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To the Graduate Council: .

I am submitting herewith a thesis written by James Hall Williamson entitled "A Comparison of Two Methods of Milk Feeding, with and without Rumen Inoculation, upon the Growth and Feeding Efficiency of Dairy Calves." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Dairy.

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A COMPARISON OF TWO METHODS OF MILK FEEDING,
WITH AND WITHOUT RUMEN INOCULATION, UPON THE
GROWTH AND FEEDING EFFICIENCY OF DAIRY CALVES

33A

A THESIS

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CHAPTER I

INTRODUCTION

Milk is the most expensive ingredient of the calves' ration, yet it is believed that a certain amount of milk or milk solids is essential for normal growth of calves. Because of the expense of whole milk feeding, investigators have from time to time undertaken to raise calves on smaller amounts of milk than are generally recommended. In order to raise calves more economically, the usual recommendation is to feed calves lightly on milk and encourage them to consume other less expensive feeds at an early age to supplement the limited milk diet.

Milk replacements have been used quite successfully in raising calves for the past few years, but unfortunately very young calves do not have the proper rumen development to utilize large amounts of starchy or fibrous feeds, such as hay and grain, thus fairly large quantities of milk replacement and calf starter are needed for normal growth of the calves.

It has been postulated that the establishment of an adult-like flora as early as possible would increase the efficiency of roughage utilization enabling farmers to feed low-cost roughages and grains for part of the costly milk and calf starters.

It is believed that a well-started calf should be able to shift to a non-milk diet quicker without loss of weight than a poorly-started calf. This study was conducted to determine whether more satisfactory calf raising can be accomplished by limited milk feeding for nine weeks or by liberal milk feeding until the "normal" nine weeks weight is reached, and to further determine whether rumen inoculation is beneficial to calves raised under these conditions.

CHAPTER II

REVIEW OF LITERATURE

Several investigators (1, 50, 51, 55, 56, 57) have demonstrated that calves can be raised successfully on milk replacements. However, these milk replacements have only been developed in the last few years. Prior to the use of milk replacements other substitutes were used. Skim milk was recognized many years ago as a good substitute for whole milk for feeding dairy calves, but even then whole milk was recommended for the first three to four weeks (45).

For many years the general milk-feeding recommendations for rearing dairy calves have remained practically unchanged (7, 46). The generally accepted schedule has been to feed the new-born calf colostrum for the first two or three days, follow with whole milk for two to four weeks, gradually change to skim milk at the rate of one pound daily over a period of a week or ten days, and then continue feeding skim milk to six months of age. Since most dairymen sell whole milk, skim milk is not usually available for feeding calves. In an experiment using Holstein calves, Krauss and Crawford (25) compared whole milk, skim milk, skim milk powder in water, and skim milk powder in a grain mixture for feeding calves. The calves receiving the reconstituted skim milk made the fastest gain. It was concluded that powdered skim

milk was equivalent to skim milk when properly used. Rupel (46) also reported gains of 1.69 pound per day for calves receiving reconstituted skim milk.

Because of the economic considerations, many investigations (7, 8, 10, 28, 45) have been made with dairy calves to determine the minimum amount of milk necessary to raise calves successfully. Fraser and Brand (10), and Lindsey (28) studied the minimum amount of milk essential for desirable growth of dairy calves and concluded that calves could not be raised on less than 140 to 200 pounds of whole milk and about 500 pounds of skim milk. Davis and Cunningham (8) fed calves whole milk for ten days and gradually substituted calf-meal gruel into the diet. They found that calves could be raised to five months of age successfully on 150 to 300 pounds of whole milk when calf-meal gruel was used. Ragsdale and Turner (45) raised 30 calves to six months of age with an average of sixty to eighty-five pounds of milk per calf. Growth rates were approximately 70 per cent of normal with the poorest growth occurring after the change from milk to grain and hay. Most of the calves had regained normal weight at nine months to one year of age. Converse (7) reported that 102 male and 54 female calves were reared successfully with no whole milk whatever. They were fed colostrum for three days and then changed immediately to skim milk, which was supplemented with vitamin A, and continued on skim milk to

six months of age. In later experiments Converse reported that calves could be raised on about 300 pounds of skim milk and no whole milk at all.

Ingham, et al. (21) reported that approximately one hundred pounds of whole milk and from sixty to eighty-five pounds of dry skim milk were required to raise a normal calf.

In several experiments (8, 17, 21, 31, 53) various substitutes, such as gruels and calf starters, were fed in attempts to shorten the period of whole milk feeding and to reduce the amount of liquid milk fed to dairy calves. Various grain feeds mixed with dry skim milk or some form of dried blood were fed as dry calf starters or mixed with milk or water and fed as gruels. Maynard and Norris (31) compared gruel with skim milk feeding and found that the six month gain for the calves receiving skim milk was 1.71 pound per day as compared to 1.44 pound per day for the calves changed to gruel after they were four weeks old. Ingham, et al. (21) reported a gain of 1.45 pound per day for skim milk fed calves as compared to 1.36 pounds per day for the calf-meal fed calves. The cost per pound gain was eight cents for each group.

Wallace, et al. (53) attempted to formulate substitute mixtures which would satisfactorily replace fluid whole milk in the ration of dairy calves after ten to fourteen days of age. Approximately normal growth was obtained with mixtures

containing large amounts of dried milk solids. In general the calves were rougher from the third to seventh week of age than those fed whole milk. The rate of growth was somewhat slower on the substitutes during the first month than on the milk, but the difference was largely overcome by the time the calves were four to six months old.

The results of the above type of experimental feeding, which is summarized by Savage and McCay (48), indicate that the recommended amount of whole milk fed with gruels or starters vary as much as 200 to 500 pounds for thirty to sixty days at different experiment stations. As early as 1902, Hayward (17) reported that dairy calves could be raised on calf-meals just as well as skim milk, but that neither was as good as whole milk for raising calves. Davis, et al. (8) confirmed this in 1923, but added that calves should not be changed entirely from milk to calf-meals until they were sixty days of age.

In recent years milk replacement formulas have been developed which have been nearly equal to whole milk for calf growth, and they are usually 50 to 70 per cent cheaper than whole milk (1, 55, 56, 57). Williams and Knodt (56) fed different milk replacement formulas to three groups of calves which were gradually taken off whole milk from the fifth to the tenth days of age. They found no significant difference in body weight between these groups and a control

group which was fed whole milk. However, the cost per pound gain was higher for the control group. In a similar experiment Ingham, et al. (21) found that the cost of whole milk feeding was almost twice the cost of reconstituted skim milk feeding with no significant difference in weight gains between the two groups.

In experiments to determine the best ingredients and the correct proportion to use in milk replacement formulas, Williams and Knodt (55) reported that ground raw soybeans were not satisfactory when they constituted 40 per cent or more of the milk replacement formula. They also found that a formula containing 50 per cent dry skim milk gave consistently better results than those containing 20 per cent or less. Brumbaugh and Knodt (1) experimented with different ingredients and found that when skim milk was reduced to 35 per cent of the total formula, growth rates were reduced. The 50 per cent level of skim milk gave results comparable to one with 65 per cent, but when fish solubles were added at the expense of the skim milk the growth rates decreased. The addition of 10 per cent ethyl molasses solubles and 5 per cent butyl molasses solubles with soya bean oil meal also retarded growth rates. However, the ethyl molasses solubles did effectively replace dried whey. Some of the milk replacement formulas which have given results equal to whole milk are shown in Table I.

TABLE I

MILK REPLACEMENT FORMULAS COMPARABLE TO WHOLE MILK

Ingredients	Formulas			
	I ^a lbs	II ^b lbs.	III ^c lbs.	IV ^d lbs.
Dried skim milk	38.5	49.5	50.0	65.0
Dried whey	5.0	10.0	10.0	10.0
Distillers' dried corn solubles		15.0	10.0	20.0
Blood flour		10.0	10.0	
Oat flour	5.0	5.0	5.0	
Dextrose	7.0	7.0	7.0	
Soybean flour	35.0			
Dried brewers' yeast	5.0			
Dicalcium phosphate	2.5	2.0		2.0
Aurofac "D" ¹	1.0	1.0		
Quadrex	0.5			
Trace minerals	0.5	0.5	0.5	0.5
Irradiated yeast			0.1	
Vitamin A and D meal ²		0.5		0.5
Stablized vitamin A feed ³			0.22	
Fish solubles				2.0

¹Five grams aureomycin activity per pound.

²Contains 1,814,544 I.U. vitamin A and 226,800 I.U. vitamin D per pound.

³Contains 2,220,000 U.S.P. units per pound.

^aStein and Knodt (50).

^bKnodt (26).

^cWilliams and Knodt (55).

^dBrambaugh and Knodt (1).

In a recent report Stein and Knodt (51) suggested that soybean flour, when fed with whey solubles and dried brewers' yeast, could replace dried whey, distillers' dried corn solubles, blood meal, and up to 43 per cent of the non-fat dry milk solids in milk replacement formulas for calves. They (50) later reported that soybean flour and whey solubles, when fed in a 7:1 ratio in dried processed form was more effective in replacing oat flour, dextrose, and dried brewers' yeast than the individual components.

In studies to determine the response of dairy calves to whole milk replacements containing dried whey products, dried skim milk and fat, Young (57) found that isocaloric replacement of 80 per cent of whole milk with whey product, or whey product plus fat, slightly reduced growth and increased diarrhea. Similar replacement by a combination of whey, dried skim milk and fat resulted in a lower incidence of diarrhea and in a mean daily gain in weight of 1.17 pounds. Complete replacement of whole milk by this combination increased the incidence of diarrhea, but produced growth equal to that of calves fed whole milk.

In discussing the milk replacement method of raising dairy calves, two important questions that arise are how much milk to feed, and at what age to wean the calves. The usual recommended feeding level for milk is one pound per ten pounds body weight. Recent ad lib. feeding with nipple pails

showed that nursing calves consume fifteen to eighteen pounds of milk daily per 100 pounds body weight (13). The milk required per pound gain, in addition to colostrum, varied from eight to eleven pounds. Neville et al. (35) fed milk at the rate of ten, fourteen and eighteen pounds per 100 pounds body weight for four months. The average daily gain for the four month period was 1.26, 1.42, and 1.50 pounds respectively. Differences in growth rate for the first six weeks were significant at the one per cent level between the 10 and 14, and the 10 and 18 per cent groups, but significant at the 5 per cent level between the 10 and 18 per cent group only for the entire four month period.

As early as 1919 Swett (52) reported weaning calves from all milk at sixty days of age, and Gullickson (16) in 1924 reported weaning calves from all milk at sixty to seventy days of age. In both cases the growth of the calves was not retarded. In 1930 Ingham, et al. (21) suggested that vigorous calves could be dropped from liquid feeding from thirty to forty-five days of age, while less vigorous calves should not be weaned until they were sixty days old. Converse (7) confirmed this in later studies when he reported weaning calves at ninety, sixty, forty-five and thirty days of age. He found that the growth rates were under normal prior to six months of age, but the tendency to recover was strong and most of the early weaned calves

reached normal weight before they were twelve months old, and some before six months. The conclusion was that calves could be raised successfully without whole milk and with less than 300 pounds of skim milk, and that calves could be weaned at thirty to forty-five days of age provided they were consuming at least one pound of grain per day and nibbling at some hay.

Jarvis, et al. (22) using Guernseys and Jerseys, fed milk for either three, seven, nine or twelve weeks. The calves received alfalfa hay ad lib. and a complete calf starter to four months, and calf grower to six months. They were limited to four pounds of concentrate daily. The average daily gains to six months of age were 1.01, 1.00, 1.05 and 1.16 pounds respectively. The feed cost varied from \$39.90 for the calves fed milk for three weeks to \$59.46 for the calves weaned at twelve weeks of age.

