THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Examination

This is to certify that we the undersigned, as a committee of the Graduate School, have given Sylvester Warren Mead final oral examination for the degree of Master of Science. We recommend that the degree of Master of Science be conferred upon the candidate.

Minneapolis, Minnesota

Dec 21 1920

C H Eckles

Chairman

L S Palmer

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THE UNIVERSITY OF MINNESOTA

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Report

of

Committee on Thesis

The undersigned, acting as a Committee of the Graduate School, have read the accompanying thesis submitted by Sylvester Warren Mead for the degree of Master of Science. They approve it as a thesis meeting the requirements of the Graduate School of the University of Minnesota, and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science.

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THE MINIMUM MILK REQUIREMENT FOR RAISING DAIRY CALVES

A Thesis Submitted to the

Faculty of the Graduate School of the

University of Minnesota

by

Sylvester W. Mead

In partial fulfillment of the requirements

for the degree of

Master of Science

June

1921

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INTRODUCTION

To be in the highest degree successful the dairy farmer must have efficient cows. The matter of obtaining these animals has always been somewhat of a problem, but in recent years it has become increasingly difficult.

Years ago when nearly every family had a cow with which to supply themselves with milk, the expense of calf raising was almost negligible. Every farmer had more milk than he could use, and the price paid for milk or cream in most cases was hardly worth bothering with. For this reason the milk was mostly used on the farm and fed to calves, the best of which were raised to maturity and the poorer ones killed for veal. At that time it was quite a simple matter to keep the herd replenished. In recent years, however, the increase in urban population has called for a vast increase in the amount of whole milk sold on the market. The mounting cost of feed and labor and the vast quantities of milk being used by cheese factories and condensories are also factors tending to increase the price of milk. As a result of these conditions the question of raising the calf has become a serious one on all farms from which the whole milk is sold.

At the present time there are two methods practiced of replacing the old cows with new; namely, buying mature cows, and second, raising the heifer calves from the best producers in the herd. It seems evident that the first method should surely be eliminated. By bringing new cows into the herd there is a very great danger of bringing in disease such as tuberculosis and contageous abortion, two diseases which have spelled disaster for many a dairy farmer. Also the cash value of cows is increasing every year. This is due to the increased cost of raising and to the fact that the practice of not raising the heifer calves from the herd is becoming more prevalent every year. The dairy farmer is selling them good as well as the bad and indifferent calves for veal. The excuse for this practice, which makes no provision for perpetuating the herd or the milking qualities of the best cows, is the increased cost of raising the animals from birth to six or eight months of age.

With this increasing market value of cows and the danger of disease being brought into the herd, it can be readily recognized that buying mature cows to replenish the herd, is not the most practical or efficient method to be used.

If the excessive cost of raising calves could be eliminated, it is clear that the surest, most economical and most satisfactory way to build up an efficient dairy herd, or to keep it supplied with good cows after it is once established is to raise the heifer calves from the best cows in the herd bred to a good pure-bred sire.

The matter of cost of raising calves is then the determining factor. For this reason experiment stations and many others interested have been experimenting for years on methods of feeding by means of which calves may be raised in an economical and at the same time satisfactory manner.

The first experiments were carried on with a view of eliminating the feeding of the butter-fat in the milk which has always been the most expensive constituent of the milk on the market. The amount of experimental work done on this subject both in this country and in foreign countries has been extensive and also quite successful until at the present time the feeding of skimmilk to calves has well passed the experimental stage. It is a well recognized fact by all up-to-date breeders and dairymen that skimmilk fed with a grain supplement after the calf is two to four weeks old gives equally as good results as does whole milk.

As the demand for whole milk increased, investigators became interested in the problem of obtaining some feed or mixture of feeds which would take the place of whole or skimmilk after the calf is two or three weeks old. While these mixtures have been called "milk-substitutes", the term implies somewhat more than the results obtained through their use would warrant. In most cases they have given only fairly satisfactory results. There is still much need for investigation especially in view of the recent discoveries in nutrition.

There is still one other method of eliminating a large amount of milk from the ration, that is, by the use of the minimum amount of milk necessary to give the calf a good start in life and then cutting the calf off from milk entirely, using grain and hay rations in its place. A limited amount of work has been done in an attempt to determine at what age it is possible to eliminate the milk from the calf's ration, but the results so far have proved sufficiently satisfactory to warrant further investigation. It was in view of this fact that the writer has attempted to collect further data which it is hoped will throw a little more light upon the subject.

It was thought that a study of the literature on the so-called milk-substitutes and a review of our more recent knowledge of nutrition would help to show why the use of milk-substitutes has proved so unsatisfactory.

REVIEW OF LITERATURE

Milk Substitutes

The dairy farmer, who is selling cream, has at his disposal a certain amount of skimmilk. In this case he may use this by-product in the raising of calves with highly satisfactory results. However, increasing numbers of dairymen throughout the country are selling whole milk for city consumption, for cheese making, or for the manufacture of condensed and evaporated milk. In this case no skimmilk is usually available. Should the dairyman wish to raise a few calves by the skimmilk method, it would necessitate the purchase of a separator and sacrificing of part of his trade. In many cases the value of the milk used for feeding would far exceed the value of the animal at weaning time.

For this reason the interest in so-called "milk substitutes" is constantly increasing. Several different concentrate mixtures have been used with a limited degree of success, but in most cases they are expensive and require great care in their use. Commercial firms have availed themselves of the opportunity of placing upon the market countless numbers of calf meals, some of which have given fairly satisfactory results, but in most cases have also proved expensive.

As early as 1898 Somerville (1) recommended the following as a satisfactory feed for young calves:

Flour	1 part
Flaxseed	2 parts
Ground linseed cake	3 parts

Two and one-half pounds of this mixture to be considered a day's allowance. It should gradually take the place of whole milk after the first fortnight.

Crawford (2) in 1900 gives oil cake and oatmeal 1 : 1, cooked with hay tea and a little milk as a useful food for calves.

The first experiments of note, with milk substitute in this country were carried on by Hayward (3) of the Pennsylvania Station. He used as the basis of his early work an English formula, as follows:

Flour	16-2/3 lbs.
Flaxseed meal	33-1/3 lbs.
Linseed oilmeal cake	50 lbs.

In preliminary trials, he used combinations of flour, flaxseed meal, linseed meal, sugar, glucose, cocoanut meal, dried blood, fenugreek and fennel seed. Sugar seemed to have a bad effect on the bowels, fenugreek and fennel seed did not seem to produce an effect that would warrant their use as a part of the meal.

In 1901, the following mixture was made up and proved quite satisfactory.

Wheat flour	30 lbs.
Cocoanut meal	25 lbs.
Nutrium	20 lbs.
Linseed meal	10 lbs.
Dried blood	2 lbs.

It was fed as follows: One pound to six pounds of hot water. When seven to ten days old, it was given twice daily, three pounds of whole milk and one-half pound of calf meal mixed in water. This was fed for four to seven days and the animals then put on calf meal alone. For the first five to six weeks calves were fed two pounds per day, after that, two and one-half pounds up to weaning time.

The nutrium used in this trial was a soluble skimmilk powder, and it is probably to this that the success of the calf meal was largely due.

In his summary, the author concludes that while the calf meal was a complete success, it is not as satisfactory a food as whole milk for very young calves and that for the first few weeks on this ration the calf does not have the vigor or power of resistance that it would have if fed upon its natural food.

H. H. Dean(4) found that cocoa shell milk made by boiling 1/4 pound of cocoa shells in two gallons of water, when fed one and one-half to two gallons per day with bran and oats, green feed, etc. appeared to be a very good substitute for skimmed milk. He concluded, however, that there is probably no substitute which will entirely take the place of milk for young stock.

Lindsey (5) compared Blatchford's calf meal with Hayward's mixture. He concluded that Blatchford's calf meal was hardly as satisfactory as Hayward's mixture. He also stated that he did not believe it possible to raise delicate calves on the meal entirely.

At the Kansas station, Otis (6) attempted to use hay tea as a substitute for milk, but the results were not favorable. Two kinds of hay tea were used. One from the mixed hay and the other from alfalfa hay. The tea from the mixed hay proved better than that from the alfalfa, because the latter produced scouring which was difficult to control. It was also impractical to substitute whey for whole milk.

Beach (7) compared a calf meal prepared at the Storrs Experiment station with skimmilk and found that it required 1.09 pounds of dry matter in the skimmilk to produce 1 pound of gain, where it took 1.79 pounds of dry matter in the calf meal to produce the same gain. The skimmilk calves made nearly twice the gains of the calves fed calf meal. He states that "the smaller gains made by Lot 2 (that is, the calves receiving calf meal) is attributed to the inability of the calves to digest and assimilate the calf meals." He concludes as follows: "For the young animal a satisfactory substitute for milk must be capable of being easily digested and assimilated."

Woodward and Lee (8) in the same bulletin in which they give the results of a trial in feeding Blackstrap molasses to young calves to supplement skimmilk, also gives the formula for a milk substitute employed by a farmer in Louisiana. The mixture consisted of bean soup, shorts, blood-meal, and sometimes cotton-seed meal. The calves were given whole milk for the first five days. The milk was then reduced until at the end of ten days the calf was receiving one pint of milk twice daily, at the same time that the milk was being reduced, bean soup, shorts, blood meal and sometimes cotton-seed meal was added to the calf's ration until at the end of ten days it was receiving twice daily in addition to the milk, bean soup from 4 ounces of navy beans, 3 ounces of shorts, 1 ounce of blood meal, and probably half the time 3 ounces of cotton-seed meal. The calf receives this ration until it is six weeks old, when the milk is discontinued and the same amount of substitute fed as before until the calf is four months old, when it is weaned, that is, put on dry feed entirely.

Michels(9) used rolled oats with very good results as a partial substitute for milk. The daily allowance per calf during the thirteen weeks of the experiment was as follows:

First week	-	10 pounds of whole milk
Second week	-	8 pounds of whole milk 4 ounces of rolled oats
Third week	-	6 pounds of whole milk 8 ounces of rolled oats
Fourth week	-	4 pounds of whole milk 12 ounces of rolled oats

and from the fifth week through the ninth week, two pounds of whole milk and twelve ounces of rolled oats, and from the tenth week through the thirteenth week, no milk and twelve ounces of rolled oats as before.

Besides this a grain mixture was given after the fourth week, which consisted of one part each of cornmeal, linseed meal, and wheat bran. In addition the calves received all the hay they would eat, during the winter, (bulletin does not indicate kind of hay used), while in the spring they received one feed of hay with pasturage additional. The authors state that their results indicate that one pound of rolled oats, when fed in moderate quantity, is nearly equal to one gallon of whole milk at corresponding periods of age.

At the Cornell Station(10) Wing, Savage, and Tailby made a thorough study of two commercial calf meals; Lactina Swisse, which is a vegetable milk powder manufactured in France, and Schumacher calf meal. These were compared with skimmilk. The calves fed skimmilk were designated as Lot A, those fed Schumacher calf meal as Lot B, and those fed Lactina Swisse, Lot C. The average gain for Lot A was 1.76 pounds per day, for Lot B, 1.25 pounds per day and for Lot C, 0.7 pounds per day. The cost per pound of gain was greatest in the case of Lactina Swisse. All lots of calves were fed all the dry grain they would eat up clean each day. The grain mixture is as follows:

6 lbs. corn and oats (ground half and half by weight)

3 lbs. wheat bran

1 lb. oilmeal

Mixed hay with a good percentage of clover was kept before the calves at all times. The authors conclude that skimmilk is the best substitute for milk; Schumacher calf meal does not appear to be a complete substitute for skimmilk, and that Lactina Swisse was too expensive and not nearly equal to skimmilk or Schumacher calf meal at any corresponding period of age.

The following year four lots of calves were used in another trial. Lot D, fed skimmilk made an average daily gain of 1.53 pounds. Lot E, fed skimmilk powder, 1.23 pounds per day. Lot F, fed Schumacher calf meal, 1.10 pounds per day, and Lot G, fed Blatchford's calf meal, 0.87 pounds per day on the average. The authors conclude as follows:

"Skimmed milk gave the best results as a substitute for whole milk.

Dried skimmed milk powder was worth the most as a substitute for skimmed milk at an economical cost.

Schumacher calf meal is not an economical food if the third grade dried skimmilk powder can be purchased for feeding.

Blatchford's calf meal is in about the same class as the Lactina Swisse, which was used the year before."

Guiliani, (11) carried on an experiment with five calves to ascertain how far Blatchford's calf meal could actually replace milk. His results lead to the conclusion that Blatchford's calf meal cannot entirely replace milk, either from the physiological or the economic point of view. Physiologically, though not economically, it can be used as a partial substitute for milk.

An experiment was carried on by Archibald[12] comparing a home mixed calf meal with two commercial calf meals with the following results:

The calves receiving the home-mixed calf meal made an average daily gain of 1.61 pounds. Those receiving the commercial calf meals made average daily gains of 0.038 pounds and 0.87 respectively. The home-mixed calf meal consisted of ground oats, ground corn and ground flax, 2 : 4 : 1.

Lindsey[13] found Schumacher's and Biby's calf meals to be satisfactory as partial substitutes for milk. He also tried several preparations of his own, of which the following two proved most successful.

35 lbs. ground oat flakes
12½ lbs. barley malt.
1½ lbs. blood flour.
1½ lbs. bicarbonate of potash
½ lb. salt.

- -

22 lbs. ground oat flakes
10 lbs. flaxseed meal
5 lbs. flour middlings
11 lbs. fine cornmeal
1½ lbs. prepared blood flour
½ lb. salt.

The author writes that his results indicate that calf meals may be purchased or prepared which will take the place of a considerable amount of whole or skimmilk and not interfere with the normal growth of the calf. "It is doubtful if we will be able to find any article or combination of articles which will completely take the place of milk during the first two or three months of a calf's life." In the case of the authors own observations with different calf meals, he did not think it advisable to attempt to rear the calves during the first four months without the use daily of three to five quarts of skimmilk.

Hunziker and Caldwell (14) of the Purdue Experiment Station fed three lots of calves.

Lot I. Skimmilk

Lot II. Home-mixed calf meal (consisting of hominy feed, linseed meal, red dog flour, and dried blood, equal parts by weight.)

Lot III. Blatchford's calf meal.

All lots received a dry mash of ground corn and oats, also alfalfa hay and corn silage.

The calves in Lot I received whole milk until three weeks of age and were then put on skimmilk, grain, hay and corn silage.

Lots II and III were allowed whole milk until five weeks of age and were then receiving the home-mixed calf meal and Blatchford's calf meal respectively, otherwise they were fed the same as Lot I.

The average daily gains were as follows:

Lot I. - 1.21

Lot II. - .95

Lot III. - .73

The authors conclude that so long as skimmilk is available as a feed for livestock, milk substitutes for dairy calves are of comparatively little value. Under contrary conditions the use of a home-mixed calf meal is advisable although the calf so produced will not be as well developed at six months of age as if fed milk during its early growing period. The results from the standpoint of gain in weight and growth in height produced by feeding Blatchford's calf meal do not warrant recommendation as an absolute milk substitute for the growing of dairy calves.

The following mixture is recommended by the California Experiment Station[15] rolled or ground barley, oats, wheat middlings and linseed meal or flaxseed meal, two parts of the first three feeds, and one part of linseed meal or ground flaxseed, if it can be purchased within a few dollars of the price of linseed meal per ton.

Experiments were carried on by the Purdue Experiment Station[16] in continuation of the work done in 1916; with a mixture of various vegetable proteins and also a mixture of vegetable and animal proteins from various sources. The object was first, to determine to what extent a calf meal made up of both animal and vegetable feeding materials, rich in protein, could take the place of skimmilk and second, to determine whether the proteins from wholly vegetable sources are capable of producing growth and development of the calf to the same extent as the proteins from animal sources.

