyn colorimeter using a 540 filter. Hemoglobin was calculated from the formula. $X = \frac{100L}{2.58}$ gm. of hemoglobin per 100 cc of blood. The L values were read from a table of corresponding transmittance values.

The blood plasma was analyzed for protein-bound-iodine (PBI). The method of determining PBI was that of Brown (9) as revised by Lennon and Mixner (38) and modified for use with an Evelyn Photoelectric Colorimeter. The blood serum was analyzed for calcium and inorganic phosphorus. Calcium was determined by a modification of the Clark-Collip (10) and Kramer-Tisdall Method (35). Inorganic

phosphorus was determined by the Fiske and Subbarow Method (21).

Comparisons were made between the groups to determine the effects upon blood cells, mineral elements and growth and development of the calves. The analysis of variance (62) was used in determining whether a significant difference existed among the various groups in respect to body weight gains.

CHAPTER IV

RESULTS

Weight gains. The average weekly gains for the four ration groups were determined separately for the Holsteins, U. T. Jerseys and W. T. Jerseys. These are shown in Table IV. There were some differences in gain among the groups but there was no noticeable trend due to treatments. The averages of all groups on the same ration were also determined. The total gains for the 15-week period (7-112 days) were 121.7, 118.9, 125.1, and 121.6 lb. for groups I, II, III, and IV, respectively. This shows that the calves receiving plain skimmilk and mineralized starter gained the most. However, there was not a statistically significant difference among any of the groups for the 15-week period ($P =< .05$). The gains within the breed were compared with Ragsdale's standard (54). The four Holstein groups weighed 249.7, 243.7, 247.3, and 251.3 lb. at 16 weeks of age. Ragsdale's recommended weight is 243.0 lb. at 17 weeks of age. At 16 weeks of age the four U. T. Jersey groups averaged 183.5, 169.2, 178.0, and 169.5 lb. with Ragsdale's standard being 158.0 lb. at 17 weeks of age. These Jersey calves were slightly heavier at birth than the standard weight which Ragsdale has set forth. The four W. T. Jersey groups averaged 141.9, 155.9, 154.6, and 148.3 lb. at 16 weeks of age. These weights are somewhat lower than Ragsdale's standard and this is probably the result of poor hay and starter consumption which will

be discussed later.

The one-to eight-week weight gains are shown in Table IV. These gains were used to determine if the calves receiving the supplemented skimmilk gained any faster during the milk feeding period than did the calves not receiving supplement. All of the calves on supplemented skimmilk gained an average of 57.5 lb. while the non-supplemented skimmilk calves gained an average of 57.1 lb. This difference was not significant statistically ($P =< .05$).

The influence of the mineralized starter should have appeared clearer after the milk feeding period which was six weeks for Holsteins and eight weeks for Jerseys. However, the 8 to 16 week gains were in favor of the calves receiving the plain starter. The calves on plain and mineralized starter gained 69.0 and 65.1 lb., respectively. The difference was not statistically significant.

Increase in height at withers. The average weekly height measurements are shown in Table V. The overall average increase in height was 6.6, 6.7, 6.7, and 6.5 inches for groups I, II, III, and IV, respectively. No significant differences in total height increases among the groups were observed. The increases for the four Holstein groups were 7.3, 7.0, 6.8, and 7.2 inches for the 15-week period. Ragsdale's standard shows an increase of 7.1 inches for 17 weeks. The four U. T. Jersey groups increased 6.7, 6.6, 6.5, and 5.8 inches with Ragsdale's standard showing an increase of 6.9 inches. The W. T. Jersey groups increased an average of 6.0, 6.4,

TABLE IV

AVERAGE BODY WEIGHTS OF FOUR GROUPS OF CALVES COMPARING SKIMMILK AND STARTER SUPPLEMENTED WITH TRACE MINERALS

Age	Plain skimmilk plain starter (I)				Mineralized skimmilk plain starter (II)				Plain skimmilk mineralized starter (III)				Mineralized skimmilk mineralized starter (IV)			
	Hol- steins	Jerseys U.T.	Jerseys W.T.	All	Hol- steins	Jerseys U.T.	Jerseys W.T.	All	Hol- steins	Jerseys U.T.	Jerseys W.T.	All	Hol- steins	Jerseys U.T.	Jerseys W.T.	All
Wk.	(lb.)															
1	90.5	58.6	54.6	67.7	91.8	58.0	57.1	68.9	90.3	54.2	56.0	66.9	91.5	57.3	55.2	67.9
2	98.1	61.0	55.4	71.2	98.0	62.5	59.8	73.3	97.4	57.1	60.7	71.9	101.8	59.2	59.6	73.6
3	109.1	64.5	62.4	78.6	107.7	65.7	64.6	79.3	106.7	65.5	67.1	79.9	110.5	65.3	64.3	80.0
4	117.2	70.1	69.2	85.4	116.1	74.1	73.1	87.7	118.1	72.4	74.4	88.4	124.5	74.4	70.4	89.6
5	129.8	85.6	77.5	97.2	129.1	79.2	81.1	96.6	130.7	82.8	82.1	98.5	136.8	82.1	78.5	98.9
6	144.1	93.4	84.9	107.0	139.9	89.4	90.2	106.6	143.8	90.1	91.1	108.4	146.8	89.0	86.6	107.4
7	151.3	101.6	93.6	115.1	151.1	99.3	97.6	115.9	154.2	100.0	100.7	118.3	159.2	96.5	95.0	116.8
8	162.4	112.4	101.6	124.9	159.5	105.3	110.1	125.3	158.6	111.2	102.9	123.8	167.8	105.8	103.2	125.5
9	173.1	121.1	104.1	131.8	172.3	115.1	111.9	132.9	170.1	118.9	113.3	133.8	179.1	114.9	106.1	132.9
10	183.4	131.1	107.3	139.3	183.6	123.7	116.5	140.9	181.2	126.4	117.2	141.1	188.5	122.8	106.3	138.3
11	196.4	141.1	111.6	148.1	187.8	132.1	121.1	146.4	191.3	134.0	122.5	148.6	204.0	133.0	113.5	149.1
12	203.3	138.4	115.2	153.4	205.2	136.9	126.2	155.5	200.0	144.3	126.8	156.1	212.9	140.6	118.7	156.2
13	215.9	154.9	122.1	162.5	211.5	144.7	131.9	162.0	215.7	151.9	133.1	165.9	226.6	149.4	123.9	165.2
14	226.9	164.5	127.2	170.8	223.3	151.2	137.9	170.1	224.3	159.0	138.7	170.1	233.2	158.2	133.1	173.4
15	239.4	174.8	133.0	180.1	233.4	158.9	147.9	179.5	237.5	166.7	145.8	182.2	237.3	167.8	140.4	180.3
16	249.7	183.5	141.9	189.4	243.7	169.2	155.9	188.8	247.3	178.0	154.6	192.0	251.3	169.5	148.3	188.5
Total gain																
	159.2	124.9	87.3	121.7	151.9	111.2	98.8	118.9	157.0	123.8	98.6	125.1	159.8	112.2	93.1	121.6
S.D.	15.9	8.7	23.6	35.6	12.4	11.2	14.0	26.6	16.5	22.8	25.4	33.0	16.6	16.2	17.5	33.3
1-8 wk. gain																
	71.9	53.8	47.0	57.2	67.7	47.3	53.0	55.4	68.3	57.0	46.9	56.9	76.3	48.5	48.0	59.6
S.D.	11.9	18.3	13.5	15.5	10.6	13.3	6.9	13.1	10.0	8.9	6.7	10.1	13.2	13.8	10.5	18.1
8-16 wk.gain																
	77.3	71.1	40.3	74.5	84.2	63.9	45.8	63.5	88.7	66.8	51.7	68.2	83.5	63.7	45.1	62.0
S.D.	14.8	10.0	14.3	24.4	11.4	12.3	11.5	20.0	16.3	16.9	20.7	26.3	18.0	12.4	11.3	21.4