A good dairy cow generally produces much more colostrum than her own calf can consume. The surplus colostrum may be stored for considerable periods by freezing it. Recent studies have shown that colostrum may be successfully substituted for milk in feeding young dairy calves, thus saving saleable milk. Gaunya, et al. (15) divided fifteen calves into three groups and fed one group whole milk, one group colostrum diluted with an equal amount of warm water, and the remaining group undiluted colostrum. The colostrum was pooled from the first six milkings of cows which freshened

during that period and frozen. The milk or colostrum was fed at the rate of seven pounds daily for the second through seventh days, and six, five, four, and two pounds for the second through the fourth weeks respectively. The average gains from birth to thirty-five days were 18.0, 19.4, and 24.5 pounds for the three groups respectively. The incidence of scours was higher in the colostrum groups, the average scour days being 2.6, 4.4, and 6.8 respectively. Keyes, et al. (24) divided thirty-six Holstein calves into three groups and fed for eighty days as follows: Group I was fed colostrum and whole milk intermittently, group II was fed whole Holstein milk from different cows intermittently, and group III was fed whole Holstein milk continuously from one cow. The colostrum was substituted 100 per cent for milk at each sixteen days cycle for group I with no significant difference between the three groups in appearance, scours, or TDN per pound gain.

It has been stated (8) that if calves are weaned at an early age they must be able to consume large amounts of grain and roughage at an early age.

The growth standards set up by Ragsdale (44) are usually accepted in determining whether a calf's gain is below or above normal. These growth standards are based upon weights and measurements taken in the Missouri, Kansas, and Iowa Agricultural Experiment Station herds. Ragsdale states that the growing dairy animal uses food less

efficiently with advancing age and that greater economy may be attained by growing calves more rapidly than is usually customary. Individual animals may deviate from the standards approximately ten per cent or even 15 to 20 per cent in live weight and still be considered normal.

The new-born calf does not ruminate, but as it grows older and consumes roughage it acquires the ability to regurgitate the softened material for further chewing (23). The age at which a calf begins rumination may vary greatly. Williams and Knodt (56) found that Holstein male calves began ruminating at the average age of thirty-five days. Pounden and Hibbs (39) showed that characteristic rumen microorganisms were present in only five out of fifteen calves at thirty days of age and were not present in two out of seventeen calves at ninety days of age. Kesler, et al. (23) concluded that rumination occurs at about six weeks of age in calves and noticed that by six weeks that the contents had the color, consistency and odor like that of the adult ruminant. Mead and Goss (32) reported that Holstein heifers which were maintained on a no roughage diet, did not have regular rumination at eighteen months of age.

There are many factors that may influence the time at which rumen organisms become established. Pounden and Hibbs (43) found that characteristic rumen organisms could be established before calves are one week old, provided the

calves were receiving good quality hay and no grain. They (42) showed in further studies that when the ratio of hay to grain was such that the major part of the rumen ingesta was grain, rumen conditions were unsuitable for either the establishment or growth and multiplication of characteristic organisms. Protozoa were present in calves receiving all rations, but more were present in the high hay ration. Hibbs, et al. (19) reported that the 2:1 or 4:1 hay to grain ratios gave good gains but the calves fed the 4:1 ratio consumed more milk. The rumen function was sufficiently developed in most calves by seven weeks of age to permit all milk and other sources of animal protein to be taken from the diet without decreasing the growth rate. High proportions of legumes in the hay seemed most desirable.

Even though the percentage of hay in the ration has an effect on the establishment of a characteristic rumen flora, Gardner and Stuff (14) showed by feeding dried mixtures containing roughage levels of 0, 20, 40, and 60 per cent to the five dairy breeds that there was no significant difference in weight gains from birth to sixteen weeks. The TDN required per pound gain was very similar in all groups. Pounden and Hibbs (41) studied calves which were being pastured and concluded that from several weeks to several months are required for all calves to develop characteristic rumen organisms.

Proper function of the rumen will depend upon its size and the size will depend upon the feed consumed. Hastings (18) concluded that the size of the rumen increased under the stimulus of solid feed. Marshall, et al. (30) demonstrated that while the abomasum is the largest stomach at birth, the weight and volume of rumen tissue and weight of fresh rumen contents exceeded that of the abomasum as early as seven to thirty days of age. Warner, et al. (54) showed that the diet had a profound influence on the rumen development. They found that the rumen displacement, liters per 100 pounds of ingesta-free body weight, of two calves fed only milk was 9.5, for one calf receiving only grain 9.3, and for two calves receiving only hay 23.8 liters at sixteen weeks of age.

The number of organisms present in a milliliter of rumen fluid is a debatable question. Bryant and Burkey (2) found the number to average about twenty billion per gram of fresh rumen content. In another study Bryant and Burkey (3) found that the number of bacteria cultured from rumen content varied somewhat with the ration of the animal. The highest number were observed with an increase in the concentrate ration.

A true rumen organism has been defined by Gall and Huhtanen (11) as follows:

1. Anoerobiosis.
2. Present in number of at least one million per

- gram fresh rumen content.
3. At least ten isolations of a similar type bacterium from two or more animals.
 4. Isolation of similar type bacterium in at least two geographical places.
 5. Production by an organism of end-products found in the rumen from substrates found in the rumen.

For the identification of the characteristic types of bacteria in the rumen, Pounden and Hibbs' classification as modified by Rusoff, et al. (47) and Lengemann (27) has been used. The classification included two hay groups, two grain groups, a miscellaneous group, and a spiral group.

The hay I group consisted of G + Cocci in closely knit pairs or fours or more. Hay II group was divided into three subgroups as follows: (a) large G + square ended rods, (b) G - large cigar-shaped organisms, and (c) G - rods in groups of fours. The grain I group referred to G + rods, while the grain II group consisted of coliform like rods. The miscellaneous group was composed of G + small Cocci in pairs, and the spiral group included G - spiral shaped organisms only.

Under normal farm conditions, the usual changes in rations do not materially affect the rumen bacteria. Bryant and Burkey (3) found no marked differences in the relative proportions of fourteen different species when the ration was from a maintenance level of feeding to a higher level or when alfalfa silage was substituted for alfalfa hay. Gall, et al. (12) reported that both high-grain and high-roughage rations

produce characteristic rumen flora patterns. High-roughage rations encourage a rumen flora of delicate obligate anaerobic bacteria which may act on fiber to produce propionic, butyric and acetic acids, and some gases. The rumen bacteria of animals fed high-grain rations are of a less strictly anaerobic type, most of which act on readily available carbohydrates to produce lactic acid.

Conditions in the rumen of cattle fed normal rations are favorable for the growth and multiplication of rumen bacteria and protozoa. It has been shown (29, 33) that most, if not all, of the digestive action in the rumen is due to the function of these microorganisms. Not only cellulose but also other complex starches are largely digested by the aid of organisms. These organisms utilize the more complex compounds in building their bodies. McNeill, et al. (34) reported that no material has been found which possesses the same stimulatory effect for over-all rumen population as does rumen fluid. Certain complex nitrogenous sources stimulate the growth of a few types of rumen bacteria, but seem to do so at the expense of the remainder of the rumen population.

Pounden and Hibbs (37) reported that certain characteristic organisms are destroyed in various parts of the digestive tract. Some disappear rapidly in the abomasum, others are not digested until they reach the small intestines, and still others are found throughout the digestive tract.

In later experiments (40) it was shown that rumen protozoa are not essential to the animal but that calves lacking the characteristic rumen organisms appeared pot-bellied and had rough coats.

Inoculation of young calves with cud from a cow has been proposed (38, 43) as a method of early establishment of favorable rumen flora. Conrad, et al. (5, 6) have shown that calves inoculated at eleven, sixteen and twenty-one days of age digested a higher percentage of cellulose and dry matter than the uninoculated calves, with a hay:grain ratio of 3:2 giving the highest digestion (4). Calves freed of all characteristic rumen indicator organisms by heavy grain feeding showed decreased ability to digest cellulose. It was thought that calves were more thrifty and consumed hay at an earlier age when they were cud inoculated (38).

Though not as important quantitatively as cellulose digestion, the digestion of protein occurs in the rumen. Conrad and Hibbs (4) showed that cud inoculations gave a significantly greater digestion of protein in calves fed a hay:grain ratio of 3:1. Pounden and Hibbs (43) reported that no significant difference was noted between the weight of calves inoculated at five, ten, fifteen, and twenty-one days of age and non-inoculated calves.

Pounden and Hibbs (41, 43) have shown that certain characteristic microorganisms failed to become established

in young calves regardless of the number of cud inoculations, when most of the dry feed given them was grain. Hibbs and Pounden (20) found that rumen inoculations would increase the ascorbic acid levels but did not affect the plasma carotenoids, plasma vitamin A or blood carotenoid levels.

The effect of cud inoculation upon the size of the paunch is not definitely known. Pounden and Hibbs (40) found that calves that were not inoculated had rougher hair coats and were more pot-bellied than inoculated calves. No other reports were found concerning paunch development.

CHAPTER III

EXPERIMENTAL PROCEDURE

This study to determine whether calves could be raised more successfully by limited milk feeding for nine weeks or by liberal milk feeding until the normal nine weeks weight was reached, and to determine the value of inoculating calves with fresh cud material taken from adult cows was conducted at the University of Tennessee Agricultural Experiment Station at Knoxville. The experiment was started August 4, 1953 and continued through April 18, 1954.

All normal pure-bred Jersey and Holstein calves born in the University herd were divided into four groups and compared according to Table II.

All calves were allowed to remain with their dams for one or two days after birth. They were then separated from their dams and placed in individual pens and taught to drink from open pails. The pens were bedded with wood shavings once each day. These pens were cleaned as often as it was necessary.

The calves received colostrum for the first three days after birth. Reconstituted milk from a milk replacement formula (Table III) was gradually added to the whole milk during the seventh through the tenth day so that the calves were getting all reconstituted milk beginning the

TABLE II

OUTLINE FOR THE COMPARISON OF DIFFERENT TREATMENTS
FOR JERSEY AND HOLSTEIN CALVES

Groups	I	II	III	IV
Number of calves	10	9	12	8
Milk - per cent of body weight	10	15	10	15
Milk feeding period				
Holsteins	9 wk.	150 lb.	9 wk.	150 lb.
Jerseys	9 wk.	90 lb.	9 wk.	90 lb.
Starter fed/day (max.)	4 lb.	4 lb.	4 lb.	4 lb.
Hay fed	ad lib.	ad lib.	ad lib.	ad lib.
Rumen inoculated	No	No	Yes	Yes

TABLE III

MILK REPLACEMENT FORMULA

	Pounds
Skim milk	600
Dried whey	200
Soya flour	150
Dextrose	40
Salt	5
Minerals*	5
A & D meal**	<u>2.5</u>
	1002.5

*Mineral Mixture

Dicalcium phosphate	15 pounds
Magnesium carbonate	8
Ferric citrate	1.18
Cupric sulfate	.38
Manganese sulfate	.40
Cobalt chloride	<u>.04</u>
	25.00

**Contains 10,000 USP units of vitamin A and 1250 USP units of vitamin D₂ per gram.

eleventh day. The milk was fed twice daily and the change over to reconstituted milk was made according to Table IV.

The reconstituted milk was mixed to contain 20 per cent dry mix and 80 per cent warm water, which made it nearly equivalent in energy value to whole milk. Milk allowances were adjusted each week on the basis of the weekly body weight of each calf. Milk feeding was stopped abruptly in Groups I and III when the calves were nine weeks of age and in Groups II and IV when the first weekly body weight was ninety pounds for Jerseys and 150 pounds for Holsteins.