The calf meals were mixed with water, 4 ounces of meal to 3 pounds of water at first, increasing to 12 ounces of meal with 9 pounds of water and fed at the same temperature as the skimmilk. The dry mash consisted of equal parts of ground corn and oats.

FEEDING PERIODS AND FEEDS RECEIVED BY EACH CALF

Calf	B-40	B-43	B-41	B-44
Period I 29 days	Skimmilk Alfalfa hay Dry mash	Skimmilk Alfalfa hay Dry mash	Vegetable meal Alfalfa hay Dry mash	Home mixed meal Alfalfa hay Dry mash
Period II 25 days	Home mixed meal Alfalfa hay Dry mash	Vegetable meal Alfalfa hay Dry mash	Skimmilk Alfalfa hay Dry mash	Skimmilk Alfalfa hay Dry mash
Period III 18 days	Vegetable dried blood meal Alfalfa hay Dry mash	Home mixed casein meal Alfalfa hay Dry mash	Vegetable dried blood meal Alfalfa hay Dry mash	Home mixed casein meal Alfalfa hay Dry mash

The meals used were mixed as follows:

1. Vegetable meal

Linseed meal O.P. Soy bean meal Cottonseed meal Wheat middlings	Equal parts by weight, N 4.97 per cent

2. Home-mixed meal

Hominy feed Linseed meal O.P. White swan flour Dried blood	Equal parts by weight, N 5.60 per cent

3. Vegetable dried blood meal

Soy bean meal Linseed meal O.P. Cotton seed meal Wheat middlings Dried blood	Equal parts by weight, N 6.00 per cent

4. Home-mixed casein meal

Hominy feed......	9 parts by weight	N 5.02 per cent
Linseed meal O. P.	9 " " "	
White Swan Flour	9 " " "	
Casein..........	8 " " "	

Nitrogen content of the other feeds

Skimmilk	N 0.55 per cent
Mash	N 1.46 " "
Alfalfa hay	N 2.53 " "

The conclusions reached by the authors are as follows:

1. The nitrogen intake was rather constant per kilo of body weight. The maximum difference was 12 per cent.

2. Less nitrogen was excreted from the vegetable ration than from the dried blood ration, there being a difference of 4.7 per cent.

3. It seems that when the nitrogen in the ration was the most suitable for growth, the nitrogen excreted was about evenly divided between the feces and the urine.

4. The total nitrogen excreted from each of the five rations indicates that the nitrogen in the skimmilk ration was absorbed to the greatest advantage and the other feeds in the order named; home mixed meal, home mixed casein meal, vegetable meal, and vegetable dried blood.

Two years before this work at the Purdue Station, Gowin and Andoward (17) did some work in a small way along this same line. A three months old calf was fed for 11 weeks; during the first four weeks a ration high in amid content (potatoes and manioc) and during the last six weeks a saccharose feed in which carob-bean meal predominated. During the first period the ration contained 218 grams of saccharose per 1000 kilograms weight, and during the second period 420 grams. The average daily increase in weight was 821 grams, in the first period, and 905 grams in the second. There was found to be a reduction in the amount of urine secreted in the urinary nitrogen, and in the nutrients digested with the increased allowance of saccharose.

In a later publication by the Purdue Station (18) a report is made of a new calf meal which the authors state gives promise of being the best milk substitute for young calves that has yet been worked out. These investigators have made use of the newer knowledge of nutrition in formulating this ration.

The important factors considered was not merely the quantity of proteins, but special attention was given to the quality of proteins together with the required quantity of salts essential for growing animals. The following mixture was selected as the one giving best results:

Ground corn	8 parts
Oil meal	1 part
Dried blood	3 parts

To supply the deficiency of ash, one and one-half per cent of steamed ground bone meal was added. In their experiments alfalfa hay was fed ad libitum. It is very probable that the successful results obtained by these investigators were in a large degree due to this hay.

Caldwell[19] reports on an experiment carried on in continuation of the work done in 1917. Two mixtures were tested as substitutes for milk:

1. Linseed meal, red dog, hominy feed and liquid beef blood.

   1 : 1 : 1 : 4

2. Ground corn, gluten feed, red dog, and buckwheat flour.

   5 : 5 : 5 : 3

plus an infusion of clover hay containing 0.1 per cent nitrogen. The calves fed the substitutes received limited amounts of milk during the first four periods. All calves received either alfalfa or clover hay throughout, and a mash which consisted of corn and oats except with the clover juice ration, when some of the grain mixture of this ration was fed dry.

One calf received the liquid blood mixture for the first 9 periods, and consumed more nitrogen, excreted a larger proportion through the urine, and retained a smaller proportion than any of the others, but the actual amount retained was about equal to the average of the two calves fed milk. During the remainder of the test this calf was given one part of dried blood in place of the 4 parts of liquid blood. The amounts of nitrogen consumed and retained remained unchanged, but the path of excretion changed from urine to feces. This calf made the most rapid growth of the four, the average daily gain being 1.15 pounds.

A second calf receiving the clover juice ration for 9 periods consumed a small quantity of nitrogen, retained the smallest amount, and showed a high proportion of fecal nitrogen after milk feeding ceased. During the last 3 periods, the liquid blood ration was given this calf, the proportion of retained nitrogen diminished, and the urinary nitrogen increased. This calf made the least satisfactory growth, the average daily gain being 0.68 pounds.

The other two calves received a mill ration for 8 and 9 periods, respectively. With only a medium consumption of nitrogen, a high proportion was retained and a fair degree of equality was maintained between the fecal and the urinary nitrogen. Toward the end of the experiment one of these calves was changed to the liquid blood ration and the other to the clover juice ration. The former showed an increase in the urinary nitrogen and the latter an increase in the fecal nitrogen.

In a series of experiments at 30 centers in 17 counties in Ireland,[20] crushed oats was compared with a standard calf meal composed of ground flaxseed oat meal, and maize meal (1 : 2 : 2)

In the experiments which lasted an average of 116 days, 202 calves were used. They averaged one-half week of age at the beginning of the test. The crushed oats ration was fed dry and the calf meal was steeped in hot water for 12 hours. An average daily gain of 1.41 pounds per head was made on the crushed oats and 1.44 pounds on the calf meal.

Voelecher[21] reports the results of a 14 weeks trial with crushed oats calf meal, beans, palm-nut cake, and maize and fish meal. The highest gains were given with the maize and fish meal mixture, closely followed by the palm-nut cake, and oats mixture. Difficulty was experienced in getting the calves to eat the palm-nut cake alone in the beginning though they did well on it.

Washington Station[22] gives the formula of two mixtures which may be used to advantage if "used by a careful feeder."

Mixture No. I

Low grade flour	16-2/3	pounds
Whole flaxseed meal	33-1/3	"
Linseed oilmeal	50	"

Mixture No. II

Ground oat flakes	22	pounds
Flaxseed meal	10	"
Flour middlings	6	"
Fine cornmeal	11	"
Blood meal flour	1½	"
Salt	½	"

White[23] investigated the use of corn silage in conjunction with a milk substitute, and grain and hay. The milk substitute in this case was Schumacher calf meal. The average age at which meal was begun was 22 days, and at 58 days of age they were completely off milk and receiving calf meal in gruel form together with grain, hay and silage. Grain mixture was 2 parts hominy, 2 parts crushed oats and 1 part bran. There was some difficulty in getting the calves to take the calf meal. One calf refused it unless some milk was added. The authors conclude that "so far as the feeding of silage with the calf meal is concerned, it is of doubtful value in the ration at least under three months. The difficulty of securing sufficient nutrients for growth from the calf meal are such that the digestion is probably disturbed or hindered by the presence of silage especially during the first three months of the calf's life.

Wing[24] of Missouri conducted an experiment to determine the possibility of using powdered skimmilk for feeding young dairy calves, and also the economy of such a practice. The plan of the experiment was as follows:

Three lots of calves, three in each group were used.

Lot I. A group of calves fed in the usual manner on skimmilk, hay and grain.

Lot II. A group of calves fed and cared for in the usual manner except to receive powdered skimmilk in place of the ordinary skimmilk. The powdered skimmilk to be fed in the dry form mixed with ground corn, equal parts by weight. The calves to receive this ration until 120 days of age. The calves were then to be placed on a ration of grain and hay.

Lot III. A group of calves fed and cared for the same as Lot II except they be fed the powdered skimmilk and ground corn until they were 90 days of age. The data from this group is expected to indicate to some extent at least the minimum amount of powdered skimmilk required.

The calves in Lot I made an average daily gain of 1.20 pounds up to 150 days of age. Lot II, an average daily gain of 0.86 pounds up to 180 days of age, while those in Lot III made an average daily gain of 0.92 pounds up to 180 days of age. The author states that all of the calves in Lot II and III made gains near enough to the normal so that they should be able to catch up during the four months that follow this feeding period or the time when they are on pasture.

According to prices assumed by the author, the average cost of raising calves was as follows:

Lot I	Skimmilk	14.55
Lot II	Powdered skimmilk for 120 days	23.10
Lot III	Powdered skimmilk for 90 days	21.15

The cost for Lot I is for only 5 months while that for Lots II and III is for six months.

Present Status of Milk Substitutes

In the preceding pages there have been reviewed the most important experiments carried on with milk substitutes. Some of the mixtures used have proven fairly satisfactory from a nutritional standpoint. In most cases, however they have been expensive and have required much time and care in their preparation and use. The proprietary calf meals in every case have been expensive, and it has been found that "home-mixed" calf meals may be prepared which will give equally as good results at much less expense. The best results from the use of either home-mixed calf meals or proprietary calf meals have been where some milk has been used in connection with them. In many cases it has been found difficult to induce calves to eat the calf meal. White[23] found it absolutely necessary in the case of one animal to feed some milk along with the meal.

Hayward[3] points out that calves raised upon milk substitutes should have warm, dry quarters as they are apt to be less resistant to disease than milk fed calves.

Hooper[25] at the Kentucky Station found calves reared on rolled oats gruel less vigorous than those fed on skimmilk.

Henry and Morrison[26] state in regard to proprietary calf meals: "These meals are fairly satisfactory substitutes for skimmilk, but give no better returns than home-mixed meals that are much less expensive."

Reed[27] writes as follows: "There are a great many milk substitutes advertised on the market today, but these are usually expensive and for the best results some milk should be fed with them."

In circular 50[28] of the Iowa Station the authors conclude that "Where milk substitutes must be used, it is probably best to wait until the calves are six or eight weeks old and then substitute gradually".

Nystrum[22] states, that, "there is no good substitute for milk to be obtained at any price. This fact has recently been proved by scientists though practical feeders have known that to be so for years, but supplementary feeds can be found which will cut the cost of raising calves materially. Some calves will not respond to the substitute as will others, and all calves will do better on the calf meal when a little milk is given with it. If skimmilk is plentiful it is wise to keep feeding it until the calf is four to five months old. However most calves will grow well on the substitute alone after they are ten weeks old, providing they have never had a set back, have learned to eat grain and hay, and are in a good thrifty condition."

Eckles[(29)] writes of proprietary calf meals as follows: "On the whole the calf meals that are on the market give fair satisfaction as supplements to skimmilk, but no better than grain mixtures that can be fed at much less expense. It is possible to use them as substitutes for milk in raising calves after they are two or three months old, but equally as good results are found by feeding mixtures of grain prepared by the feeder at less expense. The most satisfactory of the prepared calf meals seem to be those that contain a certain amount of dried skimmilk."

Woll[(15)] states "It is a difficult undertaking to raise very young calves successfully without milk, and calls for constant care and watchfulness on the part of the feeder. Commercial calf feeds will give satisfactory results in some cases but are relatively expensive."

Hulce and Nevens[(30)] write as follows: "The calf meals sold on the market are useful as supplements to whole milk but as yet they have not been so compounded that they will successfully replace whole milk before the calf is several weeks old. Calf meals alone, or calf meals, grain and hay do not form a complete ration for the young calf, since they do not supply the necessary nutrients in a form readily digested and assimilated. It is doubtful if under average conditions good gains will be made unless some milk is fed until the calf is about 60 days of age.

The following is quoted from Bulletin 164 of the Massaschusetts Station(13) "It is well known that the stomach of the calf is very sensitive during the first few months of its life, and it is doubtful if any substitute can be found or compounded which will completely take the place of milk." -"Results indicate that calf meals may be purchased or prepared that will take the place of a considerable amount of whole or skimmilk and not interfere with the normal growth of the calf. It is doubtful however, if one will be able to find any article or combination of articles that will completely take the place of milk during the first two or three months of the calf's life. In the case of the writers own observations with different calf meals, he did not think it advisable to attempt to rear the calves during the first four months without the use daily of three to five quarts of skimmilk."

Sweet(31) concludes as follows: "Fair success can be secured by feeding calf meals or the so-called "milk substitutes" provided all precautions are duly observed. The results in growth and general condition by this procedure will probably not quite equal those produced by skimmilk feeding."

From these quotations we find that the objections to the use of the so-called "milk substitutes" are as follows:

1. They are expensive.
2. They do not supply the necessary nutrients in a form readily digested and assimilated.
3. Their use requires constant care and watchfulness.
4. For the best results some milk must be used in connection with them.

The Use of a Minimum Amount of Milk in Calf Raising

It will readily be seen from the preceding pages that the use of so-called "milk substitutes" does not entirely solve the problem for the farmer who is selling whole milk. There is however a modification of this method which may be employed, that is, the use of a minimum amount of milk, sufficient to give the calf a satisfactory start in life; then cut the calf off from milk and put it upon a ration consisting of merely grain and hay. Very little data is available on this method, in fact only two pieces of investigation are known to the writer, but of those very good results have been recorded.

The first work was done at the Illinois station by Fraser and Brand. (32) Three tests were made using in all twenty-eight calves which were allowed to remain with their dams during the first twenty-four hours and were then removed and weighed. The first four days they were fed their mothers milk according to their appetite. After this they were fed whole and skimmilk in various amounts and for various durations of time.

In the first test four of the calves were given only 15 - 21 pounds of whole milk each. Changing to skimmilk so early had a tendency to disarrange their digestions at first. These calves did not do very well afterwards even though they were later given plenty of skimmilk. Three calves were entirely cut off from milk at 42, 45, and 60 days of age, and fed on grain and hay. These calves all had trouble with the digestive organs, due to the fact that they ate excessive amounts of the hay and grain. When their ration was cut down, they improved very rapidly, and according to the authors developed into good animals. The authors conclude that their results showed that "during the first two weeks of their lives the calves must be fed a reasonable amount of whole milk. After this their feed may be gradually changed to skimmilk, but until they are about eight weeks old they must still receive practically all of their nourishment in the form of milk. If required to obtain even a portion of their nourishment from grain or hay when they are less than seven weeks old, their digestion will become badly deranged."

In the second test it was found that the calves made very good gains with an average of 152 pounds of whole milk and 435 pounds of skimmilk, if kept on pasture and given grain until six months old. The third test confirmed the results of the second test.

The authors conclude as follows: "The calves should be continued on 12 pounds of skimmilk a day until they are about 7 weeks old, and thereafter the amount may be rapidly reduced, so that at 8 weeks old they will be receiving no milk. Where it is possible, more milk than herein recommended should be fed."

Fohrman (33) of Missouri conducted the second experiment on this method of raising calves. He used three lots of three calves each, which were weaned at an average age of 64 days, and were then fed on a dry grain and hay ration for 120 days.

Two grain mixtures were used.