TABLE V

AVERAGE WITHERS HEIGHT OF FOUR GROUPS OF CALVES COMPARING SKIMMILK AND STARTER SUPPLEMENTED WITH TRACE MINERALS

Age	Plain skimmilk and plain starter (I)				Mineralized skimmilk and plain starter (II)				Plain skimmilk and mineralized starter (III)				Mineralized skimmilk and mineralized starter (IV)			
	Hol- steins	Jerseys U.T.	Jerseys W.T.	All	Hol- steins	Jerseys U.T.	Jerseys W.T.	All	Hol- steins	Jerseys U.T.	Jerseys W.T.	All	Hol- steins	Jerseys U.T.	Jerseys W.T.	All
Wk.	(in.)															
1	27.2	24.9	25.6	25.9	27.6	24.6	25.7	26.0	27.6	24.4	25.8	26.0	27.4	25.1	25.5	26.0
2	27.8	25.3	25.9	26.4	28.2	24.6	26.0	26.3	27.7	24.9	26.3	26.4	28.2	24.9	26.0	26.4
3	28.4	25.7	26.3	26.8	28.5	25.6	26.5	26.9	28.6	25.5	26.9	27.1	28.9	25.4	26.3	26.7
4	29.3	26.2	26.9	27.5	29.1	26.2	27.2	27.5	29.1	25.8	27.5	27.5	29.2	25.9	26.9	27.4
5	29.9	26.9	27.5	28.1	20.0	26.5	27.6	28.1	29.6	26.2	28.1	28.1	29.7	26.6	27.4	27.9
6	30.5	27.5	27.9	28.7	30.2	26.6	28.2	28.4	30.3	26.5	28.6	28.6	30.4	26.5	28.0	28.4
7	30.6	27.7	28.6	29.0	30.8	27.7	28.7	29.1	30.6	27.1	29.3	29.1	30.8	27.5	28.5	29.0
8	30.9	28.7	29.0	29.6	31.0	28.1	29.4	29.6	30.9	28.1	29.7	29.7	31.6	27.9	29.1	29.6
9	31.4	28.7	29.4	29.9	31.0	28.8	29.9	29.9	31.7	28.4	30.1	30.2	31.7	28.0	29.5	29.8
10	31.8	29.3	29.8	30.3	31.7	28.8	30.1	30.3	32.8	29.1	30.5	30.8	32.2	28.4	29.7	30.2
11	32.2	29.7	30.2	30.7	32.5	29.0	30.4	30.7	32.3	29.3	30.8	30.9	32.7	28.9	30.1	30.6
12	33.1	30.0	30.4	31.2	33.0	29.2	30.7	31.1	32.6	29.2	31.2	31.1	33.0	29.2	30.4	30.9
13	33.4	30.7	30.7	31.6	33.4	29.7	30.9	31.4	33.1	29.8	31.5	31.6	33.6	29.4	30.7	31.3
14	33.6	31.2	31.0	31.9	33.8	30.0	31.3	31.8	33.8	29.8	31.8	32.3	33.9	30.3	31.2	31.9
15	33.9	31.5	31.2	32.2	34.2	30.8	31.6	32.3	34.0	29.9	32.1	32.1	34.0	30.5	31.5	32.0
16	34.5	31.6	31.6	32.5	34.6	31.2	32.1	32.7	34.4	30.9	32.4	32.7	34.6	30.9	32.0	32.5
Total increase	7.3	6.7	6.0	6.6	7.0	6.6	6.4	6.7	6.8	6.5	6.6	6.7	7.2	5.8	6.5	6.5
S.D.	1.6	1.5	1.1	1.5	1.6	1.3	2.1	1.2	1.4	1.5	1.1	1.3	2.0	1.7	0.8	1.7

6.6, and 6.5 inches. The substandard height increases of the U. T. Jerseys cannot be explained on the basis of this experiment, since their weight gains were above the standard. One would expect the W. T. Jerseys to be below the standard in respect to withers height since their weights were subnormal.

Heart girth increases. The average weekly heart girth measurements and total increase are shown in Table VI. There were no appreciable differences among the four combined groups. The total increase for the 15-week period for groups I, II, III, and IV was 10.9, 11.3, 10.9, and 11.1 inches respectively. The increases within the breeds were compared with Ragsdale's recommended increases (54). The Holsteins and U. T. Jerseys were equal to the standards, but the W. T. Jerseys were slightly below the standard.

Milk consumption. The average total consumption of skimmilk from the seventh day until weaning was 458.8, 457.9, 461.5, and 456.6 lb. for groups I, II, III, and IV, respectively. The average weekly milk consumption is presented in Table VII. Milk consumption for the four groups should have been nearly the same since the groups were equalized according to size at birth and their milk feeding schedule was based upon the birth weight. With very few exceptions milk was not refused by any calves.