All of the extra colostrum that was produced was fed in place of whole milk or mixed with the reconstituted milk and fed to the calves. If any of the calves were still receiving whole milk, colostrum was substituted pound for pound for the whole milk. The remainder of the colostrum was mixed with the reconstituted milk and fed to the calves at the usual rate.

When the calves were seven days of age, an 18 per cent protein, pelleted calf starter mixture containing 380 pounds yellow corn, 200 pounds oats, 100 pounds wheat bran, 100 pounds linseed meal, 100 pounds soybean oil meal, 30 pounds fish meal, 20 pounds fish solubles, 50 pounds molasses, 10 pounds salt, and 10 pounds trace minerals and limestone was fed ad lib. until they were consuming four pounds daily. Grain was fed at this level until the calves

TABLE IV

SCHEDULE FOR CHANGING FROM WHOLE MILK TO RECONSTITUTED MILK

Day	Jersey - 10%		Jersey - 15%		Holstein - 10%		Holstein - 15%	
	Milk	Rec. M.	Milk	Rec. M.	Milk	Rec. M.	Milk	Rec. M.
7	2.5	0.5	3.5	1.0	3.8	1.0	5.5	1.5
8	2.0	1.0	2.5	2.0	2.8	2.0	4.0	3.0
9	1.0	2.0	2.0	2.5	2.0	2.8	3.0	4.0
10	0.5	2.5	1.0	3.5	1.0	3.8	1.5	5.5
11		3		4.8		5.0		7.5

were 120 days of age. One or two handfuls of pellets were placed in each calf's mouth following milk feeding in order to start consumption at an early age.

Mixed grass-legume hay was fed ad lib. to all calves, beginning when they were seven days of age, and continued for the entire experimental period. It was chopped coarsely to reduce waste and also to increase the accuracy of the consumption data. Enough of the hay was chopped at the beginning of the experiment to last the duration of the investigation.

Each calf in Groups III and IV was forced to swallow pieces of fresh cud material from a normal ruminating cow. These inoculations were made once each week during the third, fourth, fifth, and sixth weeks. In order to study the developmental picture of the microorganisms in the inoculated and uninoculated calves, samples were taken from some of the calves in each group weekly, beginning the fourth and continuing through the tenth week. This was accomplished by means of a three-eighths inch plastic tube which was passed into the rumen. This was connected to a 500 ml. suction flask which was in turn attached to a vacuum pump. The hose was passed into the rumen several times in order to get a representative sample for examination. The samples were then taken to the laboratory and processed as soon as possible.

The rumen samples were handled as follows:

The samples were strained through a single layer of

cheese cloth. The solid material retained by the cheese cloth was discarded. The liquid portion was used to make slides for Gram stains for the identification of the characteristic types of bacteria. The slides were prepared for staining by mixing one loop full of rumen fluid with two or three drops of water on the slide.

For identification of the characteristic types of bacteria, the Pounden and Hibbs classification as modified by Rusoff et al. (47) was used. The group was further modified by Lengemann (27) by adding another group of spiral like organisms. The classification is as follows:

- Hay I - G + Cocci in closely knit pairs, fours or more but not in chains. Pairs 2.8 x 2.3 microns, groups 4.4 x 4.0 microns.
- Hay II a. - Large, G +, thick square ended rods 3.2 - 5.5 microns long and about 2.5 microns wide. Frequently in pairs.
- b. - G - extremely large cigar-shaped organisms often as much as twenty-one microns long and about 4.0 microns wide.
- c. - G - rods about 1.0 x 0.8 microns and tend to group in fours and multiples of four.
- Grain I - G + rods 1.7 - 3:4 microns long by 0.8 microns wide resemble lactobacilli.
- Grain II - G - rods coliform like.
- Misc. I - G + Cocci in pairs similar to Hay I but smaller, 0.5 - 1.0 microns.

Spiral - G - spiral shaped organisms 4 to 18 microns in length and 0.5 microns or less in width.

The calves were fed milk and grain twice daily. Hay was kept before the calves at all times and the hay boxes were refilled whenever necessary. Water was provided in two and one-half gallon pails which were cleaned and refilled at each feeding. Complete feed consumption records were kept for each calf.

The calves were weighed individually the day after birth and at seven-day intervals thereafter. At each weighing body measurements were taken. These measurements included height at withers, heart girth, and maximum paunch circumference. The final weight and measurements were taken when the calf was 120 days of age.

Diarrhea and other physiological disorders were noted for each calf daily. If the diarrhea was not severe, the calves were treated with Kaolin Bismuth Pectinized with Sulfathiazole by the person caring for the calves. In severe cases the University veterinarian treated the calves.

The analysis of variance was the method used in determining whether a statistically significant difference in growth existed between the various groups.

CHAPTER IV

RESULTS

Growth

Weight

The weekly gains in weight for both Jersey and Holstein calves are shown in Figure 1. The 15 per cent Jersey group gains were above the 10 per cent group gains, but the 15 per cent cud inoculated group did not show any advantage over the 10 per cent groups. Both 15 per cent groups of the Holstein breed made faster gains throughout the experimental period than the 10 per cent groups.

There was no significant difference between the cud inoculated and the uninoculated groups. Therefore, a summary was made in Table V without considering the cud inoculated groups as such, but the calves were included in the 10 or 15 per cent groups. As shown in Table V the average nine week weight gains for all calves in the 15 per cent group was 72.1 pounds as compared to 59.0 pounds for all calves in the 10 per cent group. This was a highly significant difference.

From 64 to 120 days of age, the 15 per cent group's average gain was eighty-five pounds, and the 10 per cent group's average gain was 78.2 pounds. The average total gain was 157.1 and 137.3 pounds for the 15 and 10 per cent

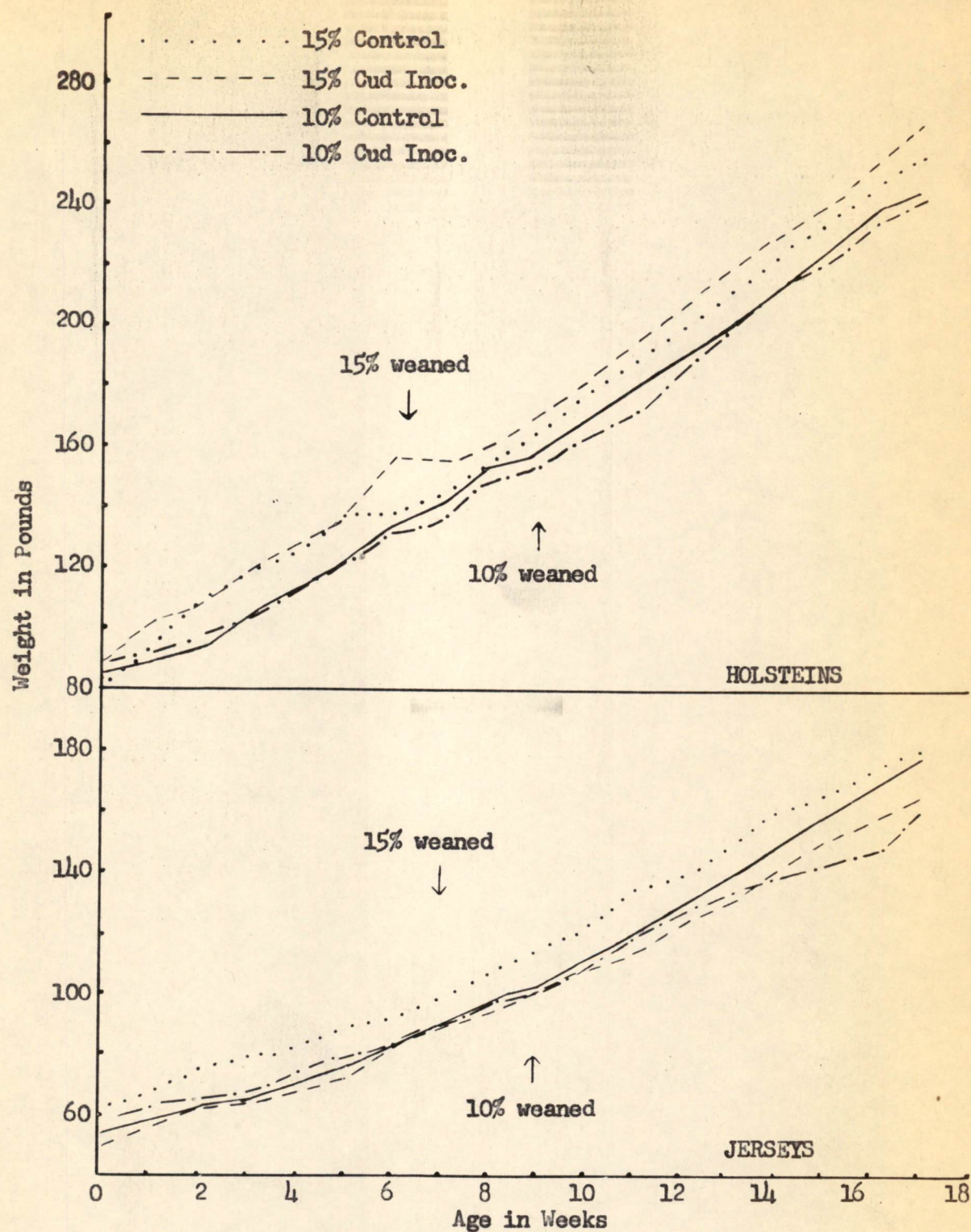


Figure 1. Average Gain in Weight of Calves by Groups

TABLE V

GROUP AVERAGE WEIGHT AND GAIN IN WEIGHT BY BREED AND SEX AT DIFFERENT AGES

		10%				15%			
		No. of	Weight	Gain in Weight		No. of	Weight	Gain in Weight	
Breed Sex		Calves	Id.	64d.	120d.	Calves	Id.	64d.	120d.
				1-64	64-120			1-64	64-120
J	M	4	54.0	96.0	167.2	2	64.5	123.0	194.5
					42.0			58.5	71.5
					113.2				130.0
J	F	6	57.3	104.3	167.8	4	51.0	97.7	161.0
					47.0			46.7	63.3
					110.5				110.0
J	M & F	10	56.0	101.0	167.6	6	55.5	106.2	172.1
					45.0			50.7	66.0
					111.6				116.7
H	M	6	88.0	165.8	260.2	7	84.0	170.1	266.0
					77.8			86.1	95.7
					172.2				181.8
H	F	6	83.2	146.8	228.3	4	84.2	164.0	258.7
					63.6			79.8	94.7
					145.1				174.5
H	M & F	12	85.6	156.3	244.2	11	84.1	167.9	263.3
					70.7			83.8	95.4
					158.6				179.2
All Calves		22	72.1	131.2	209.4	17	74.0	146.1	231.1
					59.0			72.1	85.0
					137.3				157.1

groups respectively. Even though the difference in gain of the two groups was highly significant for the first nine weeks, the difference from 64 to 120 days and 1 to 120 days was only significant at the 5 per cent level.

The Jersey Calves in the 10 per cent group gained an average of 0.93 pounds per day, while the calves in the 15 per cent group gained an average of 0.96 pounds per day. The Holstein calves in the 10 per cent group made an average daily gain of 1.31 pounds per day as compared to 1.49 pounds per day for the calves in the 15 per cent group. The 15 per cent group average gain in weight was above those reported by Ragsdale (44) for calves of the same age, but the 10 per cent group average gain was slightly below his standard.

When analyzed by sexes and breeds, it was found that there was a highly significant difference between sexes and breeds for the 120 days, but from 64 to 120 days the difference in sexes was only significant at the 5 per cent level. As shown in Table V, male calves made faster gains in every instance. The greatest difference was in the 10 per cent group of the Holstein breed with a total gain of 172.2 pounds per calf for the male calves and a 145.1 pounds per calf for the female calves. For Jerseys the gain was 113.2 and 110.5 pounds per calf for males and females respectively. For the 15 per cent group the Jersey males gained 130.0 pounds and the females gained 110.0 pounds per calf. The

Holstein males gained 181.8 pounds as compared to 174.5 pounds per calf for the female calves.