Grain mixture "A" was made up of

Corn	40 parts
Oilmeal	10 "
Wheat bran	10 "

Grain mixture "B" was made up of

Corn	40 parts
Wheat bran	10 "
Linseed meal	5 "
Blood meal	5 "

Lot I was fed calf mixture "A" and alfalfa hay. Lot II was fed calf mixture "B" and alfalfa hay. Lot III, in which two of the animals were fed calf mixture "A" and the other calf mixture "B", alfalfa hay was fed until they were 90 days old, and then they received timothy hay.

Lot I made nearly normal gains.

Lot II made no better gains than Lot I.

Lot III dropped behind normal and did not compare well with the other groups.

The author concludes as follows:

1. Dairy calves in good thrifty condition can be weaned at the age of 60 to 70 days and will continue to grow and develop at approximately the normal rate when fed on a suitable grain mixture and alfalfahay.

2. Blood meal in the grain mixture fed to calves more than two months old has no pronounced nutritional value, and its high cost does not warrant its use for calves of this age.

3. A grain mixture of ground corn, wheat bran, and linseed meal in quantities prescribed in this experiment fed in conjunction with alfalfa hay apparently supplies all the requirements for normal growth of calves from two to six months old.

4. Raising calves by weaning at sixty days of age and subsequently feeding them on grain and alfalfa hay is more economical than feeding skimmilk, grain and hay until the animals are six months old. This is true only where there is a market for skimmilk.

In adopting the method used in the last two experiments reviewed, slightly more milk was used than is usually recommended in the use of milk substitutes. However, slightly better results have been obtained by this method and the time and labor required for the preparation of the milk substitute is eliminated in the daily care of the calf.

SOME FACTORS WHICH INFLUENCE THE NORMAL GROWTH OF ANIMALS

Physiological Factors of Growth

Any study of the nutrition of the immature animal involves some consideration of growth from the physiological as well as from the nutritional standpoint. Among the physiological questions which arise in this connection are the nature and limitations of growth and the internal factors which may accelerate or inhibit growth, either of the body as a whole or of certain organs.

The importance of these factors justifies a review and discussion of the question from the standpoint of physiology as well as of nutrition.

Definition.

It is a difficult matter to give a satisfactory definition of growth, that is, one which will be accepted by all students of physiology. As it is, each writer on the subject has a different definition and while all of these convey to the reader some conception of the nature of growth, none of them are entirely satisfactory according to the authorities on the subject.

Mumford[(34)] speaks of growth as follows: "From the fertilization of the egg until the full development of the mature individual the animal increases in volume and changes in form. This increase and change of form is called growth."

Martin[(35)] defines growth as "the property based on assimilation of increasing in size by building up the body protoplasm faster than it is broken down", and later speaks of growth as "the manufacture of new tissue."

Starling[(36)] goes about defining growth in this way. "Our conception of life must involve the idea of a constantly recurring cycle of processes, one of building up, repair or integration, and the other associated with activity or destruction or desintegration. If the former process predominates, we obtain a steady increase in the mass of the organism, an increase which we speak of as growth."

Mendel[37] writes of growth as follows: "What is growth? We cannot penetrate far into the literature of the subject without meeting with a bewildering confusion in the significance of the term. Various expressions such as growth, organic growth, development and emplasia have been applied to the same phenomena, and the numerous attempts to define their meaning and precise application have almost invariably ended in a failure to meet criticisms which might be urged against each definition submitted. The most general definition of growth is "increase in volume" or "increase in size" (Huxley). Increase in volume does not always serve as an index of organic growth for the increase may merely be due to swelling. Sachs defined growth as an increase in volume accompanied by a change in form. No universally acceptable definition has been framed nor is it likely that one can consider all of the manifold features of growth in a single category."

Nature and Limitations.

At the time of the fertilization of the egg, a force is set free which enables this bit of living matter to grow, to increase in size and to change in form. This force which is set free has its maximum power at sometime before birth and from then on there is a decline to old age. From Minot[38] we find that the rate of growth is far greater before birth than at any period after birth.

The power to grow may be checked by abnormal conditions, but when placed under favorable conditions may again proceed at an accelerated rate. Mumford[34] in writing on growth states that "the final size of an animal is determined by the rate of growth and the length of the growth period", and continues, "the young of any species tend to develop and grow in accordance with the normal habit of the species."

Mendel[37] writes as follows: "Experience shows that there is a fairly definite upper limit in size which the individuals of any species rarely exceed. There are forms for which the variations may be very wide and it is reported that some of the lower forms, e.g., actinians can be caused by suitable feeding to reach a colossal size far beyond that which they ordinarily attain in nature. To the mammalian species with which we are primarily concerned here, however, this does not apply except in the limited degree determined by heredity. Why the body size is thus fixed is not known". He continues, "Whatever may be the ultimate cause of growth, the capacity to grow is currently associated with a youthful character of the cells involved. From this standpoint age is an important factor in the possibility of youth. An embryonic condition of the cells is accordingly most favorable to growth".

Minot's (38) third low of age, dealing with the growth function reads, "The rats of growth depends on the degree of senescense." From a purely theoretical standpoint it is quite conceivable that ordinary cessation of growth may be due to a natural inhibitory factor which develops in the course of time rather than because the capacity to grow is lost.

Waters (39) has shown that animals under adverse conditions may continue to grow in skeleton and at the same time remain at constant weight.

So we see that while food may be essential for growth, it can in no sense be regarded as the supreme cause of growth. Nutrition can only give the growth impulse free play.

Very little can be said of the growth impulse or the tendency to grow, except that this factor is hereditary in its origin and sets to growth the limits which nutrition cannot fundamentally alter. It may also be said that cell division and its attendant features is dependent upon the action of hormones which are products of internal secretion and cellular metabolism.

Kellicott (40) writes as follows: "It seems quite likely therefore that in organisms in general the growth of each tissue or even each organ is controlled by a specific internal secretion. These substances may regulate growth either through inhibition or acceleration and the effect produced may be due either to the presence or the withdrawal of the specific substance."

Internal Secretions of the Ductless Glands.

It must be remembered that Endocrinology, the name applied to the science of internal secretions, is a comparatively new and exceedingly complicated field of study, and though intensely interesting, is at the same time almost outside the field of study of those interested in the applied phases of animal nutrition. Nevertheless a discussion of the more important features of this science will bring out the importance of the bearing which these glands of internal secretion may have upon growth.

Hid away in various parts of the human frame is a series of more or less obscure bodies or glands; which in recent times have come to be recognized as parts of the machinery which regulates the growth of the body. They form(40) merely a fraction of the total mass of the body, not more than 1/180th part of it. A man might pack the entire series in his watch-pocket. The modern medical student is familiar with each of them; the pituitary body about the size of a ripe cherry, attached to the base of the brain and cradled in the floor of the skull; the pineal gland, also situated in the brain and in point of size but little larger than a wheat grain; the thyroid in the neck, set astride the windpipe forms a more bulky mass. Here we also find the parathyroids embedded in the thyroid, four being usually described. The two suprarenal bodies capping the kidneys; the interstitial glands embedded in the substance of the testicle and ovary, and the thymus located in the anterior superior thoracic cavity. The growth of the body may be retarded, accelerated or completely altered if one or more of these glands become the seat of injury or of a functional disorder. For example, exaggerated action of the pituitary gland leads to giantism, also to change of face, reduced action to dwarfism.

Some, perhaps all of the ductless glands play a role of the greatest importance in general nutrition. They yield internal secretions of one kind or another, and modern investigators[41] have demonstrated that there is a complicated inter-relation among the secretions as regards their action on body metabolism. In view of these facts the entire group of ductless glands, or glands furnishing definite internal secretions is sometimes united under the designation of the endocrin system. (endon. within, Krin I, separate).

The conception that certain glandular organs may give rise to chemical products which, on entering the circulation, influence the activity of one or more other organs, has recently found a fruitful application in the study of digestive secretions. The gastric and pancreatic secretions may be regarded as examples of internal secretions.

To such substances which are derived from one organ and influence another after their passage into the bloodstream, Starling[42] in the year 1902 gave the name of chemical messengers or "Hormones" from the Greek-I arouse, or set in motion.

The ductless glands may be divided into two groups according to the action of their hormones. There is first an acceleratory group[43], and second an inhibitory group. Schafer[41] calls attention to the fact that since the term "hormone" (hormao-I excite) etymologically considered, is not applicable to the latter group, he suggests therefore the general term of autocoid substances for both groups to indicate their drug-like action, and sub-divides them into two groups; those autocoid substances with a stimilating action, as hormones, and those with an inhibitory action,as chalones.

The thyroid, pituitary and suprarenals belong to the former group (that is, those with a stimilating action) since it has been shown that all three increases protein metabolism, that the adrenals cause mobilization of the carbohydrates and that the thyroid causes increased fat absorption.

To the inhibitory group belong the pancreas and parathyroids, since both retard protein exchange and both restrain the mobilization of carbohydrates, in each case the pancreas being the more powerful.

Much of the research work concerning the ductless glands has been from the viewpoint of relating some one gland to some particular position or restricted function of the body. Thus the pituitary[44] has been associated with the growth of the bones and certain skeletal formations, the thyroid has been associated with the nerves, and some writers have satisfied themselves that the activity of ductless glands is explained by clinical syndromes, wherein only portions of the body show abnormalities. There have been relations suggested which were based on embryologic grounds; organs and tissues derived from some common source have been supposed to be more or less related in function. Some of the most elaborate relationships of the ductless glands are based on histologic findings. These points should be kept in mind though the following discussion of each of the glands of internal secretion and deductions made accordingly.

Thyroid.

The most important and definite outcome of the work on internal secretions has been obtained with the thyroids. Recent experimental work makes it necessary to distinguish between the thyroids and parathyroids.

According to Howell[41] the thyroids proper form is two oval bodies lying at the sides of the trachea at its junction with the larynx. They have two ducts and are composed of vesicles of different sizes, which are lined by a single layer of cubic cells and contain in their interior a material known as colloid. Accessory thyroids varying in size and number may be found along the trachea as far down as the heart. They possess a vesicular structure and it is thought they have a function similar to that of the thyroid body.

From Haskins[45] we learn that the thyroid and a certain cellular system together with a portion of the hypophysis constitute a group of vascular glands which accelerate the process of carbohydrate metabolism. The balance is maintained by the antagonistic activity of those other vascular glands which like the pancreas and parathyroids exercise a retarding influence upon the consumption of sugar.

Kojina[46] found that excision of the thyroid gland in rats produces a diminution of both nitrogen and calcium output, but that thyroid feeding produces a decrease in body weight and a diminution of nitrogen and gaseous metabolism in all animals whether normal, or those having had the thyroid gland removed, or the parathyroids removed.

According to Lescohier[47] it has long been known that there is a principal produced in the thyroid gland which exerts a very marked influence upon ovarian functions. The cretin who has no thyroid gland does not develop sexually.

Writing of cretinism Mac Leod[48] states that when the gland (thyroid) is wasted away at birth the condition of cretinism soon becomes developed. The characteristic features of cretinism are:

1. An arrest of growth especially of the skeleton. Accompanied by incomplete formation of the long bones and failure of a certain portion of the skull to close properly.

2. Poor development of the muscular system.

3. An unhealthy, dry, swollen condition of the skin, so that it is yellowish in color, the face being pale and puffy.

4. An abnormal development of the connective tissues.

5. The nervous system also fails to develop properly, so that at the age of puberty or over, the child remains like an infant in his mental behavior, idiotism being common.

The administration of thyroid extract has a startling effect. According to Mac Leod[48] if the treatment is started early enough the cretinous child from being an ill-developed idiot quickly catches up with children of his own age and becomes in every respect normal.

Goiter is a disease caused by an abnormal secretion of the thyroid gland. Mills[49] reports that high external temperatures cause a diminished activity of the thyroid glands of animals, together with a slowing of the rate of growth. Low external temperatures on the contrary increases the thyroid activity and also seems to cause a faster rate of growth. He also states that morphine and quinine appear to decrease the activity of the gland; probably as a result of the lessened metabolism and diminished heat production. Strychnine on the other hand causes a greater thyroid activity very likely by increasing metabolism through its action on the spinal cord.

Parathyroids.

Four of these bodies are usually described[41] two on each side, and their positions vary somewhat in different animals or, indeed, in different individuals. In man the superior (or internal) parathyroids are found upon the posterior surface of the thyroid at the level of the junction of its upper, with its middle third. The inferior (or external) parathyroids lie near the lower margin of the thyroid on its posterior surface and in some cases lower down on the side of the trachea. The tissue has a structure quite different from that of the thyroids, being composed of solid masses or columns of epithelial cells which are not arranged in vesicles and contain no colloid.

It was only recently that the importance of the parathyroids was known. Early in the history of the subject it was discovered that complete removal of the thyroids proper in herbivorous animals is not attended by fatal results, later however, it was shown that if the parathyroid also are removed these animals die. Since then it has been shown[41] that when the parathyroids alone are removed, the animal dies quickly with acute symptoms, muscular convulsions (tetany) etc. When the thyroids alone are removed the animal may survive for a long period, but developes a condition of chronic mal-nutrition. Contrary results have been obtained by some investigators. Kojina[46] experimenting with rats found that upon removal of the parathyroids death did not take place immediately, but found that there was an increase of calcium in the urine and less retained in the body, but nitrogenous metabolism showed no definite change. Though experimental results obtained have been quite contrary to say the least, it is very evident that the parathyroids are of great importance in the normal growth of the animal.

Thymus.

The physiology of the thymus gland is very obscure, in fact nothing that is definite can be said about its function except that perhaps the gland is concerned in some way with the process of growth. If was formerly supposed[41] that the gland reaches its maximum size at birth and afterwards undergoes a process of atrophy or involution so that it is entirely absent in adult life. However, more careful observations indicate on the contrary that the gland retains its size and presumably its full activity until the periods of puberty.

Very many experiments have been made to determine the nature of the function of this tissue, but at the present it is not possible to interpret the results in a satisfactory manner.

Henderson[50] found that castration causes a persistent growth and retarded atrophy of the thymus while removals of the thymus hastens the development of the testes.

In an experiment to determine the effect of thymus feeding on the activity of the productive organs in the rat, Heuer[51] found male rats to be more susceptible to the influence of the feeding than female rats. Beyond inconstant and slight variations no definite general growth changes are brought about by thymus feeding, apart from alteration of sexual activity. With moderate doses of thymus feeding, sexual maturity is delayed. Feeding the parents with thymus caused marked delay of sexual maturity in the off-spring, both male and female.

This delay of sexual maturity appears to be rated to delayed development of the testes. With larger doses of thymus in the female no histological alterations of structure was observable. In the only breeding experiment no breeding resulted when paired with a normal male.

With large doses of thymus in the male, the testes are structurally affected. In the younger animal in the direction of retardation of the development, in the mature rats in the direction of degeneration. This degeneration is confined to the testes.

Nickerson(52) reports the investigation of the case of a calf which had a thymus in place of a thyroid. The calf was a dwarf with a relatively large head, pug nose, prognathosis jaw, short body, and very short legs. It is evident that the thymus plays a very important part in the growth and development of the animal.

Adrenal Bodies.

The adrenal bodies or as they are frequently called, the suprarenal capsules are according to Mathews(53) two small glandular organs lying like caps on the upper poles of the kidneys.

Vincent(54) states that what we call the adrenal body represents two elements, each one of which is derived from a separate and independent system. There is the adrenal body proper or cortex, and the medulla. There is no clear evidence that these two systems are functionally related to one another. The adrenal medulla is supposed to be of some assistance to the nervous system.

The cortex is derived from the germ epithelium and there is considerable evidence that it has important functions in connection with the development of the reproductive organs.