Grain consumption. The total grain consumption for the 15-week period averaged 263.0, 271.1, 265.2, and 264.2 lb. for groups I, II, III, and IV, respectively. Average grain consumption

TABLE VI

AVERAGE HEART GIRTH MEASUREMENTS OF FOUR GROUPS OF CALVES COMPARING SKIMMILK AND STARTER SUPPLEMENTED WITH TRACE MINERALS

Age	Plain skimmilk and plain starter (I)				Mineralized skimmilk and plain starter (II)				Plain skimmilk and mineralized starter (III)				Mineralized skimmilk and mineralized starter (IV)			
	Hol-	Jerseys			Hol-	Jerseys			Hol-	Jerseys			Hol-	Jerseys		
Wk.	steins	U.T.	W.T.	All	steins	U.T.	W.T.	All	steins	U.T.	W.T.	All	steins	U.T.	W.T.	All
	(in.)															
1	30.0	25.9	26.2	27.4	29.9	26.1	26.9	27.7	29.9	25.9	26.6	27.5	29.8	25.8	26.5	27.4
2	30.5	26.4	26.7	27.9	30.7	26.6	28.0	28.5	30.5	26.8	27.2	28.2	31.0	26.4	27.2	28.2
3	32.3	27.6	27.4	29.1	32.5	27.2	28.1	29.3	31.5	27.1	27.9	28.9	32.3	27.4	27.9	29.2
4	32.8	27.6	28.4	29.6	32.8	28.1	28.9	30.0	33.3	27.8	28.7	30.0	33.3	28.1	28.8	30.1
5	33.5	28.7	29.2	30.5	33.6	28.8	30.0	30.8	33.7	28.7	29.9	30.8	34.5	29.1	29.6	31.1
6	34.4	30.0	30.0	31.5	34.3	30.2	31.1	31.9	35.3	31.0	30.9	32.4	35.5	29.8	30.7	32.0
7	35.1	31.4	31.1	32.5	34.7	31.0	32.0	32.6	35.7	31.4	31.9	33.0	35.8	31.1	31.5	32.8
8	35.9	32.5	31.8	33.3	36.0	32.2	33.0	33.7	35.3	32.1	32.9	33.5	36.4	31.9	32.4	33.6
9	36.9	33.0	32.3	34.1	37.6	33.1	33.3	34.7	36.7	32.7	33.3	34.3	37.6	32.4	32.7	34.2
10	37.5	34.0	32.6	34.6	38.3	33.3	33.8	35.1	38.0	33.4	33.5	35.0	38.1	33.4	33.1	34.9
11	38.7	34.5	33.0	35.3	38.5	34.3	34.3	35.7	38.7	34.1	34.0	35.6	39.3	34.2	33.5	35.6
12	39.5	34.8	33.4	35.8	39.3	34.4	34.7	36.2	39.7	34.6	34.5	36.3	40.0	34.4	34.0	36.1
13	40.4	36.5	34.0	36.8	39.9	35.6	35.1	36.8	39.9	35.8	35.3	36.9	40.4	35.2	34.3	36.6
14	41.4	36.9	34.5	37.5	40.5	36.5	35.7	37.5	40.7	36.4	35.6	37.5	41.0	36.1	35.2	37.4
15	41.8	37.1	35.1	37.9	41.4	36.6	36.5	38.1	40.9	36.6	36.1	37.8	41.7	37.0	35.8	38.1
16	41.9	37.0	35.8	38.3	42.3	37.4	37.2	39.0	41.6	37.0	36.6	38.4	42.2	37.1	36.4	38.5
Total increase	11.9	11.9	9.6	10.9	12.4	11.3	10.3	11.3	11.7	11.1	10.0	10.9	12.4	11.3	9.9	11.1
S.D.	1.5	2.4	2.1	2.3	2.0	1.0	1.2	1.7	1.4	2.4	1.9	2.0	2.3	1.9	1.5	2.1

TABLE VII

AVERAGE WEEKLY SKIMMILK CONSUMPTION OF FOUR GROUPS OF CALVES COMPARING SKIMMILK AND STARTER SUPPLEMENTED WITH TRACE MINERALS

Group (Treatments)	Age in weeks								Total consumption
	1	2	3	4	5	6	7	8	
	(lb.)								
Plain skimmilk and plain starter (I)									
Holsteins	63.2	67.7	72.3	76.6	79.7	81.9			441.4
U.T. Jerseys	40.5	43.8	47.4	50.9	54.3	57.2	59.9	62.2	416.2
W.T. Jerseys	34.3	41.1	45.5	49.0	52.5	56.8	59.2	62.0	400.4
All calves	45.7	50.7	55.0	58.7	62.0	65.3	59.5	62.0	458.8
Mineralized skimmilk and plain starter (II)									
Holsteins	62.8	67.3	72.0	76.3	79.8	82.0			440.2
U.T. Jerseys	39.6	42.9	46.4	50.0	53.5	57.0	59.9	62.0	411.3
W.T. Jerseys	33.6	42.0	45.8	99.3	52.8	56.5	59.7	62.1	401.8
All calves	45.0	50.7	54.7	58.5	62.0	65.1	59.8	62.1	457.9
Plain skimmilk and mineralized starter (III)									
Holsteins	62.4	67.0	72.3	77.2	80.7	82.7			442.3
U.T. Jerseys	40.5	44.2	47.5	51.0	54.4	57.7	60.4	62.1	417.8
W.T. Jerseys	33.6	42.9	46.0	49.7	53.3	56.9	60.1	62.1	404.6
All calves	45.1	51.3	55.2	59.2	62.7	65.7	60.2	62.1	461.5
Mineralized skimmilk and mineralized starter (IV)									
Holsteins	62.7	67.2	71.4	75.6	79.4	82.1			438.4
U.T. Jerseys	40.4	43.8	47.3	50.8	54.1	57.2	60.0	62.0	415.6
W.T. Jerseys	32.9	41.7	45.5	49.0	52.4	56.1	58.8	61.4	397.8
All calves	44.9	50.8	54.6	58.3	61.9	65.1	59.3	61.7	456.6

is shown in Table VIII. The Holsteins on an average began consuming the maximum four pounds of grain per day during the seventh and eighth week. The Jerseys were generally some three or four weeks older before they began consuming four pounds of grain daily. Grain consumption for the W. T. Jerseys was lower than the consumption of the U. T. Jerseys.