Heart Girth

The average growth in heart girth is shown in Figure 2. All groups were very close with the 15 per cent cud inoculated group having a slight advantage in both Jersey and Holstein breeds. The 10 per cent cud inoculated group did not gain any faster than the control group.

Height at Withers

The average height gains are shown in Table VI for 1 to 64 days, 64 to 120 days, and 1 to 120 days of age. The weekly height gains are shown in Figure 3. There was a difference of 1.0 inch per calf between the two groups in favor of the 15 per cent group for all calves, with an 8.6 inch average gain for the 15 per cent group and a 7.6 inch average gain for the 10 per cent group at 120 days of age (Table VI). The difference between the 10 and 15 per cent groups for all calves was greater from 64 to 120 days than for the first 64 days. This can be seen clearly in Figure 3 for the Holstein calves, but for Jerseys this did not hold true because the 15 per cent cud inoculated group was below the 10 per cent groups.

There was no appreciable difference in height gains between sexes. The males' gains, however, were higher in

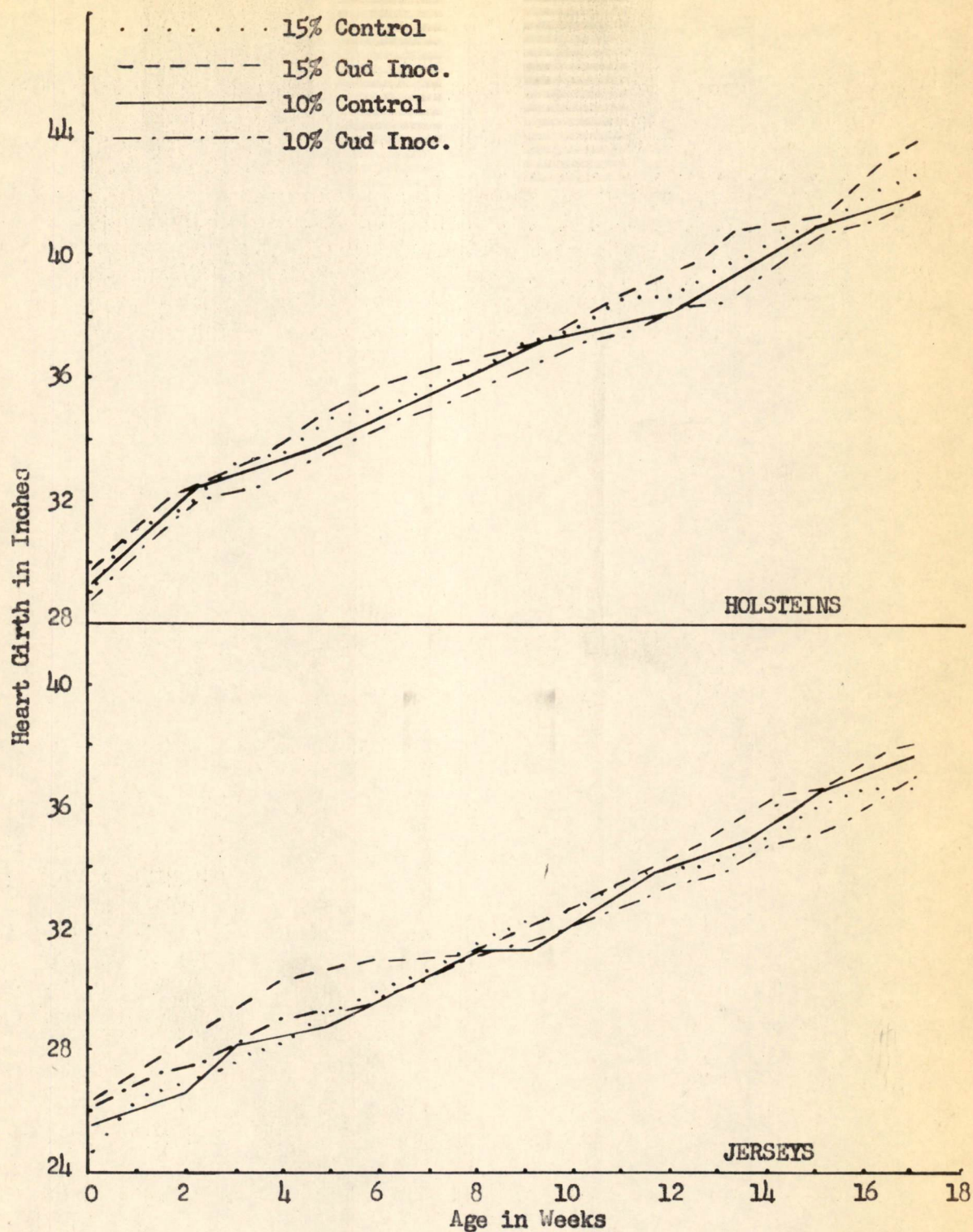


Figure 2. Average Growth in Heart Girth of Calves by Groups

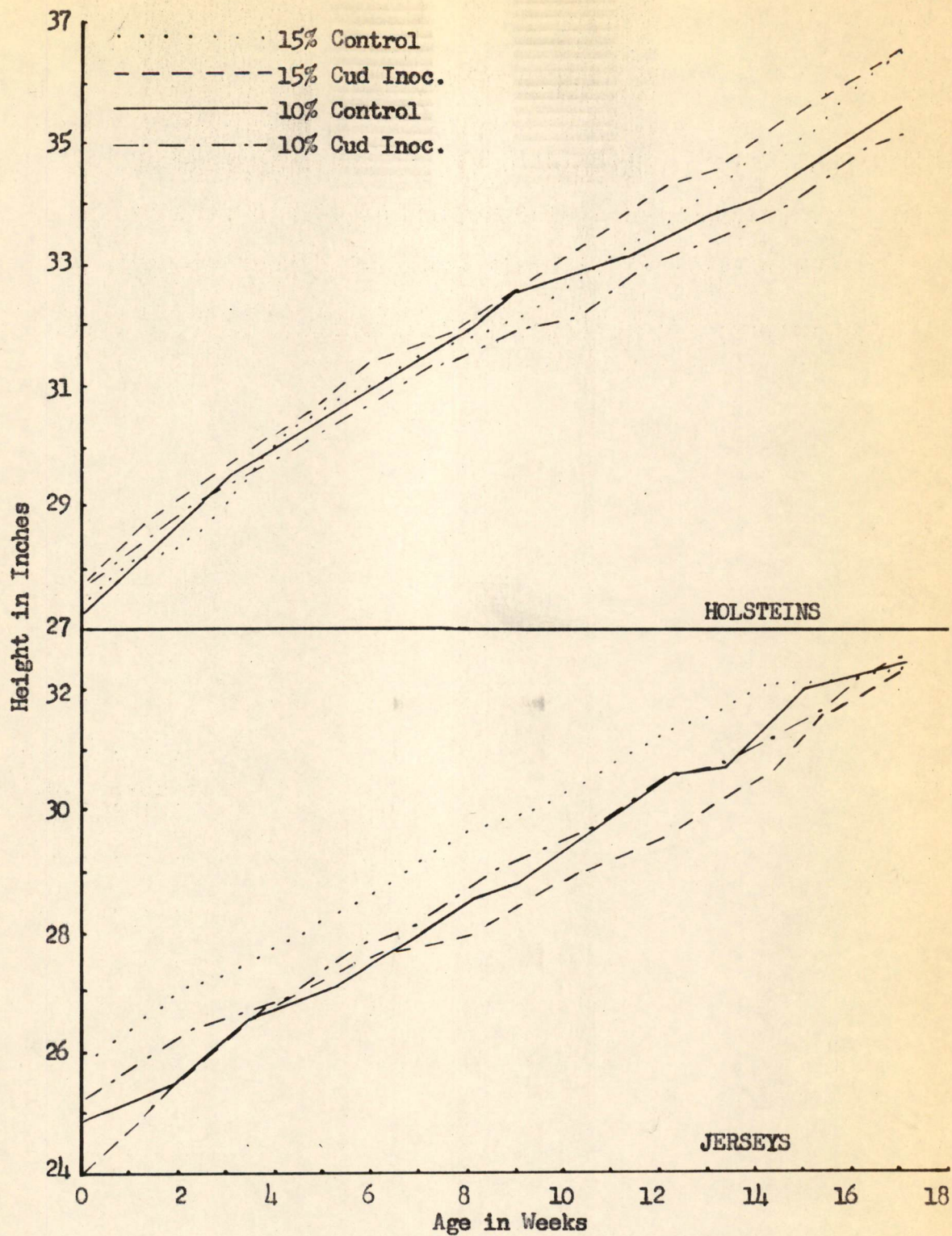


Figure 3. Average Growth in Height of Calves by Groups

TABLE VI

GROUP AVERAGE HEIGHT AND GAIN IN HEIGHT BY BREED AND SEX AT DIFFERENT AGES

10%							15%								
Breed	Sex	No. of Calves	Height (inches)			Gain in Height	No. of Calves	Height (inches)			Gain in Height				
			1d.	64d.	120d.			1-64-120	1-120						
J	M	4	25.3	29.1	32.8	3.8	3.7	7.5	2	26.2	30.9	33.6	4.7	2.7	7.4
J	F	6	25.0	29.1	32.2	4.1	3.1	7.2	4	23.9	28.3	31.8	4.4	3.5	7.9
J	M & F	10	25.1	29.1	32.5	4.0	3.4	7.4	6	24.7	29.2	32.4	4.5	3.2	7.7
H	M	6	27.6	32.5	36.0	4.9	3.5	8.4	7	27.5	32.4	36.6	4.9	4.2	9.1
H	F	6	27.4	31.8	34.9	4.4	3.1	7.5	4	27.4	32.3	36.4	4.9	4.1	9.0
H	M & F	12	27.5	32.1	35.4	4.6	3.3	7.9	11	27.5	32.3	36.5	4.8	4.2	9.0
All	Calves	22	26.5	30.8	34.1	4.3	3.3	7.6	17	26.5	31.2	35.1	4.7	3.9	8.6

all groups with the exception of the 15 per cent Jersey group in which the males gained 7.4 inches and the females gained 7.9 inches.

Paunch Growth

No difference in paunch measurement could be detected between any of the groups as shown by Figure 4. There was a large fluctuation in all groups from week to week. Therefore, any difference that might appear in Figure 4 may not be a real difference. The cud inoculations did not have any advantage in increasing the paunch size, or growth of the calves.