He states that it is the cortex which is essential to life. For since removal of both adrenal is fatal and removal of the medulla alone is not, it follows that the cortex is the essential part of the gland so far as the maintenance of life is concerned. He writes, "It is not known why its removal causes death, but it is possible that this is due to some defect of muscular metabolism.

From Sojous[55] we find that the main function of the adrenals is to supply an internal secretion which absorbs the oxygen of the air to carry it to the tissue and as a result of this fact pulmonary respiration and tissue respiration.

That the adrenals may play a role in digestion is evidenced by the fact that according to Loeper and Vespy[56] intra-muscular injections of one milligram of adrenalin in human subjects caused an increase in secretion of HCl in the stomach as well as augmentation and acceleration of the contractions in the digestive tract.

The following points of interest were taken from an article published in Volume 2 of Edocinology.[57] The actual physiological function of the adrenals has not been satisfactorily determined. These facts have proven an irresistable stimulus to speculation and theorizing, both upon the part of clinicians and of laboratory investigators. Through certain investigations people were led to believe that the adrenals play an important part in sugar metabolism. However, it may now be definitely asserted that the adrenal glands do not play any essential role in sugar metabolism.

Pituitary Body.

The pituitary body or hypophysis is situated at the base of the brain.[48] It is usually described as consisting of two parts,[41] a large anterior lobe of distinct glandular structure and a much smaller posterior lobe of nervous origin and composed chiefly of certain cells and fibers. The anterior lobe has an important relationship to the nutritive condition of the body during growth, especially of the skelatal structure, and the posterior lobe produces a very active autacoid having to do with the physiologic activity of certain muscle fibers.[48]

According to Baar[58] retardation of skeletal growth and sexual infantilism are symptoms due to insufficient activity of the pituitary glands.

Exaggerated action of the pituitary gland leads to giantism and also to change of face.

Livingston[59] carried on an experiment to determine the effect which castration would have on the weight of the pituitary gland and other glands of internal secretion in the rabbit. It was found that there was a constant relationship between the rate of increase of body weight and the response of the hypophysis to castration or spaying. There was less increase in size of the hypophysis (pituitary) in those groups in which there was an increase in the rate of growth.

It has been shown that injections of pituitary extract stimulate milk secretion. Hammond and Hawk[60] found that the flow of milk produced by injections of pituitary extract varies with the state of nutrition of the injected animal. The ration of the morning yield to pituitary yield rises with the fall of nutrition and falls as the nutrition rises again. Therefore the yield obtained as a result of pituitary injection tends to be more constant than the morning or daily yield. The fat percentage of the pituitary milk is increased by the rate of lowered nutrition in the same way as with normal milk.

Pineal Body.

This small body projects from the roof of the third ventricle which extends to the base of the brain. Howell[41]. In early life it has a glandular structure which seems to reach its greatest development at about the seventh year (Humans). After this period and particularly after puberty, it undergoes a process of involution during which the glandular structure gradually disappears and its place is taken by fibrous tissue. Howell.[41]

The functions of the pineal gland are obscure. In cases where its extirpation has been successfully accomplished (in the fowl) it has been found that the body growth is stimulated and the sexual characteristics developed more quickly (Mac Leod)[48]

Organs of Reproduction

The interstitual glands or the glands furnishing the internal secretion of the reproductive organs play an important part in the development of the sexual characteristics. They are found embedded in the substances of the testicle and ovary.

Some of the earliest work upon the effect of the internal secretions of the glands was done upon the reproductive glands, especially the testes by Brown-Sequard.[41] According to this observer, extracts of the fresh testes when injected under the skin or into the blood may have a remarkable influence upon the nervous system. Mental and physical vigor, and the activity of the spinal centers are greatly improved, not only in cases of general prostration and exhaustion of nerve-force, but also in the case of the aged. It cannot be said that his assertions have been corroborated by later work.

The most striking results were those obtained by Steinach[61] in 1910. Finding that feeding with testes material was ineffective, he transplanted these organs in animals three to six weeks old. The testes were removed to various positions on the inner surface of the abdominal muscles of some animals and removed altogether in other animals. In the latter no development of the sexual organs took place. In those in which the transplanted testes grew, the development of the organs was indistinguishable from that of normal males and the animales behaved sexually just as these. The hormone concerned did not arise from the generative cells themselves, because they were not developed in the transplanted testes, whereas the interstitual substance was fully developed.

This observer also reports that when young male rats were first castrated and then had transplanted under the skin the ovary of a female of the same species, the secondary male characteristics did not develop, but on the contrary the animals exhibited the female characteristics.

Pancreas.

The importance of the external secretion or the pancreatic juice has long been recognized, but it was not until 1889 that Von Mering and Minkouski (Howell)(41) proved that it furnishes also an equally important internal secretion. These observers succeeded in extirpating the entire pancreas without causing the immediate death of the animal, and found that in all cases this operation was followed by the appearance of sugar in the urine in considerable quantities. Complete extirpation of the pancreas is followed by loss of flesh and muscular weakness, which finally ends in death in two to four weeks.

On the basis of these and similar results obtained recently by many investigators it is believed that the pancreas forms an internal secretion which passes into the blood and plays an important and essential part in the metabolism of sugar in the body.

As can be seen, the results obtained by the investigators in this work are somewhat contradictory at times and the definite information available concerning anyone of the ductless glands is scanty at best. However, their importance in relation to growth can be readily recognized and the progress made in the last few years would indicate that in the future other, possibly even more important relations will be found.

Nutrition

In the preceding pages it has been pointed out that certain internal factors play an important role in the mechanism of growth. The other major factor which may be termed external in contrast to those designated as internal, is that of nutrition.

The study of nutrition both from the chemical and physiological standpoint has long been of great interest to investigators.

For many years following 1840, as a result of the work of the famous chemist Liebig, it was generally assumed that the essential constituents of a diet were protein and such carbohydrates as starch, sugar, and fat, and certain mineral salts. Liebig taught that such knowledge as accurate chemical analysis gives regarding those constituents of foodstuffs furnishes the basis for the calculation of such proportions of wholesome, natural food as would, if fed to an animal induce good nutrition.(66)

Since proteins; carbohydrates, such as starch and sugars; fats and mineral salts came to be regarded as the essential constituent of the normal diet, it early became the principal activity of the investigators of nutrition problems to analyze foods of every sort by chemical methods in order to determine the content of what was supposed to be the only essential food complexes.

Up to this time it was not recognized that there was any difference in the digestibility of foods. Every food was rated according to its chemical analysis regardless of its digestibility.

In 1864, Dr. Emil von Wolff presented the first table of feeding standards for domestic animals based on the digestible nutrients contained in various foodstuffs. This was a distinct step in advance, although the original figures have been modified considerably by different investigators. No consideration was given to the variation in quality of the proteins until much more recent times. However, the practical farmer had already learned through experience that certain combinations of foods gave better results than others, even though each combination supplied the same amount of digestible protein.

About 1890, Prof. Henry at the University of Wisconsin, Dr. Armsby and others were engaged in the testing of various protein supplements which is itself evidence that investigators in nutrition at that time realized that there was some factor in the ration not expressed by the content and the energy values.

The year 1906 marks the beginning of a new development in nutrition. In that year Babcock and Hart of Wisconsin(62) began an experiment with cattle in which three rations were used, one derived entirely from the wheat plant, one from the corn plant and another from the oat plant. All of the animals did fairly well although the wheat fed animals less so than the rest. But when these animals produced their first offspring very remarkable differences were observed. The wheat fed animals produced calves weighing only a little over a half as much as they should, and every one was born dead. The oat fed animals produced calves of about normal size, but these were either dead when born, or else died within twenty-four hours after birth. On the other hand, the corn fed cows produced calves which were all vigorous and healthy.

Later McCollum took up the same line of work from a different standpoint. He states the object of his experiments in these words: "What is the simplest ration on which one can get an animal to grow?" He prepared rations of purified substances and tested them on rats, but for several years was unable to obtain a ration on which the animals would live. If all that is necessary for an adequate ration is protein, carbohydrates, and certain mineral salts, these animals should have grown and developed normally on the rations supplied, which furnished what had been assumed to be essential. They did not, therefore some necessary constituent had been left out. About this time it was found by certain investigators that there are two other factors absolutely essential to an adequate diet. The first of these was discovered by Funk(63) to which he gave the name vitamine.

The second was discovered by McCollum,(64) who added both of these factors to his purified diet and found as a result of his study that a diet in order to be adequate must contain besides a sufficient amount of proteins, starches and sugars and fats, a protein of good quality, the two accessory substances mentioned above and a suitable amount of mineral matter. Anyone of these may be the limiting factor.

For example, McCollum(64) found that the wheat kernel has three things wrong with it, its inorganic content is unsatisfactory, it lacks one of the so-called vitamines and its protein is of poor quality. This is relatively true of all the seeds. It is not surprising then that most of the mixtures which have been prepared to take the place of milk for raising calves have proved so unsuccessful; when we consider how limited our knowledge has been of the requirements of a complete ration, and how difficult it is to satisfy all of the requirements as we know them with our present knowledge of nutrition.

For the purpose of discussion, the advancements made in nutrition may be taken up under three separate headings, namely, proteins, mineral matter, and vitamines.

Protein.

In a study of calf raising, we are dealing with that period of the animals life in which the most rapid growth is made, and the character of the diet is of extreme importance since if the animal is not properly nourished at this time, its future development will be greatly impaired.

At present it is a well established fact that certain individual proteins from both animal and vegetable sources are capable of supplying everything necessary in the way of nitrogen containing complexes for prolonged growth, other proteins as gliadin of wheat, suffice for maintenance but not for growth, while still others as gelatin or zein can serve only in part to replace the nitrogen lost through endogenous metabolism and are incapable when fed singly of inducing

The second was discovered by McCollum,[64] who added both of these factors to his purified diet and found as a result of his study that a diet in order to be adequate must contain besides a sufficient amount of proteins, starches and sugars and fats, a protein of good quality, the two accessory substances mentioned above and a suitable amount of mineral matter. Anyone of these may be the limiting factor.

For example, McCollum[64] found that the wheat kernel has three things wrong with it, its inorganic content is unsatisfactory, it lacks one of the so-called vitamines and its protein is of poor quality. This is relatively true of all the seeds. It is not surprising then that most of the mixtures which have been prepared to take the place of milk for raising calves have proved so unsuccessful; when we consider how limited our knowledge has been of the requirements of a complete ration, and how difficult it is to satisfy all of the requirements as we know them with our present knowledge of nutrition.

For the purpose of discussion, the advancements made in nutrition may be taken up under three separate headings, namely, proteins, mineral matter, and vitamines.

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Willcock and Hopkins[67] had conducted experiments with similar food mixtures, composed of carefully purified food-stuffs in which all the constituents were known. When the protein of the diet consisted solely of zein, from maize, the mice lived but a few days. When the amino-acid tryptopban, which is not obtained on digestion of zein was added to the diet, the animals lived distinctly longer than without this addition. This was practically the first work done on the quality of proteins.

Since then many investigations have been made. Among those contributing to our knowledge of this subject are Osborn and Mendel, Steenbach, Hart, McCollum, Abderhalden and many others. They have shown that the animal requires certain amino-acids, a few of which have been determined, and that these amino-acids must be derived from the food as they cannot be synthesized by the animal body.

A careful comparison of the various proteins which may serve as food proteins and of which the biologic properties and chemical make-up are today known in some detail, at once excludes the probability of a direct relation between them and the body proteins[68] which they must be supposed to replace or augment.

It is plain that we must know what nutrient units of any nature are indispensible and further whether a complete lack or deficit of them in the intake can be made good by direct synthesis. Thus, it has been demonstrated that glycocoll can be manufactured in the body. Lack of it in the diet would therefore not necessarily cause any nutritive disturbances. The amino-acid tryptophan on the other hand apparently cannot be produced.(69)

Osborne and Mendel(70) write as follows: "The current view of the construction of new tissue involves the synthesis of new protein as an essential feature. Growth will be limited therefore, by any factor which prevents this synthesis. The lack of any component amino-acid which cannot be manufactured directly in suitable amounts in the body represents such a limiting factor." This explains why adequate growth has never been obtained with rations in which the nitrogenous components fail to furnish sufficient proportions of certain amino-acids, such as tryptophan, lysine, or cystine.

Experience has shown that a certain minimum amount of tryptophan is essential for maintenance without growth. That lysine is not needed to the same degree for maintenance is shown by an experiment carried on by Osborne and Mendel,(69-71) in which a rat was maintained at constant body weight for 182 days on a food containing zein as its sole protein with an addition of tryptophan. Although no lysine was available except that there was possibly a little in the protein-free milk, the animal remained vigorous and at once began to grow when lysine was added to the diet. It appears then that certain of the animo-acids are necessary for maintenance, while others are needed for growth.

Osborne and Mendel(69) state as follows in regards to lysine:

"It is clear that at least in so far as nutrition in growth is concerned the normal construction of new tissue is limited by the factor of the supply of lysine. No amount of energy or protein, however abundant, has induced growth in our animals in the absence of lysine. The animal organism apparently cannot synthesize lysine."

How widely proteins differ in their content of lysine is shown by the following data.(69)

	Per Cent		Per cent
Lactalbumin	8.10	Glutenin, wheat	1.92
Casein (cow's milk)	7.61	Gliadin, wheat	0.16
Legumin, pea	4.98	Hordeino, barley	0.00
Glutalin, maize	2.93	Zein, maize	0.00

It is interesting to note that those proteins like casein and lactalbumin, which are in nature concerned with the growth of animals all show a relatively high content of lysine.

Buchner, Nollaw and Kastle(69) attempted by the use of chickens to test the validity of the conclusions drawn by Osborne and Mendel as to the necessity of lysine in the diet. They used grain mixtures which they believed to exhibit a low and high lysine content respectively. The outcome was interesting in showing the unmistakable differences in the growth of the birds. The results of these investigators, while not absolutely correct, did collaborate the conclusions of Osborne and Mendel in that the differences in growth of the chicks was due in all probability to differences in the lysine content of the feeds used. Later Osborne and Mendel(72) carried on an experiment with chicks in which they confirmed the conclusion drawn by Buchner, Nollaw and Kastle. They state in regard to the work carried on by Buchner, Nollaw and Kastle that, "although their analysis cannot be depended upon to show with sufficient accuracy the content of lysine in their crude foods, it is probable, from what we know of the proteins in the seeds used by Buchner, Nollaw and Kastle, that the lysine content of the mixture which they fed differed to a very considerable degree. In the case of our corn, gluten food, we know that its yield of lysine is very small, while that of the corn gluten plus lactalbumin,and of corn gluten plus cottonseed flour is much greater. The assumption is therefore justified, that chickens as well as rats require a sufficient amount of lysine in order to make normal growth and that this will doubtless be found true of other species.

The importance of cystine as an ingredient of a complete diet has been shown by a number of investigators. Osborne and Mendel[73] have shown that when casein is supplemented with cystine, 9 per cent of the casein is as effective as 15 per cent of casein alone.

Abderhalden[74] conducted nutrition experiments with hydrolyzed proteins from which he had attempted to remove the cystine. He did not reach any definite conclusions, although he states that cystine is apparently necessary. Mitchell[75] and Geiling[76] also added cystine to the diets used in their experiment with white mice when feeding amino-acid mixtures.

Daniels and Rich[77] attempted to substitute inorganic sulphates for cystine but without success.