Hay consumption. Hay consumption per group for the 15 week period averaged 84.4, 83.7, 86.7, and 90.5 lb. for groups I, II, III, and IV, respectively. The average weekly hay consumption is presented in Table IX which shows that the Holsteins consumed considerable more hay than the Jerseys. This would be expected because of size and rate of growth. The U. T. Jerseys consumed more hay than the W. T. Jerseys.

Blood analysis. Only the Holsteins and U. T. Jerseys were used in the blood studies. Each blood sample was analyzed for hemoglobin, cell volume, calcium, inorganic phosphorus, and protein-bound-iodine. Tables X, XI, XII, XIII, and XIV show the average values of hemoglobin, hematocrit, calcium, phosphorus and protein-bound-iodine, respectively. The tables show the average values for each breed on each of the four rations. A summary is also presented of values for the calves receiving plain skimmilk, mineralized skimmilk, plain starter, and mineralized starter. In this summary each value was used in two different groups. For example, a value for a calf in group I would be used in the plain skimmilk average and in the plain starter average. The group average blood values are so close that there

TABLE VIII

AVERAGE WEEKLY GRAIN CONSUMPTION OF FOUR GROUPS OF CALVES COMPARING SKIMMILK AND STARTER SUPPLEMENTED WITH TRACE MINERALS

Age	Plain skimmilk and plain starter (I)				Mineralized skimmilk and plain starter (II)				Plain skimmilk and mineralized starter (III)				Mineralized skimmilk and mineralized starter (IV)			
	Holsteins	Jerseys U.T.	Jerseys W.T.	All	Holsteins	Jerseys U.T.	Jerseys W.T.	All	Holsteins	Jerseys U.T.	Jerseys W.T.	All	Holsteins	Jerseys U.T.	Jerseys W.T.	All
Wk.	(lb.)															
1	0.6	0.5	0.2	0.4	0.4	0.3	0.0	0.2	0.4	0.2	0.0	0.2	0.1	0.3	0.1	0.2
2	1.6	1.9	0.6	1.3	1.4	1.2	0.5	1.0	1.1	1.1	1.0	1.1	1.4	1.8	0.7	1.3
3	4.1	2.7	1.5	2.7	3.9	2.4	2.2	2.8	3.0	2.5	3.0	2.8	5.1	3.0	1.8	3.2
4	7.4	5.3	3.6	5.3	7.5	4.7	4.4	5.5	5.7	4.7	4.4	4.9	9.4	5.1	4.2	6.2
5	10.6	8.3	5.6	8.0	11.7	7.8	7.2	8.9	10.5	9.4	6.8	8.7	12.9	6.9	6.3	8.7
6	14.8	12.4	7.8	11.4	15.1	13.8	9.4	12.5	14.8	11.6	8.8	11.8	14.8	10.7	8.4	11.2
7	24.3	15.9	10.0	16.4	22.9	16.9	11.1	16.7	25.4	13.3	10.9	16.4	25.4	13.9	10.2	16.3
8	27.4	17.5	10.5	18.0	26.3	17.3	13.4	18.8	25.7	16.3	13.2	18.2	27.0	15.6	11.8	17.9
9	27.8	25.0	18.2	23.3	27.7	22.6	21.0	23.7	27.5	23.8	22.8	24.6	27.9	21.4	19.2	22.7
10	28.0	25.9	18.7	23.8	27.9	24.8	20.7	24.3	27.7	26.0	19.2	23.9	27.9	24.0	16.2	22.2
11	28.0	27.4	19.0	24.3	28.0	26.4	20.7	24.7	27.7	25.1	21.4	24.6	27.9	25.6	19.0	23.8
12	27.9	27.9	19.9	24.8	28.0	27.3	22.4	25.6	27.5	25.6	20.3	24.2	27.8	25.9	20.2	24.3
13	27.8	27.1	21.5	25.2	28.0	27.2	21.9	25.4	27.7	25.6	22.4	25.1	28.0	27.3	22.6	25.7
14	27.5	27.4	23.1	25.8	27.8	27.6	24.1	26.3	28.0	26.1	23.4	25.7	28.0	26.7	23.8	26.0
15	28.0	27.8	22.8	25.9	28.0	28.0	25.8	27.2	28.0	27.6	23.9	26.3	28.0	27.5	26.3	27.2
16	28.0	27.6	24.3	26.4	28.0	27.6	27.1	27.5	28.0	26.5	25.6	26.7	28.0	27.5	26.6	27.3
Total consumption	313.8	280.6	207.3	263.0	312.6	275.9	231.9	271.1	308.7	265.4	227.1	265.2	319.3	263.2	217.4	264.2
S.D.	21.7	19.0	46.4	57.0	20.6	25.3	32.7	43.7	11.7	32.6	44.7	47.3	17.3	40.7	39.4	56.5