The rumen flora was not changed by inoculating the calves with fresh cud. A comparison of the rumen flora of the inoculated and uninoculated calves is shown in Table VII. At four weeks of age a sample was taken from three calves in each group for examination. All three calves in each group had the grain type organisms and the hay I type, while only two of the three inoculated calves showed the hay IIa type organisms. None of the calves had the hay IIb and c type organisms. A similar picture is shown at six weeks of age, except that the hay IIc type organism was found in two of the four inoculated calves sampled as compared to one for the uninoculated calves. This general picture is shown in Table VII through the tenth week of age. The spiral type

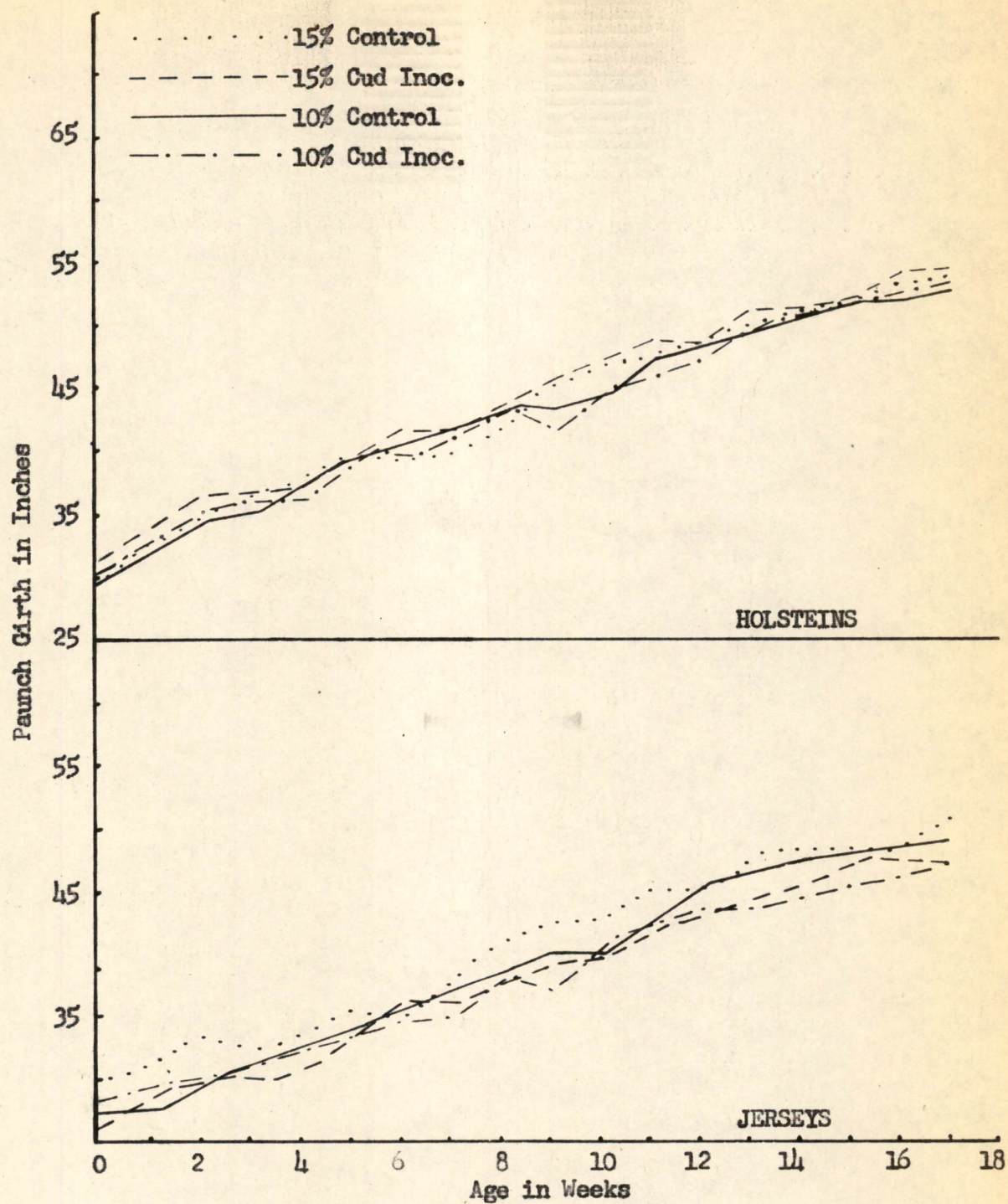


Figure 4. Average Growth in Paunch Girth of Calves by Groups

TABLE VII

COMPARISON OF RUMEN ORGANISMS IN INOCULATED AND UNINOCULATED CALVES
AT DIFFERENT AGES

Age (wks)	Uninoculated												Inoculated																											
	No. of Hay Calves				Hay				Grain				Misc.				Spiral				No. of Hay Calves				Hay				Grain				Misc.				Spiral			
	I	IIa	b	c	I	IIa	b	c	I	II	I	II	I	IIa	b	c	I	II	I	II	I	IIa	b	c	I	II	I	II	I	II	I	II	I	II						
4	3	3 ¹	3	0	0	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3						
5	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1						
6	4	4	4	0	1	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4						
7	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1						
8	4	4	4	0	1	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4						
9	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1						
10	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1						

¹Number of calves possessing characteristic type organisms.

organisms were found at an earlier age in the uninoculated calves than in the inoculated, but the reason for this was not accounted for.

Feed Consumption

The average amount of feed consumed per calf in each group is shown in Table VIII. The feed consumption is shown by breeds because there was such a small difference in feed consumption between groups of the Jersey breed. The amount of milk, grain, and hay per pound gain in body weight is shown in Table IX, which is also divided into breeds.

Milk

The average consumption per calf in the 15 per cent Holstein group was 583.6 pounds and in the 10 per cent group it was 713.3 pounds per calf. For Jerseys the average milk consumption was 443.2 pounds per calf in the 10 per cent group and 454.0 pounds per calf in the 15 per cent group. A clearer picture can be seen in Table IX. Here we see that for Jerseys the milk consumed per pound gain for 120 days was 3.99 pounds and 3.89 pounds for the 10 and 15 per cent groups respectively. For Holsteins the 10 per cent calves consumed 4.49 pounds and the 15 per cent calves consumed 3.25 pounds per pound gain in weight. The 15 per cent cud inoculated calves consumed only 3.0 pounds per pound gain.

TABLE VIII

AVERAGE TOTAL FEED CONSUMED PER CALF BY GROUPS

Group	Breed	No. of Calves	Average Age at Weaning	Average Feed Consumed		
				Milk* (lbs.)	Grain (lbs.)	Hay (lbs.)
10%	J	4	63	442.4	250.2	145.7
10%-I	J	6	63	443.7	245.2	146.4
Average			63	443.2	247.2	146.1
15%	J	3	47.3	419.4	261.5	146.6
15%-I	J	3	51.6	488.7	253.3	149.4
Average			49.4	454.0	257.4	148.0
10%	H	6	63	713.8	257.0	202.3
10%-I	H	6	63	712.7	234.8	203.8
Average			63	713.3	245.9	203.0
15%	H	6	45.6	622.0	286.8	223.2
15%-I	H	5	43.0	537.6	299.2	241.1
Average			44.5	583.6	292.4	231.3

*Includes all liquid milk fed during milk feeding period.

TABLE IX

AVERAGE FEED CONSUMED PER POUND GAIN
(120-DAY) IN BODY WEIGHT BY GROUPS

Group	Breed	No. of Calves	Av. Gain in Wt. (lbs.)	Milk/ Lb. Gain (lbs.)	Grain/ Lb. Gain (lbs.)	Hay Lb. Gain (lbs.)
10%	J	4	123.75	3.57	2.02	1.20
10%-I	J	6	103.70	4.28	2.36	1.41
10% Average			111.72	3.99	2.21	1.30
15%	J	3	118.66	3.53	2.20	1.23
15%-I	J	3	114.66	4.26	2.20	1.30
15% Average			116.66	3.89	2.20	1.26
10%	H	6	160.16	4.45	1.60	1.26
10%-I	H	6	157.17	4.53	1.49	1.30
10% Average			158.66	4.49	1.58	1.28
15%	H	6	179.16	3.47	1.60	1.24
15%-I	H	5	179.20	3.00	1.67	1.34
15% Average			179.18	3.25	1.63	1.29

The large difference in milk consumption of 1.24 pounds per pound gain between the 10 and 15 per cent calves of the Holstein breed is indicative of the fact that the latter were weaned at an earlier age and also had a faster daily gain in body weight.

Table X shows that for all calves the 10 per cent group consumed 3.69 pounds of milk and 0.60 pounds of colostrum per pound gain as compared to 2.61 pounds of milk and 0.81 pounds of colostrum for the calves in the 15 per cent group.

Grain and Hay

The difference between the inoculated and uninoculated calves in grain and hay consumption was very small. The 15 per cent cud inoculated Holstein calves, however, did consume more grain and hay than any other group, and the amount per pound gain in weight was smaller than some of the other groups (Tables VIII and IX).

There was a difference in grain and hay consumption between the 10 and 15 per cent groups. The 15 per cent calves consumed 280.0 pounds of grain per calf and the 10 per cent calves consumed 246.5 pounds per calf, a difference of 33.5 pounds per calf. The difference in hay consumption was 24.2 pounds per calf with the 10 per cent group consuming 177.7 pounds as compared to 201.9 pounds per calf for the 15 per cent group. Even though a difference existed between

TABLE X

COMPARISON OF FEED COST BETWEEN 10 AND 15 PER CENT GROUPS

	Group I 10%	Group II 15%	Difference II over I
Colostrum Consumed, lbs.	1821.2	2163.8	
Colostrum Consumed/Calf, lbs.	82.8	127.3	+ 44.5
Whole Milk Consumed, lbs.	233.1	276.9	
Whole Milk Consumed/Calf, lbs.	10.6	16.3	+ 5.7
Reconstituted Milk Cons., lbs.	10927.4	6703.7	
Reconstituted Milk Cons./Calf, lbs.	496.7	394.3	-102.4
Concentrate Consumed, lbs	5423.4	4760.9	
Concentrate Consumed/Calf, lbs.	246.5	280.0	+ 33.5
Hay Consumed, lbs.	3909.9	3432.3	
Hay Consumed/Calf, lbs.	177.7	201.9	+ 24.2
Av. Total Gain in Weight, lbs.	137.3	157.1	+ 19.8
Milk Cons./lb. Gain in Wt.*	3.69	2.61	- 1.08
Concentrate Cons./lb. Gain	1.8	1.8	
Hay Consumed/lb. Gain in Wt.	1.3	1.3	
Cost of Milk/lb. Gain @ \$3.05/cwt	11.25¢	7.69¢	- 3.56¢
Cost of Conc./lb. Gain @ \$4.60/cwt	8.28¢	8.28¢	
Cost of Hay/lb. Gain @ \$1.50/cwt	1.95¢	1.95¢	
Total Cost of Feed per Calf	\$29.49	\$28.15	- \$1.34
Total Cost of Feed/lb Gain	21.48¢	17.92¢	- 3.56¢

*Includes whole milk and reconstituted milk only.

groups for total feed consumed, the pounds of grain and hay consumed per pound gain was 1.8 and 1.3 pounds respectively for the 10 and 15 per cent groups (Table X). Although the cud inoculated calves consumed slightly more hay, the difference was not significant.

The trend in feed consumption can be seen in Figures 5, 6, 7, and 8. Figures 5 and 6 show that when the calves were weaned at an early age they began consuming grain and hay earlier than the ones which were fed milk until they were nine weeks of age.

The difference in average milk consumption per calf between groups can be seen in Figures 7 and 8.

Economy of Gain

A summary of the feed consumed and the cost per pound gain is given in Table X. Since the amount of grain and hay per pound gain was the same for both groups, the only difference in feed cost was in the milk fed. The milk consumed by the 10 per cent group cost 11.25 cents per pound gain, and for the 15 per cent group the cost was 7.69 cents per pound gain. When the grain and hay cost was added, the total cost was 21.48 cents and 17.92 cents per pound gain for the 10 and 15 per cent groups respectively. The difference in cost being 3.56 cents per pound gain in body weight. The total cost of feed per calf was \$29.49 for the 10 per cent group and \$28.15 for the 15 per cent group.