As has been stated before, some of the amino-acids usually found in proteins are not essential. Thus Ackroyd and Hopkins[78] have shown that arginine and histidine are to some extent inter-changeable. Totani[79] does not regard tyrosine as an essential amino-acid and suggests the possibility that phenylalanine may take its place in nutrition. Hopkins[80] has also shown that when both glutamic and aspartic acids were removed from the products of hydrolysis of a biologically complete protein, the resulting amino-acid residue was still adequate for normal growth.

While these studies relating to the values of isolated proteins are of fundamental importance in revealing the character of the chemical processes involved in nutrition, practical dietetics and animal production must always deal with certain groups of proteins as they are found in the naturally occurring foodstuffs.

Corn is the most abundant cereal grain inthe United States, and for this reason a number of investigators have made a study of the nutritive value of its proteins. Among those investigators are Osborne and Mendel, McCollum, Simmonds, and Pitz, Hart, Halpin and McCollum, Hogan and Johns, Finks and Paul.

Corn is known to contain several different proteins and the approximate distribution of these in the kernels of a sample of corn containing a relatively high percentage of proteins is shown in the following table which is taken from the publication by Osborne and Mendel[81]

	Per cent of protein
Gobulins - albumine "Proteoses"	21.9
Zein	41.4
Maize glutelin	30.8
Insoluble in alkali	5.9
	100.0

Zein which constitutes approximately from 41 to 52 per cent of the proteins in corn, lacks lysine and tryptophane, which are essential amino-acids for growth of animals. Willcock and Hopkins[67] have shown Zein to be insufficient for prolonged maintenance. McCollum[82] observed persistent negative nitrogen balances but pigs appeared to utilize as much as 80 per cent of the nitrogen of zein for maintenance but none for growth. Osborne and Mendel[73] have observed a steady decline in rats taking zein as the sole protein in the diet.

Corn glutelin, which is the next most abundant protein, contains all the essential amino-acids which zein lacks and promotes normal growth.[84] Osborne and Mendel[84] also state that considerable growth can be obtained from corn embryos as the sole source of protein, likewise with a mixture of corn gluten and corn embryo when a sufficient quantity of the latter is present.

Osborne and Mendel[84] write that they have never yet been able to feed a sufficient quantity of the proteins of the maize concentrate to effect normal growth in rats although there is evidence that all the essential amino-acids are present in some part of the seed. They also state "our experiments indicate that it ought to be possible to make an animal grow on a diet in which the maize kernel is the sole source of protein, provided a preparation of total proteins could be obtained, which would permit feeding them in sufficient quantity so that enough of those amino-acids which are present in certain of the proteins and not in others would be available to meet the minimum nutritive requirements of the organism". McCollum, Simmonds and Pitz(85) were also unsuccessful in an attempt to grow rats on a diet containing various mixtures of separate parts of the corn kernel.

Hogan(86) fed a mixture of corn and commercial gluten meal as the sole source of protein in the diet and obtained surprisingly good growth. He states that corn gluten seemed more efficient than either egg white or dried blood as a supplement to corn, but adds that it is possible that this result should be confirmed by a larger number of experiments. Johns, Finks and Paul(87) found that commercial corn gluten meal supplemented by dried brewer's yeast, whole, ground, yellow corn or cocoanut press-cake furnishes the necessary protein for normal growth.

Osborne and Mendel(88) in carrying on an experiment to determine the nutritive value of the proteins of the barley kernel, used the entire grain, including the husks, and added a proper salt mixture, butter-fat and starch, which are limiting factors in this cereal, making up rations of three different protein concentrations as 10, 8, and 5 per cent. They report that the results of their feeding experiments with this grain as exhibited in the gains of body weight of growing rats leaves no doubt of the adequacy of the barley proteins as a whole in the nutrition of growth.

Steenbach, Kent and Gross(89) concluded that the protein content of barley is insufficient for normal growth. They state that "the primary growth determinant in barley is inorganic salts, of secondary importance, but no less urgent are protein and fat soluble vitamins.

McCollum, Simmonds, and Parsons(90) also obtained unsatisfactory results in the use of barley for growth in rats.

It would seem that there is some question as to the nutritive value of the proteins of barley although the results obtained by Osborne and Mendel(88) would indicate that with sufficient concentration and by the incorporation in the ration of the proper mineral salts, and fat soluble vitamine, barley proteins may prove adequate for normal growth.

The confusion now existing in the literature of nutrition regarding the role of the oat protein (aside from any possible detrimental factor in the kernel as a whole) may be attributed to the conflicting statements published. Thus, McCollum, Simmonds and Pitz(91) state "The oat kernel seems to contain proteins of a poorer quality than either the maize or wheat kernel." In another publication they state that "The protein of the oat kernel has a slightly higher value for growth than has that of either wheat or corn, but the amount furnished by 90 per cent of rolled oats is below the optimum for the support of growth in a rapidly group species."(92)

In a recent report from the Wisconsin Experiment Station(93) it is stated that "In every case where the oat plant was fed, miserably poor offspring has resulted; for example with oatmeal and cutstraw and butterfat; oatmeal, casein butterfat and oatstraw." The authors conclude, however, that the trouble may be due to a deficiency of mineral matter rather than to poor proteins. McCollum and his associates(94) have recorded numerous observations upon the dietary value of the oat kernel. He states "We have not yet been able to supplement oats with purified food ingredients and attain optimum results when the oat kernel constituted from 70 to 80 percent of the food mixture. Gelatin combined with oat proteins forms a much better protein mixture than do casein and oat protein -- We have not yet determined the cause, but it is evident that a high intake of oats over a long period causes injury to the rat. This is true also for the cow, and I believe also for swine."

Osborne and Mendel(88) report as follows on an experiment which they carried on with the oat kernel. "The successful growth of several of the animals (rats) to large size must, we believe, be interpreted to indicate that the total protein of the oat kernel can furnish all the essential nitrogenous units if the intake of food and its concentration of protein are adequate." The concentration it would seem would be the limiting factor in a practical application of these experimental results.

In view of the results obtained by the above mentioned authors, it would be difficult to draw any definite conclusions as to the value of the proteins of the oat kernel, although it would appear that they are inferior to those of corn.

Information on the nutritive value of the proteins of rye are somewhat limited. McCollum, Simmonds and Parsons (90) make mention of rye while in the following statement "Such cereal grains as maize, rye and barley contain proteins of such value that when fed at 9 per cent of the food mixture, supplemented with respect to certain salts and fat soluble A, young rats are able to grow at approximately half the normal rate." In further experiments in which rye, to the extent of 50 per cent of the ration was supplemented by flaxseed, oil-meal or millet seed as a further source of protein, females grew fairly well and produced young. In another publication the same authors make the following statement. "It appears that rye and flaxseed proteins in this proportion (rye proteins 6 per cent, flaxseed proteins 3 per cent) are nearly, if not, quite equal in value for growth as the proteins of milk". Osborne and Mendel (88) found rye to give practically as satisfactory results as oats, wheat or barley. It would probably be well not to draw any conclusions as to the nutritive value of the rye proteins until further experimentation has been done.

Osborne and Mendel (97) state "that growth to large adult size can be completed at a normal rate on food containing 92 per cent of wheat. These same investigators state that they have raised a third generation of fertile rats on a diet in which the protein was derived solely from commercial wheat embryo (97). McCollum, Simmonds and Pitz (98) however, state that they have not been able to make up a ration containing wheat proteins only which was adequate for rearing of the young. They add "Over a wide range of protein content growth approximated the normal, but pronounced injurious effects of the ration were revealed in the reproduction records only." Osborne and Mendel[99] state that they have had a similar experience. They[97] found the crude protein of wheat bran to have a higher value for the growing animal than the embryo. They state "The 'crude protein' of bran appears to be quite as efficient as that of the combination of wheat flour with egg, milk or meat under the conditions of this experiment." They state that it must be remembered that their estimate of the value of the crude protein is based on a single experiment. With wheat flour Osborne and Mendel found that young rats made almost no growth.

While the exact facts in regard to the proteins from cereal grains are somewhat obscure, certain investigators have obtained fairly satisfactory results through the use of a single grain as the sole source of protein, but only in cases where a high state of concentration of that grain has been used, and only when this grain has been duely supplemented with a sufficient amount of mineral matter and the necessary vitamines.

We may sum up the matter of quality of proteins as follows:

There are certain amino-acids such as lysine, tryptophane, cystine, and probably tyrosine which are necessary for the proper growth of the animal and must be supplied in the food, as they cannot be synthesized in the animal body. Others such as glycocoll may be synthesized in the body, and lack of them in the ration will therefore not cause any nutritional disturbances. Certain of the amino-acids are interchangeable as for example arginine and histidine. While nearly all food proteins contain the necessary amino-acids, only a few contain them in nearly adequate qualities for normal growth; examples of these are lactalbumen, casein, legumin and glutalin. It has been shown that cereal grains contain these proteins only in very limited amounts and that in order to get good results they must be fed in a very concentrated form, in order that the animal may consume sufficient amounts of the necessary amino acids contained therein.

In a practical application of the results of experiments with the cereal grains, the degree of concentration would be one of the limiting factors, also the economy of such a practice would be very questionable in view of the fact that we may supplement the proteins of the cereal grains with other proteins of less expense to the feeder. To be on the safe side, the feeder should make use of a variety of feeds, in this way it is generally possible to supply the animal with the necessary amino-acids in sufficient quantity for normal growth.

Mineral Matter

The importance of the mineral elements in the nutrition of farm animals is just beginning to receive the attention which it deserves. It is conceded that the mineral elements such as calcium, magnesium, potassium, sodium, phosphorous, sulphur, iron and chlorine are required in varying proportions by all animals. Until recent years it has been assumed, however, that the mineral nutrients are contained in abundance in our feeding materials, and as a result little attentionwas given to the possibility of a deficiency.

With the development of large industries engaged in the preparation of human food materials, there has come an increased separation of the plant into its many parts. This results in a return to the farm of by-products, the mineral content of which may be much greater or much smaller than the whole product from which it was derived.[(100)] All this necessitates a more careful consideration of the problem of supplying a sufficient amount of mineral matter in the ration.

Of the mineral elements mentioned above, those in greatest demand during the life of the animal are calcium and phosphorus. This is because of their large use for skeleton building during the growing period of the animal. Their presence in liberal amounts in milk also imposes a special demand on the animal during lactation. The other mineral elements mentioned are always in demand, but it is believed that their supply is ample when good practical rations are fed. For this reason the greatest amount of investigational work in recent years has been done with calcium and phosphorus. These investigations have consisted for the most part of attempts to determine which feeds or combinations of feeds supply to the animal the greatest amount of either of these minerals and from which of these the greatest amount of the two minerals is retained by the animal, also whether it is possible to supply these minerals in the form of inorganic salts.

Hart[101] McCollum[102] and Osborne and Mendel[103] have shown that the synthetic powers of the animals are so prominent as to make the form of phosphorus necessary for a complete cycle of the animals life of less importance than was formerly believed and that inorganic phosphates, such as calcium phosphate, can serve as a complete source of phosphorus for this cycle. It has also been shown by Hart, Steenbach, and Fuller[100] that grains in general are rich in phosphorus. It appears then that the matter of the supplying an adequate amount of this mineral need not involve much difficulty in the case of the growing animal. This leaves calcium as the mineral deserving the most consideration as it has been shown that grains are decidedly deficient in calcium and that roughages vary widely in their content of this mineral.[100]

That legume hays are rich in calcium has been shown by Burnett[104] who tested the strength of the bones of hogs fed on various rations and found that the addition of alfalfa meal increased the strength of the bone. Hart, Steenbach, and Fuller[100] also conclude that "legume hays are very rich in calcium."

Forbes and Beigle[105] have demonstrated that as sources of calcium for growing swine, corn, wheat middlings, linseed oilmeal, soy beans, wheat bran and rice polish are unsatisfactory and will not maintain normal growth of bone. The authors state that the results emphasize the need of supplying those feeds rich in calcium such as pasture and forage crops, especially leguminous plants. It is very probable that these results can be applied to calves as well as swine. Hart, Steenbach, and Fuller[100] state that "ruminants consuming the usual roughage will ordinarily receive calcium enough for growth; this is especially true when the roughage has been grown on a calcium rich soil.

It is generally conceeded that a deficiency of calcium does not inhibit the actual growth of the animal. Eckles(106) fed two Jersey heifers, one on a ration high in calcium and one on a ration low in calcium. They were placed on experiment when approximately six months old and up to this time had received the usual skimmilk ration. The author states that the animal on the low mineral ration as far as could be determined by appearances thrived and apparently was in a normal condition until she was nearly eighteen months old. She then began to show symptoms of an abnormal condition. The first indication was a stiffness in the joints and an abnormal gait in walking which gradually became worse until the animal walked with the knees partially bent, and she could not get up from a lying position except with great difficulty. By making a decided change in ration and by giving bonemeal liberally, the author states that it was possible to restore the condition of this heifer to nearly normal within a month. Up to the time at which the breakdown occurred "this animal made a perfectly normal growth both in height and weight, and made a growth equal to the animal receiving the high mineral ration."

Voit(107) concluded from his experiments that animals which received rations low in mineral matter, but otherwise normal and abundant increased normally in weight. Aron and Sebauer(108) compared the rate of gains made by dogs fed on a ration high in calcium with gains made by similar animals on a ration deficient in this mineral. The rate of gains was practically the same for both rations although the deficiency was so great in the one that the bones of the animal which received it were badly affected.

While our information on this subject is quite limited, it would appear from the results obtained by the above mentioned investigators that the calcium supply will neither accelerate or inhibit the rate of growth of the animal or determine its size when mature though an inadequate supply will bring on abnormal conditions.

Under general form conditions where the animals are fed according to the feeding standard, the abundant use of concentrates is liable to decrease the calcium supply to within the danger limite, even with materials grown on a soil of normal calcium content. The use of alfalfa in the ration will do much to make up this deficiency or, if alfalfa is not available, calcium carbonate, calcium phosphate,(100) or bone meal(106) may be used to good advantage.

Had this been a study of the dairy cow the matter of supplying sufficient mineral matter in the ration would have involved a much more thorough study of the situation, as the production of milk is a heavy drain on the animal, especially in the case of high producing cows.(109)

Newer Dietary Accessory Substances.

Recent investigators have shown that food furnishing sufficient amounts of proteins, fats, carbohydrates and inorganic foodstuffs may not always prove permanently adequate. Hopkins, McCollum and Davis, Hopkins and Nevill, and Osborne and Mendel(109) found in testing the efficiency of various pure proteins and inorganic salts in promoting the growth of young white rats, that artificial diets containing some protein, such as edestin, albumin or casein (which we now know to be proteins of good quality) some inorganic salts like of those of milk, some starch, and lard nourished the animals for a time, but that sooner or later they ceased to grow, so that they seldom attained more than two-thirds of the weight normal for rats of their age. Some at least then of the food materials which go to make up a completely adequate ration must have properties beyound those which had up to that time been considered.

For centuries it has been recognized that restricted diets of monotonous character may produce diseases in man such as scurvy, beri-beri, and possibly pellagra. These were generally attributed to faulty diet, though no attempt was made to study this problem systematically until after 1900.

The origin of the "vitamine" hypothesis began with Funk(110) who in 1911 obtained a crystalline substance from the rice husk in which was carbon, hydrogen and nitrogen and was basic. This substance had a curative effect when injected into beri-beri pigeons, and because it was apparently necessary for life Funk gave to it the name of vitamine. This term has been critized by many investigators and for this reason various terms such as "growth accessories," "Accessory food factors," "dietary essentials" and "food hormones" has been suggested by various writers.