TABLE IX

AVERAGE WEEKLY HAY CONSUMPTION OF FOUR GROUPS OF CALVES COMPARING SKIMMILK AND STARTER SUPPLEMENTED WITH TRACE MINERALS

Age	Plain skimmilk and plain starter (I)				Mineralized skimmilk and plain starter (II)				Plain skimmilk and mineralized starter (III)				Mineralized skimmilk and mineralized starter (IV)			
	Hol-	Jerseys			Hol-	Jerseys			Hol-	Jerseys			Hol-	Jerseys		
	steins	U.T.	W.T.	All	steins	U.T.	W.T.	All	steins	U.T.	W.T.	All	steins	U.T.	W.T.	All
Wk.	(lb.)															
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.3	0.4	0.1	0.3	0.0	0.1	0.1	0.0	0.5	0.0	0.2	0.2	0.4	0.3	0.0	0.2
3	0.7	0.4	0.2	0.4	0.5	0.5	0.2	0.3	0.9	0.3	0.3	0.5	0.6	0.7	0.2	0.5
4	1.1	0.6	0.7	0.7	0.7	0.6	0.5	0.6	1.3	0.2	0.4	0.7	1.2	0.8	0.8	0.9
5	1.2	1.3	1.0	1.2	1.3	0.7	0.9	1.0	1.0	0.8	0.9	0.9	1.2	1.0	0.9	1.0
6	1.7	1.6	1.1	1.4	1.7	2.1	1.1	1.6	2.8	1.5	0.1	1.7	1.8	1.0	0.9	1.3
7	2.9	2.7	1.3	2.2	3.5	2.3	1.6	2.4	3.5	2.1	1.4	2.3	4.1	1.4	1.0	2.2
8	4.1	2.8	1.9	2.8	4.2	2.8	1.7	2.8	3.9	3.4	1.8	2.9	3.3	3.6	1.3	2.6
9	6.1	2.3	3.0	3.8	5.5	3.2	3.0	3.9	5.8	4.0	4.1	4.6	7.8	3.2	2.2	4.3
10	8.7	3.1	3.3	5.1	8.7	3.5	2.8	5.0	7.2	6.4	3.5	5.6	8.9	6.4	1.4	5.3
11	11.0	6.5	3.5	6.8	13.0	5.7	2.9	7.1	10.9	7.4	3.7	7.1	14.2	7.2	2.5	7.7
12	15.1	8.8	3.6	8.9	17.7	5.6	4.3	9.1	13.1	11.2	4.0	9.0	13.8	12.2	2.2	8.9
13	17.6	11.6	4.0	10.6	18.3	7.0	4.9	9.9	15.4	11.6	5.0	10.3	18.3	11.2	3.9	10.7
14	15.6	14.0	4.8	10.9	18.3	10.9	6.6	11.7	14.7	12.7	6.3	10.9	20.1	13.9	4.8	12.4
15	19.7	19.2	5.0	13.9	21.8	11.0	7.6	13.3	22.4	16.0	8.0	15.0	22.5	19.7	6.9	15.7
16	24.5	18.1	5.7	15.4	23.2	15.6	7.6	15.0	21.5	17.0	7.9	15.0	25.1	19.1	7.9	16.8
Total consumption	130.1	93.4	39.2	84.4	138.4	71.5	45.8	83.7	124.9	94.6	47.6	86.7	143.3	101.7	37.0	90.5
S.D.	33.7	33.3	36.7	51.9	50.4	18.1	34.3	54.4	45.1	48.5	28.4	52.0	58.3	26.7	20.0	59.4

TABLE X

AVERAGE HEMOGLOBIN OF JERSEY AND HOLSTEIN CALVES FED SKIMMILK AND STARTER WITH AND WITHOUT TRACE MINERAL SUPPLEMENTS TO 15 WEEKS OF AGE

Groups (Treatments)	Age in weeks							
	1	3	5	7	9	11	13	15
	(g. per 100 ml.)							
Plain milk and plain starter								
Holsteins	11.7	11.1	10.1	10.6	10.8	11.4	11.7	11.9
Jerseys	10.2	9.8	9.6	10.6	12.1	12.1	12.1	11.7
All calves	11.0	10.5	9.9	10.6	11.4	11.7	11.9	11.8
Mineral milk and plain starter								
Holsteins	13.1	12.8	11.6	11.9	12.2	12.4	12.2	12.5
Jerseys	10.0	9.2	9.0	10.2	11.5	12.2	12.3	12.2
All calves	11.7	11.2	10.4	11.1	11.9	12.3	12.3	12.4
Plain milk and mineral starter								
Holsteins	12.1	11.6	11.5	11.3	11.5	11.5	11.6	12.1
Jerseys	10.6	9.7	9.6	11.0	12.1	12.5	12.5	11.5
All calves	11.5	10.7	10.1	11.2	11.8	12.0	12.0	11.9
Mineral milk and mineral starter								
Holsteins	11.9	10.7	10.6	11.4	11.6	11.6	11.6	11.5
Jerseys	10.7	10.1	9.9	11.2	11.5	11.7	11.5	11.3
All calves	11.3	10.5	10.3	11.3	11.6	11.6	11.5	11.4
All plain milk								
Holsteins	11.9	11.4	10.8	11.0	11.2	11.5	11.7	12.0
Jerseys	10.4	9.8	9.6	10.8	12.1	12.3	12.3	11.6
All calves	11.3	10.6	10.0	10.9	11.6	11.9	12.0	11.9
All mineral milk								
Holsteins	12.5	11.8	11.1	11.7	11.9	12.0	11.9	12.0
Jerseys	10.4	9.7	9.5	10.7	11.5	12.0	11.9	11.8
All calves	11.5	10.9	10.4	11.2	11.8	12.0	11.9	11.9
All plain starter								
Holsteins	12.5	12.0	10.9	11.3	11.5	11.9	12.0	12.2
Jerseys	10.2	9.5	9.3	10.4	11.8	12.2	12.2	12.0
All calves	11.4	10.9	10.2	10.9	11.7	12.0	12.1	12.1
All mineral starter								
Holsteins	12.0	11.2	11.0	11.4	11.6	11.6	11.6	11.8
Jerseys	10.7	9.9	9.8	11.1	11.8	12.1	11.9	11.4
All calves	11.4	10.6	10.2	11.3	11.7	11.8	11.8	11.7

TABLE XI

AVERAGE HEMATOCRIT OF JERSEY AND HOLSTEIN CALVES FED SKIMMILK AND STARTER WITH AND WITHOUT TRACE MINERAL SUPPLEMENTS TO 15 WEEKS OF AGE

Groups (Treatments)	Age in weeks							
	1	3	5	7	9	11	13	15
	(cell volume, %)							
Plain milk and plain starter								
Holsteins	39.7	36.5	34.9	35.4	36.3	36.0	37.1	37.6
Jerseys	33.3	31.5	31.1	34.1	37.8	38.4	37.6	35.7
All calves	36.8	34.2	33.2	34.8	37.0	37.1	37.3	36.7
Mineral milk and plain starter								
Holsteins	43.7	40.6	36.4	39.0	38.8	38.6	39.1	39.3
Jerseys	33.0	31.2	31.3	35.0	37.6	39.2	39.3	38.8
All calves	38.8	36.3	34.1	37.2	38.2	38.9	39.2	39.1
Plain milk and mineral starter								
Holsteins	41.7	38.0	34.0	36.5	37.2	37.3	38.0	38.9
Jerseys	34.4	32.1	31.7	35.8	37.9	38.4	38.6	36.2
All calves	38.8	35.2	32.9	36.2	37.5	37.8	38.3	37.7
Mineral milk and mineral starter								
Holsteins	38.7	35.4	34.0	37.2	36.2	37.0	36.0	36.7
Jerseys	33.6	33.0	33.9	34.5	36.7	36.5	35.6	35.9
All calves	36.4	34.3	34.0	35.9	36.4	36.8	35.8	36.3
All plain milk								
Holsteins	40.7	37.3	34.5	36.0	36.8	36.7	37.6	38.2
Jerseys	33.9	31.8	31.4	35.0	37.9	38.4	38.1	36.0
All calves	37.8	34.7	33.1	35.5	37.3	37.5	37.8	37.7
All mineral milk								
Holsteins	41.2	38.0	35.2	38.1	37.5	37.8	37.6	38.0
Jerseys	33.3	32.1	32.6	34.6	32.2	37.9	37.5	37.4
All calves	37.6	35.3	34.1	36.6	34.9	37.9	37.5	37.8
All plain starter								
Holsteins	41.7	38.6	35.7	37.2	37.6	37.3	38.1	39.4
Jerseys	33.2	31.4	31.2	34.6	37.7	38.8	38.5	37.3
All calves	37.0	35.3	33.7	36.0	37.6	38.1	38.3	38.4
All mineral starter								
Holsteins	40.2	37.1	34.0	36.9	36.7	37.2	37.0	37.8
Jerseys	34.0	32.6	32.8	35.2	37.3	37.5	37.1	36.1
All calves	37.6	34.8	33.5	36.1	37.0	37.3	37.1	37.0