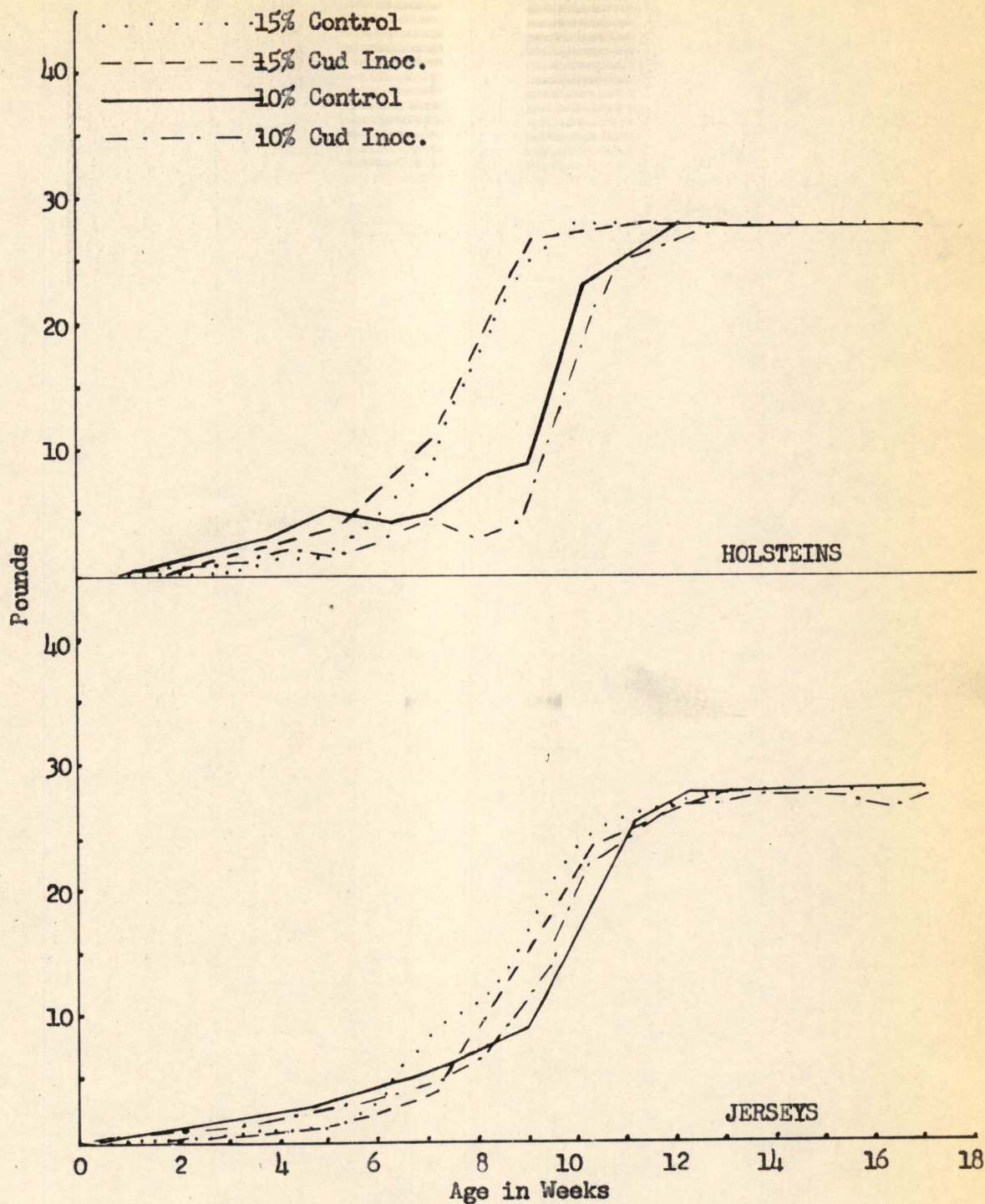


Figure 5. Average Concentrate Consumption of Calves by Groups

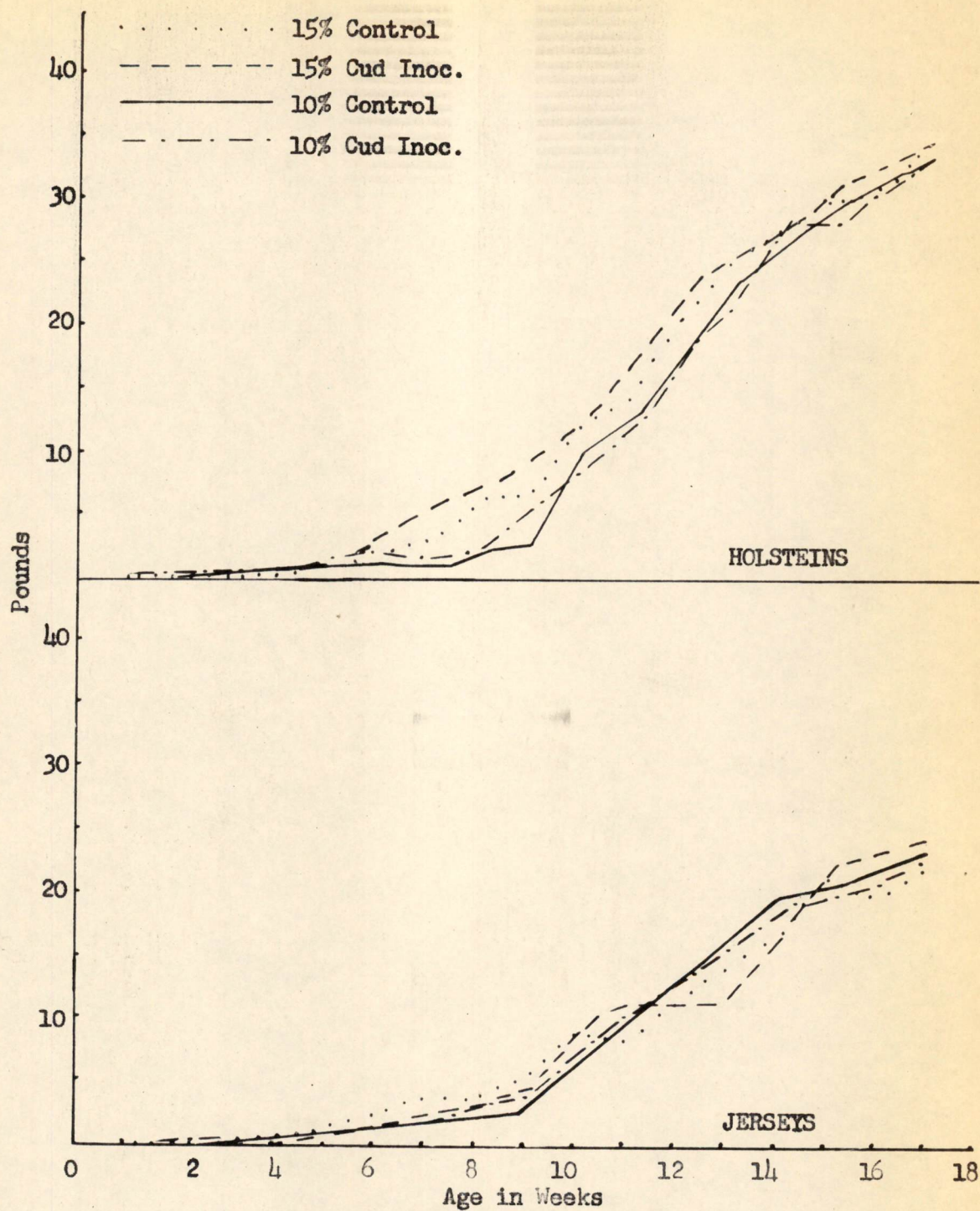


Figure 6. Average Hay Consumption of Calves by Groups

* Number of calves per group.

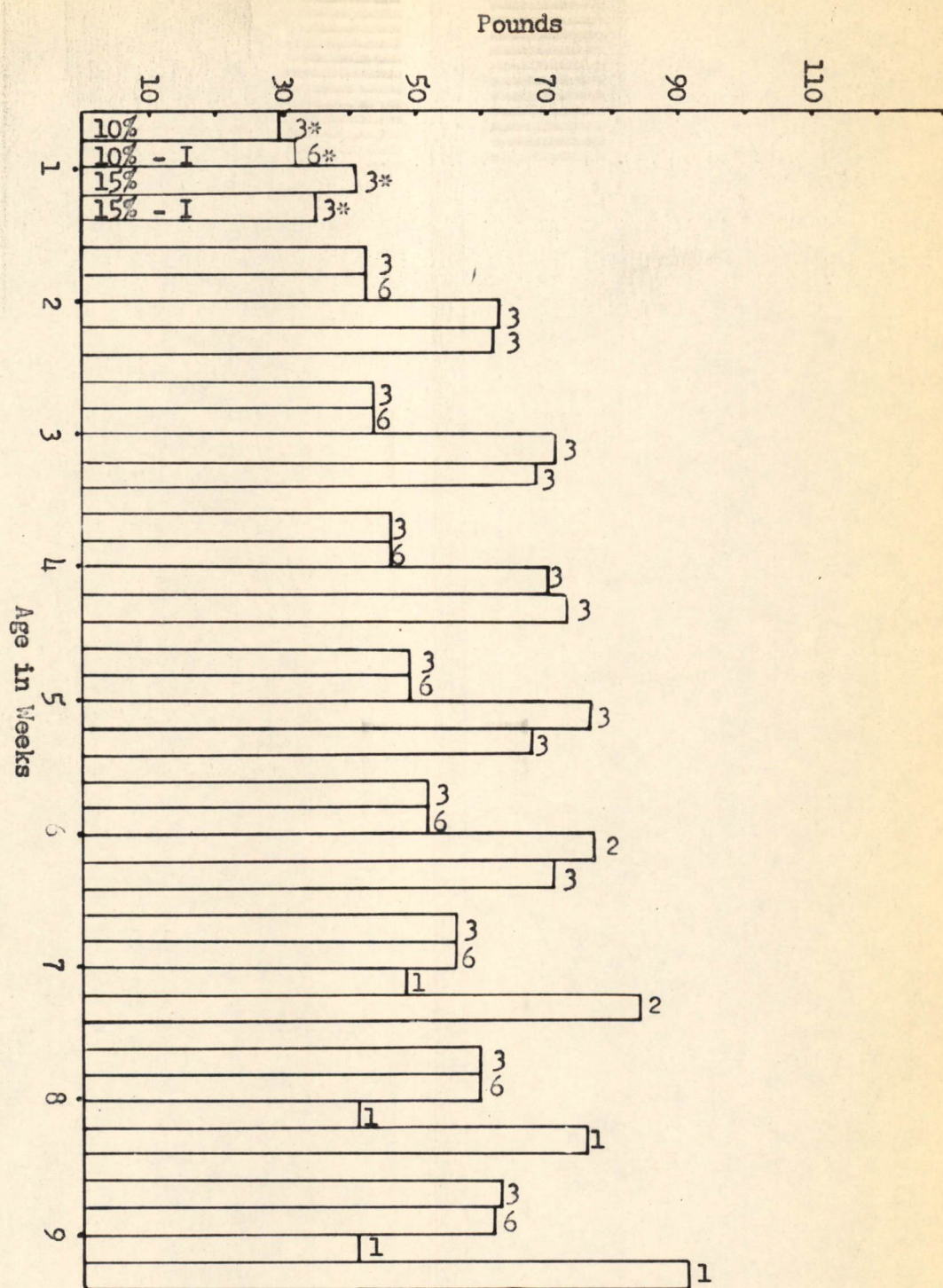
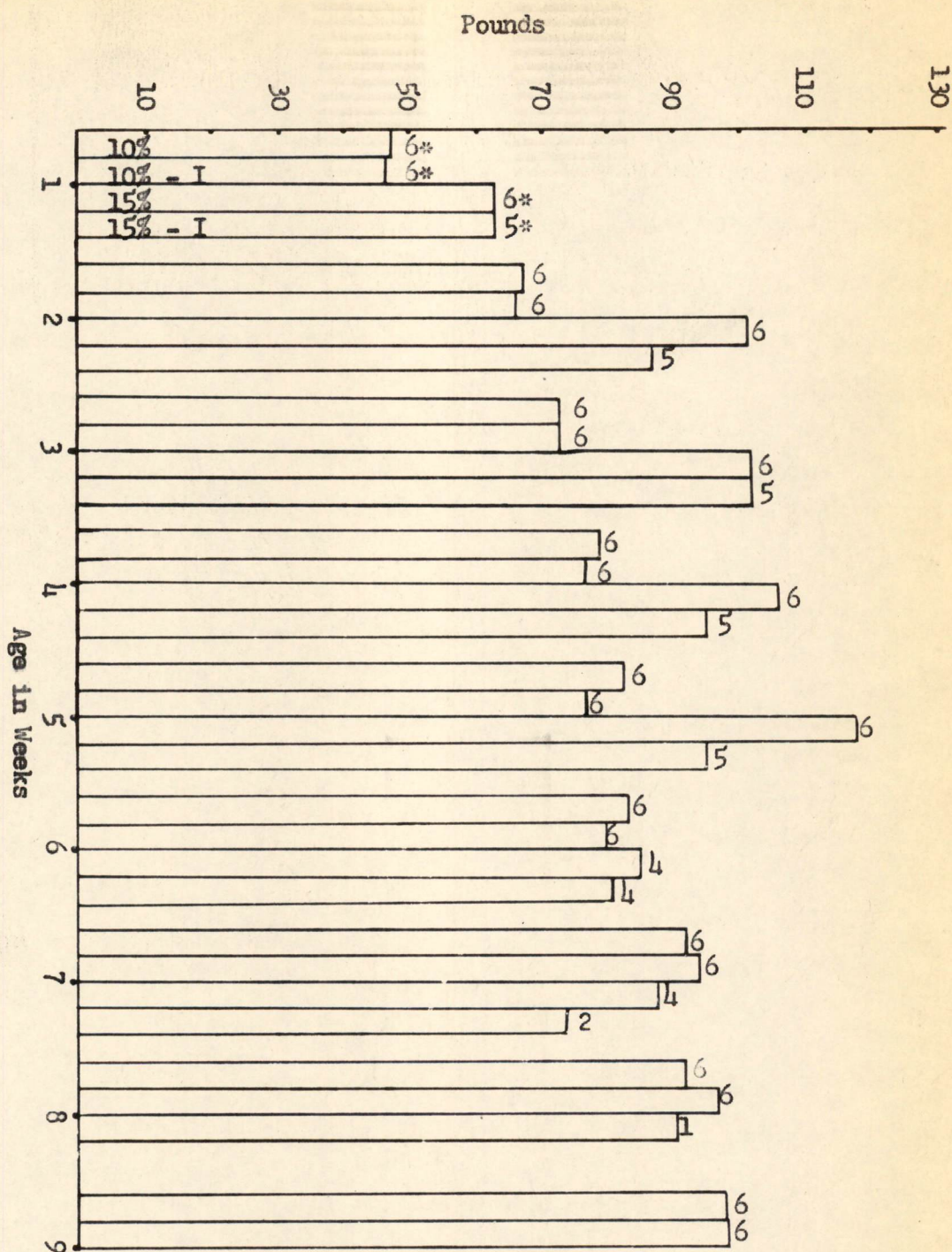