It has been shown that there are three of these accessory factors, two of which are absolutely essential for growth. Some doubt is expressed as to the relation of the third to growth, but the necessity of its presence in the ration for the prevention of scurvy is accepted by most authorities.(111)

McCollum and Kennedy(112) have named the first two factors "fat-soluble A" and"water soluble B". Their termonology has been widely adopted as being both convenient and non-committal. The third factor is usually referred to as the antiscorbutic factor, although it is sometimes given the name "water-soluble C".

Their distribution covers most all of the foods used by man and animals, at least all of the natural foods. While most foods contain but one of these factors in any appreciable amount, some foods such as milk contain all three others apparently are entirely void of any.

Following is a list of articles in which they are found. List compiled by Osborne and Mendel(113)

Fat-soluble A

Butter fat
Egg yolk fat
Cod-liver oil
Beef fat
"Oleo-oil" margarines
Pig kidney fat
Maize kernel
Rye
Wheat embryo
Wheat kernel
Cotton seed
Cabbage leaves
Clover leaves
Oat kernel
Soybeans
Sunflower seed
Alfalfa leaves
Flaxseeds
Hempseed
Millet seed

Water-soluble B

Milk
Rice
Wheat embryo
Cotton seed
Pancreas
Maize kernel
Wheat kernel
Oat kernel
Kidney bean
Yeast
Soybeans
Maize embryo
Peanut meal.

Antiscorbutic factor (114)

Foods relatively rich in this factor

Fresh vegetables
Fresh fruits
Raw milk (?)
Raw meat
Cereals sprouting

Foods relatively poor in this factor

Dried vegetables
Dried fruits
Sterilized milk
Canned meat
Dried cereals
Pork fat
Starch
Molasses
Corn syrup.

It is only natural to assume that milk should contain all of the accessory factors, as it is the food prepared by nature for the nourishment of the growing animal, and it has been found that butter-fat is practically the richest source of fat-soluble A, and that other constituents of milk are rich in water-soluble B. The third factor however, has been found to be present only in relatively small quantities.(115-116) However, it is not known definitely whether all species are equally as susceptible to scurvy.(117) Practically all the researches which have led up to the discovery of fat-soluble A, and water-soluble B have been carried out on young mice and rats. Neither of these animals appear to show any susceptibility to scurvy if we may judge from the fact that they have been nourished with apparent success over long periods upon diets which can have contained but the merest traces, if any, of the antiscorbutic substance. It is, however, quite conceivable that these two species represent types whose low susceptibility to the disease calls for a very small requirement of the preventive substance. Failure to supply an adequate amount of the factor in such cases might only bring about a comparatively slight lowering of the nutritive standard of the animal, and experimental evidence is accumulating that this is actually what occurs in the case of the rat.[118-119] In our study of calf raising, it is only natural to assume that the calf is either in the same class, in regard to its requirement of the antiscorbutic vitamine, with the two species mentioned above or that it consumed under natural conditions sufficient amounts of milk to satisfy all requirements of this third factor.

No doubt is expressed by any of our most reliable authorities as to the necessity of the fat-soluble A, and water-soluble B, for the promotion of growth in any animal.

With reference to the minimum requirements of these substances for maintenance and growth, McCollum and Simmonds[120] write as follows:

"Our results indicate that there is no low plane of intake of either of these substances which can be said to maintain an animal without loss of vitality. When the minimal amount necessary for the prevention of loss of weight is approached the life of the animal is jeopardized if the diet is persisted in.

Within certain limits growth is proportional to the supply of the fat-soluble A, and water-soluble B in the diet, all other factors being properly adjusted.

The animal can tolerate being limited to a very low intake of either the dietary A or B much better with an otherwise excellent diet than when it is less well constituted.

Without exception the records indicate that it is a dangerous procedure to attempt to fast an individual selectively for one or both of these dietary essentials."

In view of the fact that none of these factors have been isolated and identified, it is only natural that there should be much speculation as to their chemical composition, and until these factors have been either isolated or investigators have agreed upon their possible chemical make-up, it is not of interest to those of us engaged in the practical phases of nutrition to discuss the many and varied theories which have been advanced as to the chemical composition of these dietary essentials. It is much more essential that we be acquainted with their presence in the various food-stuffs, and the properties of each in order that we may know their limitations and practical application.

The presence of the fat-soluble A factor was first detected in butter and egg-yolk fat, and it is probable that these food-stuffs represent the richest sources of that substance. It has also been found present in many oils and fats derived from the animal kingdom as for example, cod-liver oil, shark liver oil, beef fat, and the fats of kidneys, beast muscle, and liver tissues, herring oil, cod oil, salmon oil, and whale oil.[117]

On the other hand, the following oils and fats, all with one exception are derived from plant sources, contain only small amounts or are deficient in the accessory factor; sunflower-seed oil, peanut oil, coco-nut oil and lard.[117] Since there is good reason to believe that the animal organism does not possess the power to synthesize either of the factors A or B, it must derive its supplies of these substances from outside sources. The primary sources of fat-soluble A are found in green leaves of plants and embryos of certain seeds.[117] The former appear to be the richer source, but the quantitative data upon the distribution of the substance is quite limited. It is, therefore, difficult to attach addefinite value to any individual food-stuff as a source of fat-soluble A.

The plant kingdom also provides the primary source of the water-soluble substance. The power to synthesize this substance is possessed generally by plants even by some which appear low down in the natural classification. Thus for example, yeast constitutes one of the richest known sources of the substance.[117] it has been shown to be present in abundance in wheat,[121] wheat germ[122] maize[123] Alfalfa leaves[124] and cabbage as well as in several foods of animal origin.

The antiscorbutic factor is found in greatest quantity in the juices of fresh fruits and vegetables. Sprouting cereals are also considered relatively rich in this factor.[114]

The properties of these accessory factors are not very clearly defined. The results obtained by numerous investigators have been somewhat contradictory. Thus Osborne and Mendel[125] recorded that butter-fat treated with steam for two and one-half hours did not appear to have lost its value as a source of the fat-soluble A. Evidence which supported that theory was given by Drummond.[126] More recent work has however cast some doubt on the stability of this accessory toward heat.[127] Experiments by Steenbach, Boutwell and Kent, indicate that the fat-soluble factor is gradually destroyed at 100°C and that four hours exposure to that temperature is sufficient to render butter-fat of little greater nutritive value from the stand-point of vitamine supply than an equivalent quantity of lard. This result has been confirmed by experiments carried on in England.[128] These same experiments show that it is completely destroyed during the "hardening" of oil by the action of hydrogen, a process now widely employed for the preparation of edible fats.[117] It has been stated to be stable to alkali under the conditions employed for hydrolysis of fats at room temperature in a non-aqueous solution.[129]

The water-soluble B factor withstands dessication for long periods of time, as may be appreciated from the fact that its principal sources are found in dry food-stuffs.[117] Its resistance to heat is also considerable. The results obtained by the various investigators[117-130-131] would indicate that destruction of this factor takes place very slowly at 100°C, but is much more rapid in the neighborhood of 120°C.

The antiscorbutic factor is much more sensitive to drying or exposure to high temperatures than either the fat-soluble A or water-soluble B.[132-33-34-35-36-37-38] Where this factor is very sensitive to temperatures of 100°C or below, the water-soluble B factor showed little destruction on exposure to 100°C for one hour or over. This greater instability of the antiscorbutic factor is a matter of greatest importance in estimating the antiscorbutic value of cooked and dried foods.

From this discussion we find that in order for an animal to grow there must be present in its ration besides a sufficient amount of proteins of good quality, carbohydrates and mineral matter, two other factors the fat-soluble A, and water-soluble B, and possibly a third or the antiscorbutic substance. What these three accessory factors are we cannot at present say, but the necessity of their presence in the adequate ration is now undisputed, and for this reason we must consider them in formulating any ration particularly for the growing animal. We now have at our disposal quite a complete list of those feeds which contain one or more of these factors, and while it is not at present possible to state their presence quantitatively, it is possible for us to supply those feeds in proper amounts, for all practical purposes, so as to satisfy the animals requirements for these all essential accessory factors.

The necessity for variety in the ration has been advocated by many writers on nutrition. It has been thought that many failures in attempts to grow farm animals were due to the fact that these animals had received too monotonous a ration. By varying the feeds used from time to time or by supplying a large number of different feeds in the ration, it was thought that the animals would make much larger gains. With our present knowledge of proteins and vitamines, it seems only natural to assume that the better results obtained from a varied ration were in all probability due to the fact that through this variety the animals were often supplied with proteins of good quality and the required accessory food factors, which they would not have been able to obtain from a smaller number of feeds, and not merely because the animals received a variety of feeds. However with our present knowledge of nutrition, it may be possible to make a more intelligent selection of feeds than formerly with a view of supplying those known to possess the desired properties and in this way feed the animal more economically. This would seem more practical than the hit or miss method generally used.

APPLICATION OF PRESENT KNOWLEDGE OF NUTRITION TO MILK SUBSTITUTES.

The many and important discoveries which have been made in the field of nutrition in recent years furnish an explanation as to why so many attempts to formulate a substitute for milk have proven unsuccessful. Previous to these recent advances in the knowledge of nutrition it was assumed to be sufficient to supply a certain amount of digestible protein, carbohydrates, and fat, these in a palatable form and with as small an amount of crude fiber as possible. Now it is well known that not only must a sufficient amount of digestible protein be supplied as well as of the other nutrients but that this protein must also be of good quality and that the ration must contain a sufficient amount of the accessory food factors. These facts furnish a basis from which it is possible to explain why some milk substitutes have given fairly good results while others have failed completely.

A study of the experiments on calf feeding, reviewed at an earlier point in this thesis, in an effort to determine why certain of them have proven more successful than others, will reveal that in many of the cases where fair success was reported some milk was used either as a powder mixed with the calf meal or fed in the ordinary fluid form. In some cases alfalfa hay was fed, in some experiments supplying almost one-half the nourishment. It is well known now that milk supplies proteins of good quality and the necessary vitamines. The proteins of alfalfa are also good and hay from this plant is rich in vitamines. The unsatisfactory results obtained with other calf meals are probably due to a lack of suitable proteins or of vitamines or possibly of both.

However, another factor may be involved. The stomach of the young animal is extremely tender and sensitive to changes in diet. Milk is an easily digested food and the stomach of the young animalsis suited for such food. It is entirely possible that a calf meal might satisfy the requirements so far as complete proteins and vitamines are concerned and at the same time not be adopted to the digestive system of the calf. This is the possible explanation of some failures in attempts by the practical feeder to use calf meals which have given fairly good results under experimental conditions. Under experimental conditions the calves are usually handled with more care and are given more attention than calves receive when raised under ordinary conditions. If the calf meals in question are lacking in quality of the proteins or in vitamines, even fair results cannot be expected under any conditions. The fact that some have proven successful under the best conditions and unsuccessful under less carefully controlled conditions indicates that some other factor is involved, possibly injury to the digestive system of the animal has resulted which was avoided in the successful trials by more careful attention.

There are then two, possibly three, reasons why certain milk substitutes have failed. First, lack of suitable proteins, second, lack of vitamines and third, a physical structure which injures the digestive system of the young animal.

As a result of the many discoveries which have been made in recent years, in the field of nutrition, we are in a position to explain some of the many difficulties involved in formulating a substitute for milk, of such a nature that it may be utilized by the very young animal handled under ordinary farm conditions. In view of these facts it would appear wise to admit that there is no substitute for milk and in place of looking for a substitute, give attention to formulating a grain mixture, not to be used as a complete milk substitute, but rather one to be fed in a dry form after the calf has reached an age when it is capable of handling such a food. The earliest age at which such a ration may be used and the feeding of milk eliminated must be determined by trials.

By such a system it should be a relatively simple matter to formulate a grain mixture which will satisfy the requirements for complete proteins and vitamines, since the calf's stomach at the time such a grain mixture could be used, as determined by trials, will be capable of handling a coarser feed.

EXPERIMENTAL WORK

Object of Experiment

A review of the literature on calf feeding reveals but two experiments conducted for the purpose of determining the earliest age at which a calf may be weaned and placed on a dry grain and hay ration. The results obtained were satisfactory but the data are too scant to justify definite conclusions. The object of the present experiment was to gather more data on the subject and under conditions somewhat comparable but not exactly the same.

General Outline

Animals used.

The animals used in the experiment, the data from which are presented in this thesis, were eleven, grade Holsteins. Four were obtained from the local stock yards and the others from a dealer in Wisconsin. The first group consisted of three heifers and one bull. All of the remaining animals were heifers. The calves were estimated to be two weeks of age when received. None of the animals were especially selected but were in a good healthy condition at the time the experiment began.

Rations used.

During the preliminary feeding the calves were given the usual amount of whole milk, except the calves in the third group which received a small amount of a low grade malted milk, known as "sweepings", after the first month of milk feeding. All of the calves were allowed grain and hay ad-libitum until they were weaned, at which time a limit of five pounds was placed on the grain but none on the hay.

The grain mixture was the same as that used by Forham(33) and consisted of 4 parts of ground corn, 1 part new process linseed meal and 1 part wheat bran. It was made up with the view of supplying in conjunction with the alfalfa hay, not only suitable protein, net energy, sufficient and suitable matter, but also the dietary accessory factors Fat Soluble A and Water Soluble B and C. The first of these factors would be supplied to some extent by the corn, since recent investigations have shown that yellow corn contains a small amount of this factor. Water Soluble B is supplied by the bran, while alfalfa hay supplies not only both of these factors but also the Water Soluble C, and a liberal quantity of mineral matter.

The alfalfa used in these feeding trials was of rather inferior quality and as a result the calves did not consume as large amounts as they would had the quality been better.

In studying the previous investigations on calf feeding, it was noticed that where the best results were obtained alfalfa hay held a prominent place in the ration and it seems probable that the good results obtained in these cases were to be attributed to a large extent, to the alfalfa hay.

Method of Feeding.

The calves were fed twice daily; all feed being carefully weighed for each individual and any grain or hay left in the boxes, was weighed back every two or three days. In this way it was possible to keep an accurate account of the amount of feed consumed by each calf.

At the time of weaning, the milk fed was gradually reduced. The entire change from milk to grain and hay as the sole source of nourishment included a period of from ten to twenty days. As a result of this gradual change the calves became accustomed to the ration of grain and hay and did not suffer any ill effects.

The calves were given all the hay they would eat, and grain up to five pounds per day. The amount eaten varied each day and increased rapidly after discontinuing the milk. After becomming accustomed to it, the man in charge of the feeding, was able to estimate closely, the amount of grain and hay which each calf would eat at a meal, so that it was possible to weigh into their feed boxes an amount such as they could clean up nicely.

Housing.

The experimental barn in which the calves were housed is of concrete and wood and has provision for confining each animal in an individual stall. It was thus possible to keep an accurate individual feed record. During fair weather the animals were turned loose during the day in a lot where they had access to water.

Weighing and Measuring.

It has been found impossible to measure properly the growth of animals either by weights, or by measurements of skeletal growth alone. Eckles has shown that, "under liberal conditions of feeding, the rate of growth as represented by weight is different from the rate as measured by skeletal growth. When the ration is somewhat limited the reverse is true and the skeletal growth is retarded much less than the gain in weight. While the rate of skeletal growth can be influenced by the character of the ration, the tendency is strong for it to continue at or near the normal rate; and only a rather wide variation in the ration exerts any marked effect. The gain in weight is much more under the control of the ration." For this reason the only satisfactory method so far determined for measuring growth is to include both weight and some measurement to represent the increase of skeleton. In this experiment the height at withers was used as a measure of the growth of the skeleton.

The calves were weighed every ten days throughout the experiment. Weights were taken on the ninth, tenth and eleventh days of each period and the average of these days was used as the weight for the tenth day.