TABLE XII

AVERAGE BLOOD CALCIUM OF JERSEY AND HOLSTEIN CALVES FED SKIMMILK AND STARTER WITH AND WITHOUT TRACE MINERAL SUPPLEMENTS TO 15 WEEKS OF AGE

Groups (Treatments)	Age in weeks							
	1	3	5	7	9	11	13	15
	(mg. per 100 ml.)							
Plain milk and plain starter								
Holsteins	11.6	11.0	12.6	10.9	10.9	11.8	12.3	11.7
Jerseys	11.4	11.1	11.1	11.9	12.7	11.9	11.9	11.8
All calves	11.5	11.0	11.9	11.4	11.7	11.8	12.1	11.7
Mineral milk and plain starter								
Holsteins	12.3	11.3	11.7	11.1	12.0	12.2	11.5	11.5
Jerseys	11.0	11.9	12.3	12.4	12.3	13.0	12.0	11.2
All calves	11.7	11.6	12.0	11.7	12.1	12.6	11.7	11.4
Plain milk and mineral starter								
Holsteins	12.0	12.1	11.7	10.8	11.6	11.8	12.3	11.5
Jerseys	11.4	11.3	11.7	11.0	11.8	12.2	12.2	11.2
All calves	11.7	11.7	11.7	10.9	11.7	12.0	12.2	11.4
Mineral milk and mineral starter								
Holsteins	11.8	11.6	11.8	11.1	11.0	11.6	11.8	11.3
Jerseys	11.5	12.6	13.0	10.8	11.1	11.9	12.0	12.0
All calves	11.7	12.2	12.3	11.0	11.0	11.7	11.9	11.6
All plain milk								
Holsteins	11.8	11.6	12.2	10.9	11.3	11.8	12.3	11.7
Jerseys	11.4	11.2	11.4	11.5	12.0	12.1	12.1	11.5
All calves	11.6	11.4	11.8	11.2	11.7	11.9	12.1	11.6
All mineral milk								
Holsteins	12.1	11.5	11.8	11.1	11.5	11.9	11.7	11.4
Jerseys	11.3	12.3	12.7	11.6	11.7	12.5	12.0	11.6
All calves	11.7	11.8	12.2	11.4	11.6	12.1	11.8	11.5
All plain starter								
Holsteins	12.0	11.2	12.2	11.0	11.5	12.0	11.9	11.6
Jerseys	11.2	11.5	11.7	12.2	12.5	12.5	12.0	11.5
All calves	11.6	11.3	12.0	11.6	11.9	12.2	11.9	11.6
All mineral starter								
Holsteins	11.9	11.9	11.8	11.0	11.3	11.7	12.1	11.4
Jerseys	11.5	12.0	12.4	10.9	11.5	12.1	12.1	11.6
All calves	11.7	11.9	12.1	11.0	11.4	11.9	12.1	11.5

TABLE XIII

AVERAGE INORGANIC BLOOD PHOSPHORUS OF JERSEY AND HOLSTEIN CALVES FED MILK AND STARTER WITH AND WITHOUT TRACE MINERAL SUPPLEMENTS TO 15 WEEKS OF AGE

Groups (Treatments)	Age in weeks							
	1	3	5	7	9	11	13	15
	(mg. per 100 ml.)							
Plain milk and plain starter								
Holsteins	8.6	8.4	8.7	9.0	8.9	8.4	9.0	9.0
Jerseys	8.5	8.4	8.6	9.6	9.8	9.6	9.4	9.2
All calves	8.5	8.4	8.7	9.3	9.3	9.0	9.2	9.1
Mineral milk and plain starter								
Holsteins	8.9	8.4	8.8	8.4	9.1	8.9	9.0	9.5
Jerseys	8.8	9.1	9.2	9.9	9.4	9.6	9.8	9.4
All calves	8.8	8.7	9.0	9.1	9.2	9.2	9.4	9.5
Plain milk and mineral starter								
Holsteins	8.9	8.8	8.2	9.0	8.7	8.7	8.9	9.7
Jerseys	8.2	8.2	8.8	8.5	9.0	9.2	8.8	8.1
All calves	8.2	8.5	8.9	8.8	8.8	8.9	8.8	9.0
Mineral milk and mineral starter								
Holsteins	8.8	8.6	8.7	9.1	8.6	8.7	8.5	8.5
Jerseys	8.9	8.6	8.6	9.2	9.2	8.9	9.7	9.1
All calves	8.8	8.6	8.6	9.1	8.8	8.8	9.0	8.8
All plain milk								
Holsteins	8.8	8.6	8.5	9.0	8.8	8.6	9.0	9.4
Jerseys	8.4	8.3	8.7	9.1	9.4	9.4	9.1	8.7
All calves	8.4	8.5	8.8	9.1	9.1	9.0	9.0	9.1
All mineral milk								
Holsteins	8.9	8.5	8.8	8.8	8.9	8.8	8.8	9.0
Jerseys	8.9	8.9	8.9	9.6	9.3	9.3	9.8	9.3
All calves	8.8	8.7	8.8	9.1	9.0	9.0	9.2	9.2
All plain starter								
Holsteins	8.8	8.4	8.8	9.2	9.0	8.7	9.0	9.3
Jerseys	8.7	8.8	8.9	9.8	9.6	9.6	9.6	9.3
All calves	8.7	8.6	8.8	9.5	9.3	9.1	9.3	9.3
All mineral starter								
Holsteins	8.9	8.7	8.9	9.1	8.7	8.7	8.7	9.1
Jerseys	8.6	8.4	8.7	8.9	9.1	9.1	9.3	8.6
All calves	8.7	8.6	8.8	9.0	8.8	8.9	8.9	8.9