Figure 7. Average Milk Consumption of Jersey Calves by Groups



* Number of calves per group.

Figure 8. Average Milk Consumption of Holstein Calves by Groups

Disease

The incidence of diarrhea was greatest in the 15 per cent group. The Jersey calves had a lower incidence of diarrhea than the Holsteins as shown in Table XI. When both breeds were analyzed together, the average time of scouring was 5.5 days per calf for the 10 per cent group and 11.4 days per calf for the 15 per cent group.

The intensity (per cent of weaning age) of diarrhea was 8.73 per cent for the 10 per cent group and 24.62 per cent for the 15 per cent group. This was a difference of 15.89 per cent.

TABLE XI

INCIDENCE AND SEVERITY OF DIARRHEA

Group	No. of Calves	Average Age Weaning(Day)	Days of Scouring Per Calf	Intensity % of Weaning Age
<u>Jerseys</u>				
10%	10	63.0	3.5	5.55
15%	6	49.4	4.8	9.71
<u>Holsteins</u>				
10%	12	63.0	7.1	11.26
15%	11	44.5	13.0	29.21
<u>Jerseys</u> and <u>Holsteins</u>				
10%	22	63.0	5.5	8.73
15%	17	46.3	11.4	24.62

CHAPTER V

DISCUSSION

This experiment demonstrated conclusively that cud inoculation under the conditions of this test was not noticeably beneficial to the growing calves. The failure of the cud inoculated calves to gain faster than the uninoculated calves agrees with Pounden and Hibbs (42) who reported that cud inoculated calves did not make faster gains than uninoculated calves. The failure of the cud inoculations to develop a different type of rumen flora was not expected. However, this may have been due to the diet of the cow from which the cud material was taken to inoculate the calves. These cows were being fed liberally on corn silage. Pounden and Hibbs believe that cows receiving a large amount of silage do not have the characteristic hay-type rumen flora. As pointed out by Pounden and Hibbs (42, 43), the ratio of grain to hay has a considerable influence on the type of organisms present. The fact that the calves in this experiment were receiving a ration with a high grain to hay ratio (almost 1.5:1) may account for the lack of difference between the two groups. Although there was no apparent difference between the inoculated and uninoculated calves, it seems reasonable to assume that if the hay-type rumen flora could be established in calves at a very early age there would be

a higher rate of cellulose digestion, especially if roughage constituted the majority of the diet. In view of other work done on this subject, it is believed that cud inoculations may have possibilities in the future. The results obtained from this study may have been completely different had a low protein diet, consisting mainly of roughage, been fed. This belief agrees with other work done previously (4).

The fact that the 15 per cent calves consumed more grain and hay, and less milk than the 10 per cent calves is believed to be due to the early weaning of the 15 per cent calves. As shown by Figures 5 and 6, the calves began consuming grain and hay when milk was taken entirely from the diet. As long as the calves were getting milk, they consumed very little grain or hay. The 15 per cent level of milk feeding resulted in faster gains and an earlier weaning age for that group. The higher level of feeding not only made the calves gain faster, but the gain per pound of milk was also higher.

When the milk was withdrawn from the diet abruptly the calves did not gain as fast, and some lost weight the following week, after which normal gains were resumed (Figure 1). One of the advantages of an abrupt withdrawal of milk is the faster adjustment to dry feed since that is all that was fed after milk feeding was discontinued. This resulted in a higher consumption of hay and grain at an earlier age.

This caused the 15 per cent group calves to consume more hay and starter per calf, but the amount consumed per pound gain was the same as the 10 per cent group. This was due to the higher daily gain of the 15 per cent calves.

Milk replacer seemed to be very satisfactory and desirable under the conditions of this experiment. This method of raising calves would be very desirable on farms where whole milk is sold since it is about two cents per pound cheaper than whole milk. The extra colostrum produced on a farm could be mixed with the milk replacer, or it could be substituted for whole milk in a limited whole milk feeding program. The colostrum which once was wasted can now be preserved by freezing and fed when needed (15). It might have been possible to obtain even better results in favor of the high level milk replacer feeding if fat had been added to the milk replacer. However, the milk replacement formula used seemed to be just as palatable and nutritious as whole milk.

The amount of scouring was greater in all calves than it should have been and especially in the 15 per cent group. The high level of milk feeding may have caused the 15 per cent calves to scour more, but it is believed that most of the diarrhea was caused by environmental conditions instead of the diet. The basis for this assumption is that the incidence of diarrhea became worse when cold weather began in the fall and cleared up almost completely in the early spring. The

rate of gain was considerably reduced during the winter months when the incidence of diarrhea was the greatest. If the calves had gained at a normal rate during that period a somewhat higher daily gain for the experimental period would have been expected. Some of the calves would refuse their milk without any apparent cause, thus decreasing the rate of gain.

Even though the 15 per cent calves were weaned earlier on the average (Jerseys 13.6 days and Holsteins 18.5 days), there were two Jerseys in that group that were not weaned until nine weeks of age. One Holstein was not weaned until the seventh week and one was fed milk for eight weeks in the 15 per cent group. Three calves were eliminated because of disease. They were not eliminated because of scours only, but they also had other complications resulting in anorexia and a decreased rate of growth. The data from these calves were not used since their sickness was not attributed to the feeding methods and procedures. Three calves died of infections during the experimental period. The cause of their deaths could not be definitely determined. These data were also excluded from the final summary.

In Table X a picture of the economic aspect was shown. The total cost of feed was higher for the 10 per cent group with the 15 per cent group averaging \$1.34 less per calf. Due to the 19.8 pounds gain per calf more for the 15 per cent

group over the 10 per cent group, the cost per pound gain was 3.56¢ less for the 15 per cent group. The higher rate of growth may be attributed to the extra growth stimulated by the high level of milk fed and the earlier consumption of grain and hay.

There was no value given to the colostrum since it could not be sold for milk. However, if a value had been charged to the colostrum, the total feed cost would still have been greater for the 10 per cent calves than the 15 per cent calves. When colostrum was available it was substituted for whole milk during the change over period from seven to eleven days of age. The colostrum not used for this purpose was fed in the reconstituted mixture.

CHAPTER VI

SUMMARY AND CONCLUSIONS

All normal pure-bred Jersey and Holstein calves born in the University of Tennessee Agricultural Experiment Station herd at Knoxville were used in this experiment. The calves were placed into one of the following four groups at three days of age. The 10 per cent group consisted of ten calves; the 15 per cent group contained nine calves; the 10 per cent cud inoculated group consisted of twelve calves; and the 15 per cent cud inoculated group had eight calves in it.

The 10 per cent calves were fed reconstituted milk for nine weeks, and the 15 per cent calves were weaned when the first weekly body weight for Jerseys of 90 pounds and for Holsteins of 150 pounds was reached. The calves in the cud inoculated groups were forced to swallow a fresh piece of cud material, taken from a normal ruminating cow, on the third, fourth, fifth, and sixth week of age. No advantage was obtained from the cud inoculations in respect to daily gains in body weight or growth, efficiency of feed utilization, or the development of an adult-like rumen flora.

The calves in the 15 per cent groups were weaned at an earlier age than the 10 per cent calves. For Jerseys the average weaning age for the 15 per cent group was 49.4 days,

and for the Holsteins the average weaning age was 44.5 days. The earlier weaning of the 15 per cent calves resulted in a lower consumption of milk, but they consumed 280.0 pounds of grain and 201.9 pounds of hay per calf, which was 34.5 pounds of grain and 24.2 pounds of hay per calf above the 10 per cent group. However, the 15 per cent calves had a higher daily gain in weight, resulting in an equal consumption of 1.8 pounds of grain and 1.3 pounds of hay per pound gain in body weight for each group. The milk consumption for the 10 and 15 per cent groups was 3.69 and 2.61 pounds per pound gain in body weight respectively.

There was an average difference in weight gains of 19.8 pounds per calf with the 10 per cent calves gaining 137.3 pounds and the 15 per cent gaining 157.1 pounds per calf for the 120 day experimental period. When analyzed statistically, this difference was significant only at the 5 per cent level of probability. However, for the first nine weeks the difference between groups was highly significant.

During the 120-day experimental period, the 10 per cent group gained 7.6 inches in height and the 15 per cent group gained 8.6 inches. The difference in paunch and heart girth measurements was very small with all groups being nearly equal.

The incidence of diarrhea was greater in the 15 per

cent group. The average days of scouring per calf were 11.4 for the 15 per cent group as compared to 5.5 days for the 10 per cent group. The intensity was 24.62 per cent for the 15 per cent group and 8.73 per cent for the 10 per cent group.