The height measurements were taken with a measuring standard at the beginning of the experiment and at the end of each thirty days. When the height measurements were taken the animal was placed on a flat, smooth floor and measured three times. The animal was moved about between measurements. This was to avoid error in measurement due to the relaxing of the muscles, a precaution necessary to obtain accuracy as has been shown by Eckles and Swett.

A Normal growth figure for weight, and height at withers formulated by Dr. C. H. Eckles was used as a basis of comparison of the growth of the animals, which makes unnecessary the use of check animals.

DISCUSSION OF DATA

In the discussion of data the animals are divided into groups according to the age of weaning. The data taken on these animals are given in tables 1-33.

Growth and Feed Consumed.

Group 1. The calves in this group were weaned at between 60-and 70 days of age, at which time they averaged 164.9 pounds in weight and 84.1 centimeters in height as compared with the normal of 164.1 pounds in weight and 82 centimeters in height for animals of their age and breed. The average normal gain in weight which animals should make between the ages of 60 and 180 days, is 1.6 pounds daily and a total of 18.9 centimeters in height for the 120 days. The four calves in this group made an average daily gain of 1.46 pounds with a total gain in height of 14.8 centimeters for the 120 days. The average daily gain made by each calf is given in the following table.

Table 34

Average daily gains and final weights and heights of calves No's 2, 3, 4, and 5.

No. of calf	Actual gain	Normal gain	Weight at end of 180 d's compared to normal	Height at end of 180 d's compared to normal
	pounds	pounds	per cent	per cent
2	1.54	1.60	99.2	101.1
3	1.34	1.60	88.2	94.9
4	1.74	1.60	104.1	100.0
5	1.21	1.60	86.7	95.7

The data presented in Tables 12, 13, 14 and 15 show that while the animals went slightly below normal shortly after being weaned, the tendency was to approach normal after the 120th day of age and at the close of the experiment one calf was four per cent above normal in weight, one was normal and the other two were steadily approaching normal. All were practically normal in height. Graph No. 1 shows this much more clearly than the tables.

The calves consumed on the average, a total of 504.2 pounds of grain and 243.1 pounds of hay. Their average daily consumption from the time of weaning to 180 days of age was 4.2 pounds of grain and 2.03 pounds of hay. The feed consumed by the individual calves each month is given in Tables 1 to 4 inclusive and a summary of these figures is given in Table 37.

There was no great difference in the amounts of feed consumed by these calves, except in the case of No. 4 which consumed 45 pounds more grain and 89 pounds more hay than was consumed on the average by the other three animals.

The animals all appeared to be in a thrifty condition but did not carry much surplus flesh. Typical animals of this group are shown in Figure 1.

Group 2. The process of weaning the calves in this group took place over a period of twenty days. It was thought that by extending the weaning period, the more gradual change would enable the calves to accustom themselves more satisfactorily to the coarser food. The process of weaning began when the calves were thirty days old and by the fiftieth day they were entirely weaned. At which time they averaged 143.5 pounds in weight and 82.7 centimeters in height compared with the normal of 145 pounds in weight and 80.3 centimeters in height for their age and breed. The average normal gain in weight which animals should make between the ages of 50 and 130 days is 1.52 pounds daily and a total of 13.24 centimeters in height for the 80 days. The four animals in this group made an average daily gain of 1.11 pounds and a total of 15.66 centimeters in height. The average figure for gain in weight was lowered quite appreciably by the poor gains made by Calf 21 which became very unthrifty during the latter part of the experiment.

Following is a table summarizing the average daily gains made by each of the calves between the ages of 18 and 130 days, and their final weights and heights compared to normal.

Table 35

Average daily gains
and
final weights and heights of calves No's 21, 23, 25 and 531.

No. of Calf	Actual gain	Normal gain	Weight at end of 180 d's compared to normal.	Height at end of 180 d's compared to normal.
	pounds	pounds	per cent	per cent
21	.77	1.42	76.7	96.0
23	.89	1.42	82.6	99.0
25	1.32	1.42	101.9	102.3
531	1.33	1.38	96.4	100.0

Calf 531 was only 120 days old at end of trial.

Tables 27, 28, 29, and 30 give the gains made by these calves by ten day periods throughout the experiment.

The growth curves for these calves (see Graph No. 2) show a gradual decline after the weaning period began. It will be noted, however, that the calves in this group were only 130 days old at the close of the experiment and since the calves in the first group did not begin to show much improvement until they were between 120 and 130 days old, it is assumed that had the calves in the second group been carried along for another month or two, their growth curves would have shown a decided improvement. The fact that their daily gains became more normal towards the close of the experiment justifies such an assumption.

The amount of grain and hay consumed by these animals varied considerably. The amount consumed being in direct proportion to the rate of growth with the exception of Calf 21. (see Table 38). Calf 25 consumed 357.2 pounds of grain and 114.1 pounds of hay and made an average daily gain of 1.32 pounds while calf 23 consumed 293 pounds of grain and 38 pounds of hay and gained on the average only .87 pounds per day. The average for the group was 310 pounds of grain and

74.9 pounds of hay. The average daily consumption between the ages of 60 and 120 days was 3.9 pounds of grain and .85 pounds of hay. The average daily consumption of feed by the calves in the first group between the ages of 60 and 120 days was 3.41 pounds of grain and .89 pounds of hay. It was necessary for comparison to use the ages between 60 and 120 days since the calves in the first group were 60 days old when the experiment was started and some of the calves in the later groups were only 120 days old at the close of the experiment.

These animals all appeared to be in a thrifty condition, with the exception of No. 21, but did not carry any surplus flesh. Typical animals of this group are shown in Figure 2.

Group 3. These calves were weaned in the same manner as the calves in group 2. They averaged at fifty days of age 134.7 pounds in weight and 79.43 centimeters in height as compared with the normal of 145 pounds in weight and 80.26 centimeters in height for their age and breed. The normal gain which animals should make between 50 and 120 days of age is 1.48 pounds in weight and a total of 11.74 centimeters in height for the 70 days. But these animals made an average daily gain of 1.39 pounds and a total of 9.41 centimeters in height. Tables 31, 32 and 33 give the gains made by the calves by ten day periods between the age of 16 and 120 days.

The curves in Graph 3 clearly show a tendency to approach normal after the sixtieth day. Table 36 is a summary of the average daily gain made by these calves between 16 and 120 days of age and the final weights and heights compared to normal.

Table 36

Average daily gains
and
final weights and heights of calves No's 532, 533 and 534.

No. of Calf	Actual gain	Normal gain	Weight at end of 180 d's compared to normal.	Height at end of 180 d's compared to normal.
	pounds	pounds	per cent	per cent
532	1.27	1.38	100.1	99.1
533	.99	1.38	83.9	94.2
534	.95	1.38	90.1	96.3

Prior to weaning, the calves in this group were given malted milk sweepings in place of raw milk, after they were one month old. Very lettle can be said in regard to the value of this feed since only three calves were used in this group. However, no digestive disturbances were noted and the gains made by these calves were practically the same as were made by the calves in the second group.

The amount of grain and hay consumed by these calves between 60 and 120 days of age was slightly in excess of that consumed on the average by the animals in either of the first two groups. They consumed on the average 4.04 pounds of grain and .94 pounds of hay per day.

In Table 37 is given a summary of the average daily feed consumed by each group and the average daily gains and increase in height made during the time each group was on experiment. Table 38 is also a summary of the daily feed consumed and average daily gains and increase in height but computed between the ages of 60 and 120 days. This table furnishes a means of comparing the animals in the three groups.

Table 37

Summary of feed consumed, average daily gains and increase in height.

Group No.	Grain consumed daily	Hay consumed daily	Average gain in weight	Average increase in height
	pounds	pounds	pounds	centimeters
1	4.2	2.0	1.46	14.75
2	2.8	.9	1.07	15.66
3	2.8	.6	1.07	12.90

Table 38

Summary of feed consumed, average daily gains and increase in height.

computed between the ages of 60 and 120 days.

Group No.	Grain	Hay	Average gain in weight	Average increase in height
	pounds	pounds	pounds	centimeters
1	3.4	.9	1.15	7.95
2	3.9	.9	1.22	13.44
3	4.0	.9	1.42	10.40

Summary

The data presented include those taken on eleven grade Holstein calves. Four of which were weaned at between 60 and 70 days of age and seven at an average of 40 days. Data were taken on the first group between the ages of 60 and 180 days, on the second group between 18 and 130 and on the third group between 16 and 120 days of age.

The results are measured by daily gains in live weight and by increase in height at withers. The basis of comparison is the normal increase in weight and height measurements at withers, as determined from data taken by Eckles.

A comparison of the gains in live weight made by the calves in all three groups between the ages of 60 and 120 days show a remarkable uniformity. There was considerable variation in the increase in height which may be explained by the fact that certain of the calves were above normal while others were below normal in height at withers when placed on experiment.

The calves in the first group consumed an average of 3.4 pounds of grain and .9 pounds of hay per day between 60 and 120 days of age. Those in the second and third groups consumed an average of 4.0 pounds of grain and .9 pounds of hay per day.

C O N C L U S I O N S

As a result of these tests the following conclusions seem justified.

1. Dairy calves can be weaned between fifty and sixty days of age and, if fed on a good grain mixture and alfalfa hay, may be expected to develop into normal, healthy animals; although growth may be somewhat checked for a time.

2. Calves which are to be weaned at this early age must be normal and thrifty at the time the milk is taken from the ration.

3. A grain mixture of corn meal, wheat bran and linseed meal, of the proportions as used in this experiment and fed in conjunction with alfalfa hay apparently supplies all requirements for the normal development of calves from the age of sixty days to six months of age.

The following tables give in detail the data taken on the animals used in the experiment.

Table 1

Feed Record of Calf 2
by Ten Day Periods

and

Comparison of Nutrients Consumed with Armsby's Standard.

				Digestible Crude Protein		Net Energy	
Age*	Milk	Grain	Hay	Con-sumed	Armsby's Standard	Con-sumed	Armsby's Standard
days	pounds	pounds	pounds	pounds	pounds	therms	therms
70	112.0	6.5	8.0	.533	.555	4.047	3.618
80	6.0	25.0	5.0	.376	.576	2.361	3.686
90		30.0	12.02	.491	.594	2.831	3.745
100		38.0	6.0	.528	.606	3.270	3.786
110		48.0	7.0	.655	.615	4.111	3.818
120		50.0	9.5	.706	.632	4.358	3.872
130		50.0	18.5	.802	.653	4.666	3.945
140		50.0	24.85	.869	.682	4.883	4.040
150		50.0	30.0	.924	.709	5.059	4.158
160		50.0	30.0	.924	.726	5.059	4.260
170		50.0	32.5	.950	.744	5.145	4.368
180		50.0	42.5	1.056	.759	5.487	4.535
Total and	118.0	497.5	225.87	88.14	78.51	512.77	478.31
Averages		4.14	1.88	.734	.654	4.273	3.985

* Age at end of ten day period.

Table 2

Feed Record of Calf 3
by Ten Day Periods

and

Comparison of Nutrients Consumed with Armsby's Standard

				Digestible Crude Protein		Net Energy	
Age*	Milk	Grain	Hay	Consumed	Armsby's Standard	Consumed	Armsby's Standard
days	pounds	pounds	pounds	pounds	pounds	therms	therms
70	112.0	7.0	12.5	.587	.543	4.242	3.586
80	6.0	18.75	10.26	.356	.565	2.037	3.650
90		30.0	15.5	.528	.577	2.950	3.691
100		38.0	3.0	.492	.585	3.167	3.718
110		48.0	4.5	.629	.594	4.025	3.745
120		47.5	7.0	.649	.613	4.070	3.809
130		50.0	14.0	.754	.636	4.512	3.886
140		50.0	22.15	.840	.656	4.791	3.954
150		50.0	27.4	.896	.676	4.970	4.022
160		50.0	27.0	.892	.696	4.957	4.086
170		50.0	32.5	.950	.713	5.145	4.182
180		50.0	41.5	1.045	.727	5.453	4.266
Total	118.0	489.25	217.31	86.18	75.81	503.19 579.00	465.95
and Averages		4.08	1.81	.718	.631	4.193 4.825	3.882

* Age at end of ten day period.

Table 3

Feed Record of Calf 4
by Ten Day Periods

and

Comparison of Nutrients Consumed with Armsby's Standard

Age*	Milk	Grain	Hay	Digestible Crude Protein Consumed	Digestible Crude Protein Armsby's Standard	Net Energy Consumed	Net Energy Armsby's Standard
days	pounds	pounds	pounds	pounds	pounds	therms	therms
70	62.0	22.0	6.5	.540	.547	3.795	3.593
80		30.0	22.1	.598	.570	3.176	3.668
90		38.0	7.0	.534	.585	3.304	3.718
100		48.0	12.0	.708	.604	4.282	3.782
110		50.0	10.5	.717	.628	4.392	3.859
120		50.0	18.5	.802	.651	4.666	3.936
130		50.0	25.3	.874	.674	4.899	4.131
140		50.0	30.0	.924	.700	5.059	4.100
150		50.0	35.5	.982	.718	5.248	4.212
160		50.0	34.6	.972	.735	5.217	4.314
170		50.0	47.5	1.109	.753	5.658	4.451
180		50.0	60.5	1.247	.767	6.103	4.647
Total and	62.0	538.0	310.0	100.07	79.32	557.99	484.11
Average		4.48	2.58	.833	.661	4.649	4.034

Table 4

Feed Record of Calf 5
by Ten Day Periods

and

Comparison of Nutrients Consumed with Armsby's Standard

				Digestible Crude Protein		Net Energy	
Age	Milk	Grain	Hay	Con-sumed	Armsby's Standard	Con-sumed	Armsby's Standard
days	pounds	pounds	pounds	pounds	pounds	therms	therms
70	113.0	6.5	9.50	.552	.537	4.128	3.574
80	6.0	25.0	4.25	.368	.555	2.336	3.618
90		30.0	18.40	.558	.568	3.049	3.659
100		38.0	3.00	.492	.577	3.167	3.691
110		45.5	2.50	.578	.584	3.755	3.714
120		47.5	5.00	.628	.595	4.002	3.750
130		50.0	10.50	.717	.615	4.392	3.818
140		50.0	24.70	.867	.642	4.878	3.909
150		50.0	30.00	.924	.670	5.059	4.000
160		50.0	32.5	.950	.689	5.145	4.063
170		50.0	34.0	.966	.705	5.196	4.134
180		50.0	45.0	1.083	.720	5.573	4.224
Totals and	119.0	492.5	219.35	86.830	74.57	506.80	461.54
Averages		4.1	1.82	.723	.621	4.221	3.846

Table 5

Feed Record of Calf 21
by Ten Day Periods

and

Comparison of Nutrients Consumed with Armsby's Standard

---Age	Milk	Grain	Hay	Digestible Crude Protein		Net Energy	
				Con-sumed	Armsby's Standard	Con-sumed	Armsby's Standard
days	pounds	pounds	pounds	pounds	pounds	therms	therms
28	120	0	0	.396	.428	3.481	3.271
38	120	1.7	1.0	.427	.441	3.653	3.349
48	84	2.2	1.3	.318	.460	2.659	3.420
58	8.0	18.5	8.03	.356	.477	1.999	3.453
68		28.5	3.50	.382	.487	2.418	3.473
78		30.0	7.50	.443	.513	2.676	3.527
88		36.5	5.30	.498	.551	3.125	3.605
98		39.5	4.30	.524	.564	3.333	3.645
108		40.0	5.00	.537	.573	3.397	3.677
118		40.0	7.00	.559	.584	3.466	3.714
128		48.0	8.00	.666	.598	4.145	3.759
130		8.0	1.00	.537	.603	3.397	3.777
Total and	332.0	292.9	51.93	56.43	62.79	377.49	426.70
Averages		2.56	.455	.495	.550	3.111	3.742