TABLE XIV

AVERAGE PROTEIN-BOUND-IODINE BLOOD LEVEL OF JERSEY AND HOLSTEIN CALVES FED SKIMMILK AND STARTER WITH AND WITHOUT TRACE MINERAL SUPPLEMENTS TO 15 WEEKS OF AGE

Groups (Treatments)	Age in weeks							
	1	3	5	7	9	11	13	15
	(mcg. per 100 ml.)							
Plain milk and plains starter								
Holsteins	5.7	5.6	5.2	4.4	4.9	5.3	4.9	4.6
Jerseys	5.8	5.9	6.0	5.8	5.1	5.3	5.2	5.7
All calves	5.8	5.7	5.6	5.1	5.0	5.3	5.0	5.1
Mineral milk and plain starter								
Holsteins	5.9	6.0	5.7	4.6	5.2	5.5	5.3	4.8
Jerseys	5.0	5.2	4.9	5.2	4.7	5.6	5.3	5.6
All calves	5.5	5.7	5.3	4.8	5.0	5.5	5.3	5.1
Plain milk and mineral starter								
Holsteins	4.7	5.9	6.2	4.9	5.6	5.9	5.3	5.4
Jerseys	4.5	5.3	5.6	5.8	4.0	4.8	4.4	4.8
All calves	4.6	5.6	5.9	5.8	4.9	5.4	4.9	5.1
Mineral milk and mineral starter								
Holsteins	6.0	7.0	6.1	5.0	5.8	6.4	5.3	5.3
Jerseys	4.7	5.3	4.8	4.8	4.2	4.6	4.7	5.4
All calves	5.4	6.2	5.6	4.9	5.0	5.6	5.0	5.4
All plain milk								
Holsteins	5.2	5.8	5.7	4.7	5.3	5.6	5.1	5.0
Jerseys	5.2	5.6	5.8	5.8	4.6	5.1	4.8	5.3
All calves	5.2	5.7	5.8	5.5	5.2	5.4	5.0	5.1
All mineral milk								
Holsteins	6.0	6.5	5.9	4.8	5.5	6.0	5.3	5.1
Jerseys	4.9	5.3	4.9	5.0	4.5	5.1	5.0	5.5
All calves	5.4	6.0	5.5	4.9	5.0	5.6	5.1	5.3
All plain starter								
Holsteins	5.8	5.8	5.5	4.5	5.1	5.4	5.1	4.7
Jerseys	5.4	5.6	5.5	5.5	4.9	5.5	5.3	5.7
All calves	5.6	5.7	5.5	5.0	5.0	5.4	5.1	5.1
All mineral starter								
Holsteins	5.4	6.5	6.2	5.0	5.7	6.2	5.3	5.4
Jerseys	4.6	5.3	5.2	5.5	4.1	4.7	4.6	5.1
All calves	5.1	5.9	5.8	5.3	5.0	5.5	5.0	5.3

was no indication that the rations affected the blood values. The hemoglobin, hematocrit, calcium, and phosphorus values are comparable to the normal values reported by Wise, et al. (78).

CHAPTER V

DISCUSSION

The results of this experiment have shown that it is not necessary to add trace minerals to reconstituted skimmilk or to the starter which is fed to a young calf. This was illustrated by several points. The body weight gains of all groups of calves were nearly the same which indicated that the calves were growing properly. The heart girth and withers height measurements were also normal and were practically the same for all groups of calves within the breed. However, growth alone could be misleading where micronutrients are involved. For this reason the effects of the trace minerals on the blood were tested directly or indirectly.

Hemoglobin level was used to determine if iron and copper were available in sufficient quantities since iron and copper have been proven necessary for hemoglobin formation. The cell volume (hematocrit) was determined to see if the presence of trace minerals necessary for the production of cells was adequate. Both hemoglobin and cell volume were high for the initial test and then about the fifth week the levels reached a low point. From the fifth week through the fifteenth week hemoglobin and hematocrit values remained fairly constant. This is the normal trend (78).

Calcium and inorganic phosphorus of the blood were also determined to see if there were any relationships between the blood

calcium and phosphorus and the level of trace minerals. Protein-bound-iodine levels were determined, but it is questionable if this test was an indication of iodine nutrition (31). There was no significant difference between the groups in the effects of the trace minerals on the blood. The values were normal when compared to values found by other workers (78).

Since these results have indicated no benefit from trace mineral supplementation, and milk is known to be low in certain trace minerals, an explanation of the lack of response should be sought. The trace minerals are needed in very minute amounts, hence the name trace minerals. With this in mind one should think of the probable sources from which the calves received trace minerals. The calf is born with a storage of certain minerals which are used during the early life of the calf. Colostrum contains more trace minerals than normal milk and the calves used in this experiment were given colostrum for two to five days after birth. During the colostrum feeding period the calves probably received adequate amounts of the trace minerals. The feeding of colostrum to young calves is a recommended practice and should be encouraged since it is not used for human consumption and is very nutritious for the calf.

The calves put on a reconstituted skimmilk diet without any mineral supplementation at eight days of age continued to gain in weight and remained healthy. Reconstituted skimmilk is considered

to be low in trace minerals. However, it does contain traces of these nutrients as is shown in Table XV. These amounts are insufficient when compared with the needs for normal growth (42). However, at three to four weeks of age, a calf will consume hay and grain in sufficient quantities to supply most of the trace minerals recommended for normal health and growth. Until these minerals can be secured from hay and grain, the calves may have been using stored minerals to support normal growth and hold blood values high, or there may have been a considerable delay in the appearance of deficiency signs.

Table XV shows the daily requirements of trace minerals for a 100 lb. calf, the trace minerals received from 9.0 lb. of reconstituted skimmilk, 0.2 lb. of hay, and 0.8 lb. of starter. These are the averages of the 3rd and 4th weeks' consumption at which time the average weight of all the calves was approximately 100 lb. The Holsteins weighed more and the Jerseys less than 100 lb. at these ages.