The cost per pound gain in weight was 21.48¢ and 17.92¢ for the 10 and 15 per cent groups respectively. The 3.56¢ per pound gain difference resulted from a lower consumption of milk since the grain and hay consumption were the same for both groups.

From the results obtained from this experiment, one may conclude that calves fed heavy on milk from the beginning can be weaned as early as six weeks of age without any harmful effects. By weaning the calves early, it was possible to start them to consuming hay and grain earlier, thereby reducing the cost of raising the calves to 120 days of age. Even though the 15 per cent calves scoured more, it did not appear to be a major problem.

It would probably be unwise to conclude from this data that it would always be profitable to feed calves at the 15 per cent level, but the data obtained do indicate that the recommendations for the future could be higher than 10 per cent, and a more economical gain as well as a faster gain for the calves could be obtained.



BIBLIOGRAPHY

BIBLIOGRAPHY

1. Brumbaugh, J. H., and Knodt, C. B. Milk Replacements for Dairy Calves. J. Dairy Sci., 35: 336. 1952. ✓
2. Bryant, M. P., and Burkey, L. A. Cultural Methods and Some Characteristics of Some of the More Numerous Groups of Bacteria in the Bovine Rumen. J. Dairy Sci., 36: 205. 1953.
3. Bryant, M. P., and Burkey, L. A. Numbers and Some Predominant Groups of Bacteria in the Rumen of Cows Fed Different Rations. J. Dairy Sci., 36: 218. 1953.
4. Conrad, H. R., and Hibbs, J. W. The Effect of Rumen Inoculations and the Ratio of Hay to Grain Eaten on Digestion and Nitrogen Retention in High Roughage Fed Calves. J. Dairy Sci., 36: 600. 1953.
5. Conrad, H. R., Hibbs, J. W., Pounden, W. D., and Sutton, T. S. The Effect of Rumen Inoculations on the Digestibility of Roughages in Young Dairy Calves. J. Dairy Sci., 33: 585. 1950. ✓
6. Conrad, H. R., Hibbs, J. W., Pounden, W. D., and Sutton, T. S. The Influence of Rumen Inoculations on the Digestibility of Dry Matter, Cellulose and Protein in Young Dairy Calves. J. Dairy Sci., 33: 378. 1950.
7. Converse, H. T. Experiments in Rearing Calves Without Whole Milk and With Limited Amounts of Skim Milk. U. S. Dept. Agr. Circ., 822. Sept. 1949. ✓
8. Davis, R. N., and Cunningham, W. S. Raising Calves on the Minimum Amount of Milk. Ariz. Agr. Expt. Sta. Bull., 111. 1923. ✓
9. Doetsch, R. N., and Robinson, R. Q. The Bacteriology of Bovine Rumen: A Review. J. Dairy Sci., 36: 115. 1953.
10. Fraser, W. J., and Brand, R. E. Milk Requirements to Raise a Calf. Ill. Agr. Expt. Sta. Bull., 146. 1913. ✓
11. Gall, L. S., and Huhtanen, C. N. Criteria for Judging a True Rumen Organism and a Description of Five Rumen Bacteria. J. Dairy Sci., 34: 353. 1951.

12. Gall, L. S., Huhtanen, C. N., Saunders, R., and Schmidt, W. Comparison of Rumen Flora and Environment in Roughage vs. Grain Fed Animals. J. Dairy Sci., 36: 587. 1953.
13. Gardner, K. E., Nevens, W. B., Ekerts, T., and Jackson, C. B. Growth Stimulants and Ad Libitum Feeding in the Production of Milk-fed Veal. J. Ani. Sci., 11: 761. 1952.
14. Gardner, K. E., and Stuff, G. S. Roughage: Concentrate Ratios for Young Dairy Calves. J. Dairy Sci., 36: 601. 1953.
15. Gaunya, W. S., Mochrie, R. D., Eaton, H. D., and Johnson, R. E. Colostrum as a Substitute for Whole Milk in a Limited Whole Milk Feeding System. J. Dairy Sci., 37: 655. 1954.
16. Gullickson, T. W., Fountaine, F. C., and Fitch, J. B. Various Oils and Fats as Substitutes for Butterfat in the Ration of Young Calves. J. Dairy Sci., 25: 117. 1942.
17. Hayward, H. The Rearing of Calves on Milk Substitutes. ✓
Pa. Agr. Expt. Sta. Bull., 60. 1902.
18. Hastings, E. G. The Significance of the Bacteria and the Protozoa of the Rumen of the Bovine.
Bacteriological Reviews, 8: 235. 1944.
19. Hibbs, J. W., Conrad, H. R., and Pounden, W. D. A High Roughage System for Raising Calves Based on the Early Development of Rumen Function. I Effect of Variations in the Ration on Growth, Feed Consumption and Utilization. J. Dairy Sci. 36: 717. 1953.
20. Hibbs, J. W., and Pounden, W. D. The Influence of the Ration and Early Rumen Development on the Changes in the Plasma Carotenoids, Vitamin A and Ascorbic Acid of Young Dairy Calves. J. Dairy Sci., 31: 1055. 1948.
21. Ingham, L. W., Meade, Devoe, and Berry, M. H. Raising ✓
Dairy Calves on Nurse Cow, Whole Milk, Remade Skim Milk, and Calf-meal. Md. Agr. Expt. Sta. Bull., 319. 1930.
22. Jarvis, R. N., Waugh, R. K., and Murley, W. R. Relationship of Growth of Dairy Calves to Length of Milk Feeding Period. J. Ani. Sci., 11: 766. 1952.

23. Kesler, E. M., Ronning, M., and Knodt, C. B. Some Physical Characteristics of Tissue and Contents of the Rumen, Abomasum and Intestines in Male Holstein Calves of Various Ages. J. Ani. Sci., 10: 969. 1951.
24. Keyes, E. A., Peace, E. J., and Brence, J. L. The Utilization of All the Colostrum Produced by a Dairy Herd for Feeding the Calves. J. Dairy Sci., 37: 655. 1954.
25. Krauss, W. E., and Crawford, C. H. Powdered Skim Milk as a Feed for Dairy Calves. Ohio Agr. Expt. Sta. Bimonthly Bull., 14: 49. 1929.
26. Knodt, C. B. Successful Dairying. McGraw Hill Book Company, Inc., New York. 1954.
27. Lengemann, F. W. "The Development of Rumen Function in the Dairy Calf." Ph. D. Thesis, University of Wisconsin. 1953.
28. Lindsey, J. B. Substitutes for Milk in the Rearing of Dairy Calves. Mass. Agr. Expt. Sta. Bull., 164. 1915.
29. Mangold, E. The Digestion and Utilization of Crude Fiber. Nutrition Abst. Rev., 3: 647. 1933.
30. Marshall, S. P., Arnold, P. T. Dix, and Becker, R. B. Postpartum Development of Bovine Stomach Compartments and Observations on Some Characteristics of Their Contents. J. Dairy Sci., 33: 379. 1950.
31. Maynard, L. A., and Norris, L. C. A System of Rearing Dairy Calves With Limited Use of Milk. J. Dairy Sci., 6: 483. 1923.
32. Mead, S. W., and Goss, H. Ruminant Digestion Without Roughage. J. Ani. Sci., 18: 163. 1935.
33. McAnally, R. A., and Phillipson, A. T. Digestion in the Ruminant. Biol. Rev. Cambridge Phil. Society, 19: 41. 1944.
34. McNeill, J. J., Doetsch, R. N., and Shaw, J. C. Some Nutritional Requirements of Bovine Rumen Bacteria. J. Dairy Sci., 37: 81. 1954.

35. Neville, W. E., McCullough, M. E., Sell, O. E., and Baird, D. M. The Effect of Three Levels of Milk Feeding to Young Calves on Their Growth Rate and Feed Consumption. J. Ani. Sci., 11: 722. 1952.
36. Pouden, W. D. Demonstration of Collection of Rumen Samples for Examination and Transfersion. Am. Vet. Med. Assoc. Proc., 49. 1952.
37. Pouden, W. D., Ferguson, L. C., and Hibbs, J. W. The Digestion of Rumen Microorganisms by the Host Animal. J. Dairy Sci., 33: 565. 1950.
38. Pouden, W. D., and Hibbs, J. W. Rumen Inoculations in Young Calves. J. Am. Vet. Med. Assoc., 114: 33. 1949.
39. Pouden, W. D., and Hibbs, J. W. Some Possible Relationship Between Management, Fore-stomach Contents and Diarrhea in the Young Dairy Calf. J. Dairy Sci., 30: 582. 1947.
40. Pouden, W. D., and Hibbs, J. W. The Development of Calves Raised Without Protozoa and Certain Other Characteristic Rumen Microorganisms. J. Dairy Sci., 33: 639. 1950
41. Pouden, W. D., and Hibbs, J. W. The Influence of Pasture and Rumen Inoculations on the Establishment of Certain Microorganisms in the Rumen of Young Dairy Calves. J. Dairy Sci., 32: 1025. 1949.
42. Pouden, W. D., and Hibbs, J. W. The Influence of the Ratio of Grain to Hay in the Ration of Dairy Calves on Certain Rumen Microorganisms. J. Dairy Sci., 31: 1051. 1948.
43. Pouden, W. D., and Hibbs, J. W. The Influence of the Ration and Rumen Inoculations on the Establishment of Certain Microorganisms in the Rumen of Young Calves. J. Dairy Sci., 31: 1041. 1948.
44. Ragsdale, A. C. Growth Standards for Dairy Cattle. Mo. Agr. Expt. Sta. Bull., 336. 1934.
45. Ragsdale, A. C., and Turner, C. W. The Minimum Milk Requirement for Calf Raising. J. Agr. Res., 26: No. 9. 1923.

46. Rupel, I. W. Raising the Dairy Calf. Wis. Agr. Expt. Sta. Bull., 404. 1929.
47. Rusoff, L. L., Davis, A. V., and Alford, J. A. Growth-Promoting Effect of Aureomycin on Young Calves Weaned From Milk at an Early Age. J. Nutr., 45: 289. 1951.
48. Savage, E. S., and McCay, C. M. The Nutrition of Calves: A Review. J. Dairy Sci., 25: 595. 1942.
49. Snedecor, G. W. Statistical Methods. 3rd Edition. Iowa State College Press, Ames. 1940.
50. Stein, J. F., and Knodt, C. B. Further Studies on the Use of Soyflour and Whey Solubles in Milk Replacement Formulas for Dairy Calves. J. Dairy Sci., 37: 655. 1954.
51. Stein, J. F., Knodt, C. B., and Ross, E. B. Use of Special Processed Soybean Flour and Whey Solubles in Milk Replacement Formulas for Dairy Calves. J. Dairy Sci., 37: 373. 1954.
52. Swett, W. W. Raising Calves on Farms Where Whole Milk is Sold. Mo. Agr. Expt. Sta. Cir. 88. 1919. ✓
53. Wallace, H. D., Loosli, J. K., and Turk, K. L. Substitutes for Fluid Milk in Feeding Calves. ✓ J. Dairy Sci., 34: 256. 1951.
54. Warner, R. C., Bernholdt, H. F., Grippin, C. H., and Loosli, J. K. The Influence of the Diet on the Development of the Ruminant Stomach. J. Dairy Sci., 36: 599. 1953.
55. Williams, J. B., and Knodt, C. B. The Further Development of Milk Replacement for Dairy Calves. J. Dairy Sci., 33: 809. 1950.
56. Williams, J. B., and Knodt, C. B. The Value of Milk Replacements in the Ration of Dairy Calves. ✓ J. Dairy Sci., 32: 986.
57. Young, F. B. Response of Dairy Calves to Whole Milk Replacements Containing Dried Whey Products, Dried Skim Milk and Fat. ✓ J. Dairy Sci., 36: 600. 1953.