It is shown in Table XV that a very small amount of hay and grain will provide the needed amounts of trace minerals. Although there was still a dietary deficiency of some trace minerals at three to four weeks of age, by the fifth or sixth week the calves were consuming enough hay and starter to over-supply the required amounts. Actually the hay consumption had increased only slightly, but grain consumption had increased from 0.8 lb. to 1.4 lb. per day which was the average of the fifth and sixth week.

Supplemented skimmilk supplied an ample amount of trace minerals.

TABLE XV

TRACE MINERAL REQUIREMENTS AND AMOUNTS RECEIVED FROM SKIMMILK, HAY, AND STARTER BY DAIRY CALVES AT THREE TO FOUR WEEKS OF AGE

Mineral	Daily requirement for 100 lb. calf	Amounts received from:		
		9.0 lb. skimmilk	0.2 lb. hay	0.8 lb. starter
	(mg.)			
Iron	50.0	0.27	10.5	24.0
Copper	5.0	0.078	0.6	3.0
Cobalt	0.1	0.0006	0.006	0.24
Manganese	20.0	0.018	2.0	14.0
Zinc	0.5	2.22	0.8	6.0
Iodine	0.2	0.024	0.0055	0.120
Magnesium	600.0	70.0	137.0	1000.0

Nine pounds of reconstituted skimmilk containing 1.35 lb. of solids were supplemented to furnish 85.0 mg. of iron, 3.8 mg. of copper, 1.8 mg. of cobalt, 30.0 mg. of manganese, 0.6 mg. of zinc, and 0.8 mg. of iodine. All of these amounts with the exception of copper are above the recommended levels.

The supplemented starter, which half of the calves received, provided even more trace minerals. The mineral supplement in 0.8 lb. of supplemented starter furnished 24.0 mg. of iron, 1.1 mg. of copper, 0.5 mg. of cobalt, 8.8 mg. of manganese, 0.18 mg. of zinc, and 0.24 mg. of iodine in addition to the minerals in the plain unsupplemented starter.

Table XVI shows the level of trace minerals which the calves on supplemented skimmilk and supplemented starter received along with the total amount received including the amount received from hay. It is readily seen that the amount received from either skimmilk or starter alone was sufficient to provide the daily requirements.

From this study it may be seen that if good quality hay and starter are provided, calves will receive their needed trace minerals. Of course a calf must eat the hay and starter, but this is no problem when the limited milk feeding plan is used along with palatable hay and starter. There may be a possibility that trace minerals would be deficient on an unsupplemented ration if the calves were being fed a maximum amount of skimmilk with rapid growth as the objective. However, most dairymen are of the opinion that the

TABLE XVI

TRACE MINERAL REQUIREMENTS AND AMOUNTS RECEIVED FROM HAY, SUPPLEMENTED SKIMMILK, SUPPLEMENTED STARTER AND TOTAL FOR DAIRY CALVES AT THREE TO FOUR WEEKS OF AGE

Mineral	Daily requirement for 100 lb. calf	Amount received from: 0.2 lb. hay	9.0 lb. supplemented skimmilk	0.8 lb. supplemented starter	Total
	(mg.)				
Iron	50.0	10.5	85.3	48.0	143.8
Copper	5.0	0.6	3.9	4.1	8.6
Cobalt	0.1	0.006	1.8	0.7	2.5
Manganese	20.0	2.0	30.0	22.8	54.8
Zinc	0.5	0.8	2.8	6.2	9.8
Iodine	0.2	0.0055	0.8	0.4	1.2
Magnesium	600.0	137.0	70.0	1000.0	1207.0

most rapid growth plan should not be followed in a calf raising plan.

The feed consumption was approximately the same for all calves, thus the addition of trace minerals to the milk and starter had no effect on feed efficiency. The appetite for hay might have been increased by the mineralized starter since the average hay consumption for the 15-week period was 84.1 and 88.6 lb. for the calves on plain starter and mineralized starter, respectively. The appetite for starter could not be determined since the calves were limited to four pounds per day, and this was eaten readily after about eight weeks of age.

Since calves can be raised satisfactorily without supplementing the skimmilk and starter with trace minerals, the feed cost and labor will be less if the trace mineral supplementing is done by the dairyman only on those farms where it is known to be needed. In areas known to be deficient in iodine or cobalt, only the needed supplement should be added. In other areas, such as in Florida, a more complex mixture of trace minerals may be necessary. There are no areas in Tennessee which are known to be deficient in trace minerals; therefore, calves can be raised in Tennessee on a ration of plain skimmilk, farm-mixed starter unsupplemented with trace minerals, and good quality hay.

CHAPTER VI

SUMMARY

This experiment was conducted to determine if the trace minerals, iron, copper, cobalt, manganese, iodine, and zinc should be added to a ration of reconstituted skimmilk, normal starter, and average quality hay for young dairy calves.

A total of 144 calves, 96 Jerseys and 48 Holsteins, which were divided into four equal groups were used in this study. The study was so designed that it could be determined if trace minerals should be added to the skimmilk, to the starter, or to both. The four experimental groups were as follows:

Group I. Plain skimmilk and plain starter formula

Group II. Mineralized skimmilk and plain starter formula

Group III. Plain skimmilk and mineralized starter

Group IV. Mineralized skimmilk and mineralized starter

The calves were on the experiment from one week to sixteen weeks of age. Growth rates were determined from weekly body weights, heart girth and withers height measurements. In addition, daily feed consumption was measured and bi-weekly blood samples were analyzed for hemoglobin, cell volume, calcium, inorganic phosphorus, and protein-bound-iodine.

There was no statistically significant difference in body weight gains, heart girth or withers height measurements among the

groups. The average total body weight gains for the four groups were 121.7, 118.9, 125.1, and 121.6 lb., respectively. This showed that the calves receiving plain skimmilk and mineralized starter held a slight edge over the other three groups in respect to body weight gains.

The feed consumption of skimmilk, starter, and hay was practically the same for all groups within the breed, which indicated that trace mineral supplementation did not affect feed efficiency. The blood values of hemoglobin, cell volume (hematocrit), calcium, inorganic phosphorus, and protein-bound-iodine were not affected by adding trace minerals to either skimmilk or starter. These values were normal for all rations.

From this study it was concluded that supplementation of trace minerals to the skimmilk or starter fed to young dairy calves was not necessary for normal growth and health of the calves.

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