Table 6

Feed Record of Calf 23
by Ten Day Periods

and

Comparison of Nutrients Consumed with Armsby's Standard

Age	Milk	Grain	Hay	Digestible Crude Protein Con-sumed	Digestible Crude Protein Armsby's Standard	Net Energy Con-sumed	Net Energy Armsby's Standard
days	pounds	pounds	pounds	pounds	pounds	therms	therms
28	74.0	0	0	.244	.438	2.147	3.331
38	114.0	0	0.3	.379	.453	3.317	3.407
48	84.0	2.5	0.7	.315	.477	2.762	3.453
58	8.0	18.5	0	.250	.490	1.724	3.480
68		28.5	0	.345	.507	2.299	3.513
78		30.0	0	.363	.540	2.420	3.580
88		35.0	5.9	.486	.562	3.025	3.641
98		40.0	2.9	.515	.576	3.325	3.686
108		40.5	5.0	.543	.589	3.437	3.732
118		40.0	10.0	.590	.602	3.568	3.773
128		48.0	13.0	.719	.619	4.316	3.832
130		10.0	1.0	.658	.626	4.203	3.854
Total and	280.0	293.0	38.8	54.07	64.79	365.43	432.82
Averages		2.52	.346	.482	.578	3.262	3.864

Table 7

Feed Record of Calf 25
by Ten Day Periods
and

Comparison of Nutrients Consumed with Armsby's Standard

Age	Milk	Grain	Hay	Digestible Crude Protein Con-sumed	Digestible Crude Protein Armsby's Standard	Net Energy Con-sumed	Net Energy Armsby's Standard
days	pounds	pounds	pounds	pounds	pounds	therms	therms
28	95.0	0	0	.314	.437	2.756	3.323
38	114.0	3.6	0.9	.429	.453	3.628	3.407
48	84.0	7.6	2.0	.390	.490	3.118	3.480
58	8.0	21.5	7.6	.367	.520	2.226	3.540
68		32.5	7.5	.473	.555	2.878	3.618
78		39.0	13.0	.610	.576	3.590	3.686
88		47.0	13.1	.708	.599	4.239	3.763
98		48.0	8.5	.671	.621	4.162	3.836
108		48.0	16.0	.751	.641	4.419	3.904
118		50.0	15.0	.765	.663	4.546	3.977
128		50.0	25.0	.871	.683	4.888	4.045
130		10.0	5.5	.897	.694	4.974	4.081
Total and	301.0	357.2	114.1	72.46	69.32	454.24	446.60
Averages		3.19	1.01	.647	.618	4.055	3.987

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Table 8

Feed Record of Calf 531
by Ten Day Periods

and

Comparison of Nutrients Consumed with Armsby's Standard

Age	Milk	Grain	Hay	Digestible Crude Protein Consumed	Digestible Crude Protein Armsby's Standard	Net Energy Consumed	Net Energy Armsby's Standard
days	pounds	pounds	pounds	pounds	pounds	therms	therms
26	104.0	0	0	.343	.407	3.017	3.143
36	130.0	0	0	.429	.421	3.771	3.229
46	60.0	5.0	6.15	.324	.436	2.354	3.314
56	2.0	24.5	8.00	.388	.453	2.308	3.407
66		30.0	11.00	.480	.507	2.796	3.513
76		37.0	11.50	.570	.551	3.378	3.604
86		36.0	10.00	.542	.565	3.246	3.650
96		44.4	9.00	.633	.584	3.889	3.714
106		50.0	10.00	.712	.604	4.375	3.782
116		50.0	19.5	.812	.628	4.700	3.859
120		20.0	9.5	.857	.645	4.845	3.918
Total and	296.0	296.9	94.65	60.90	58.01	386.79	391.33
Averages		2.85	.910	.585	.557	3.719	3.762

Table 9

Feed Record of Calf 532
by Ten Day Periods

and

Comparison of Nutrients Consumed with Armsby's Standard

Age*	Milk	Malted Milk	Grain	Hay	Digestible Crude Protein Con-sumed	Digestible Crude Protein Armsby's Standard	Net Energy Con-sumed	Net Energy Armsby's Standard
days	pounds	pounds	pounds	pounds	pounds	pounds	therms	therms
26	81	2.6			.297	.427	2.588	3.263
36	62	7.5			.291	.436	2.487	3.314
46	1	9.8	11.5		.255	.450	1.856	3.400
56		1.1	23.5	2.0	.318	.477	2.065	3.453
66			30.0	5.0	.416	.523	2.591	3.547
76			35.5	9.0	.525	.558	3.171	3.627
86			37.5	12.0	.581	.576	3.445	3.686
96			45.0	11.0	.662	.595	4.006	3.750
106			50.0	18.0	.796	.615	4.649	3.818
116			50.0	26.5	.886	.634	4.940	3.881
120			20.0	12.5	.936	.653	5.102	3.945
Total	144	21.0	303.0	96.0	59.63	59.44	369.00	396.84
and Averages			2.91	.923	.573	.571	3.548	3.815

* Age at end of ten day period

Table 10

Feed Record of Calf 533
by Ten Day Periods

and

Comparison of Nutrients Consumed with Armsby's Standard

Age*	Milk	Malted Milk	Grain	Hay	Digestible Crude Protein Consumed	Digestible Crude Protein Armsby's Standard	Net Energy Consumed	Net Energy Armsby's Standard
days	pounds	pounds	pounds	pounds	pounds	pounds	therms	therms
26	79	2.50			.289	.407	2.521	3.143
36	62	7.50	0.5		.297	.410	2.527	3.160
46	7	9.25	8.5		.232	.418	1.738	3.211
56		1.10	23.5		.297	.427	1.996	3.263
66			27.0		.327	.444	2.178	3.366
76			35.5	3.6	.468	.483	2.986	3.467
86			36.6	7.0	.517	.517	3.191	3.533
96			40.0	6.0	.548	.551	3.431	3.605
106			50.0	6.0	.669	.569	4.238	3.664
116			49.0	13.0	.731	.588	4.397	3.727
120			20.0	5.0	.738	.603	4.460	3.777
Total and	148	20.35	290.6	40.6	51.13	54.17	336.63	379.16
Averages			2.79	.390	.491	.520	3.236	3.645

* Age at end of ten day period

Table 11

Feed Record of Calf 533
by Ten Day Periods

and

Comparison of Nutrients Consumed with Armsby's Standard

Age*	Milk	Malted Milk	Grain	Hay	Digestible Crude Proteins Con-sumed	Digestible Crude Proteins Armsby's Standard	Net Energy Con-sumed	Net Energy Armsby's Standard
days	pounds	pounds	pounds	pounds	pounds	pounds	therms	therms
26	81	2.60			.297	.440	2.588	3.340
36	62	7.50			.291	.448	2.487	3.391
46	7	9.25	8.5		.232	.470	1.738	3.440
56		1.10	14.0		.182	.473	1.230	3.447
66			18.0		.218	.490	1.452	3.480
76			31.5	3.9	.423	.520	2.674	3.540
86			37.0	6.3	.515	.551	3.200	3.605
96			43.9	8.0	.616	.570	3.814	3.670
106			50.0	6.0	.669	.585	4.238	3.718
116			50.0	14.5	.759	.606	4.529	3.786
120			20.0	7.0	.791	.626	4.632	3.854
Total and	150	20.45	272.9	45.7	49.93	57.79	325.82	392.71
Averages			2.62	.439	.480	.555	3.132	3.776

* Age at end of ten day period

Table 12

Weights and Height Measurements of Calf 2

by

Ten Day Periods .

Age days	Weight pounds	Weight compared to normal per cent	Height at withers centimeters	Height compared to normal per cent
60	161.5	102.9	86.26	105.1
70	178.16	104.0		
80	191.0	102.8		
90	203.5	101.7	90.0	103.6
100	209.0	96.6		
110	218.6	93.9		
120	231.5	92.9		
130	252.16	94.5	95.3	101.9
140	272.66	95.8		
150	295.50	97.8		
160	307.8	96.8		
170	332.0	99.6	100.1	100.6
180	346.3	99.2	102.0	101.1

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Table 13

Weights and Height Measurements of Calf 3

by

Ten Day Periods

Age days	Weight pounds	Weight compared to normal per cent	Height at withers centimeters	Height compared to normal per cent
60	156.16	99.4	84.0	102.4
70	171.0	99.8		
80	181.5	97.7		
90	188.66	94.3	84.5	97.3
100	194.8	90.0		
110	200.96	86.3		
120	221.3	88.8		
130	236.5	88.6	88.3	94.4
140	249.8	87.8		
150	267.0	88.4		
160	278.8	87.7		
170	297.5	89.2	95.1	95.7
180	308.1	88.2	95.8	94.9

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Table 14

Weights and Height Measurements of Calf 4

by

Ten Day Periods

Age days	Weight pounds	Weight compared to normal per cent	Height at withers centimeters	Height compared to normal per cent
60	155.0	98.7	82.66	100.8
70	174.5	101.8		
80	186.0	100.1		
90	197.0	98.5	88.0	101.3
100	213.8	98.8		
110	231.5	99.5		
120	248.3	99.7	93.3	101.4
130	264.8	99.3		
140	287.0	100.9		
150	299.8	99.3		
160	321.8	101.2	97.6	99.6
170	338.6	101.5		
180	363.5	104.1	101.0	100.0

Table 15

Weights and Height Measurements of Calf 5

by

Ten Day Periods

Age days	Weight pounds	Weight compared to normal per cent	Height at withers centimeters	Height compared to normal per cent
60	156.33	99.5	83.5	101.8
70	166.50	97.19		
80	173.30	93.30		
90	183.16	91.58	86.16	99.2
100	187.36	86.6		
110	193.60	83.2		
120	204.0	81.9		
130	223.3	83.7	91.3	97.6
140	244.66	86.7		
150	262.30	86.8		
160	273.5	86.0		
170	287.6	86.2	96.0	96.5
180	302.6	86.7	96.6	95.7

Table 16

Weight and Height Measurements of Calf 21

by

Ten Day Periods

Age days	Weight pounds	Weight compared to normal per cent	Height at withers centimeters	Height compared to normal per cent
18	117.83	109.3	76.3	101.9
28	123.0	103.5		
38	136.5	104.5		
48	140.83	98.7		
58	146.0	94.4	81.6	99.9
68	147.5	87.5		
78	161.5	88.3	82.66	97.3
88	171.16	86.8		
98	179.6	84.3		
108	185.3	80.8	85.8	95.4
118	195.0	79.4		
128	205.3	78.0		
130	204.5	76.67	89.8	96.0

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Table 17

Weights and Height Measurements of Calf 23

by

Ten Day Periods

Age days	Weight pounds	Weight compared to normal per cent	Height at withers centimeters	Height compared tonormal per cent
18	122.33	113.4	78.66	105.1
28	132.0	111.1		
38	141.83	108.5		
48	145.83	102.2		
58	150.0	90.5	84.8	103.8
68	154.8	91.9		
78	170.5	93.3	85.8	101.0
88	179.0	90.8		
98	190.3	89.3		
108	198.0	86.3	88.6	98.5
118	209.5	85.3		
128	223.3	84.8		
130	220.3	82.6	92.6	99.0

Table 18

Weights and Height Measurements of Calf 25

by

Ten Day Periods

Age days	Weight pounds	Weight compared to normal per cent	Height at withers centimeters	Height compared to normal per cent
18	123.33	114.4	77.33	103.4
28	129.50	109.0		
38	143.33	109.7		
48	151.0	105.9		
58	162.8	105.3	84.0	102.8
68	176.3	104.6		
78	192.5	105.3	87.66	103.2
88	209.66	106.4		
98	224.5	105.3		
108	241.0	105.1	91.8	102.1
118	256.1	104.2		
128	270.8	102.9		
130	271.8	101.9	95.7	102.3

Table 19

Weights and Height Measurements of Calf 531

by

Ten Day Periods

Age days	Weight pounds	Weight compared to normal per cent	Height at withers centimeters	Height compared to normalA per cent
16	101.83	96.4	75.16	100.9
26	109.16	93.6		
36	121.3	94.6		
46	130.5	93.0	79.5	99.9
56	142.0	93.2		
66	162.66	98.2	81.66	98.4
76	169.8	94.3		
86	184.1	94.7		
96	196.5	93.6	86.1	98.0
106	215.0	95.0		
116	230.0	94.8		
120	240.0	96.4	92.0	100.0

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Table 20

Weights and Height Measurements of Calf 532

by

Ten Day Periods

Age days	Weight pounds	Weight compared to normal per cent	Height at withers centimeters	Height compared to normal per cent
16	117.6	111.3	79.3	106.5
26	121.3	104.0		
36	129.66	101.1		
46	140.0	99.0	82.16	103.2
56	146.8	96.4		
66	167.16	100.9	83.8	101.0
76	175.66	97.6		
86	191.60	98.6		
96	204.50	97.4	87.0	99.0
106	220.5	97.5		
116	233.6	96.3		
120	249.2	100.1	91.2	99.1

Table 21

Weights and Height Measurements of Calf 533

by

Ten Day Periods

Age days	Weight pounds	Weight compared to Normal per cent	Height at withers centimeters	Height compared to normal per cent
16	106.0	100.3	72.5	97.3
26	103.8	89.0		
36	110.83	86.4		
46	115.66	82.4	75.8	95.2
56	122.16	80.2		
66	139.50	84.2	77.66	93.6
76	150.66	83.7		
86	159.60	82.1		
96	172.10	82.0	80.6	91.7
106	186.5	82.4		
116	199.3	82.2		
120	209.0	83.9	86.7	94.2

Table 22

Weights and Height Measurements of Calf 534

by

Ten Day Periods

Age days	Weight pounds	Weight compared to normal per cent	Height at withers centimeters	Height compared to normal per cent
16	125.3	118.6	76.0	102.0
26	130.33	111.7		
36	138.33	107.8		
46	142.8	101.8	80.3	100.9
56	140.66	92.4		
66	154.16	93.0	81.5	98.2
76	158.5	88.1		
86	173.0	89.0		
96	187.8	89.5	84.1	95.7
106	194.8	86.1		
116	216.6	89.3		
120	224.5	90.1	88.6	96.3

Table 23

Gains per day

Compared to Normal

Calf 2

Ten day period	Age at end of ten day period	Gain in Weight	Normal gain in weight
	days	pounds	pounds
1	70	1.666	1.430
2	80	1.284	1.436
3	90	1.250	1.434
4	100	.550	1.630
5	110	.960	1.630
6	120	1.290	1.640
7	130	2.066	1.766
8	140	2.050	1.766
9	150	2.284	1.768
10	160	1.230	1.560
11	170	2.420	1.560
12	180	1.430	1.580
Total gain		184.800	192.000
Average gain		1.54	1.60

Table 24

Gains per Day

Compared to Normal

Calf 3

Ten day period	Age at end of ten day period days	Gain in Weight pounds	Normal gain in weight pounds
1	70	1.484	1.430
2	80	1.050	1.436
3	90	.716	1.434
4	100	.614	1.630
5	110	.616	1.630
6	120	2.034	1.640
7	130	1.420	1.766
8	140	1.330	1.766
9	150	1.720	1.768
10	160	1.180	1.560
11	170	1.870	1.560
12	180	2.060	1.580
Total gain		160.940	192.00
Average gain	——	1.341	1.60

Table 25

Gains per Day

Compared to Normal

Calf 4

Ten day period	Age at end of ten day period days	Gain in weight pounds	Normal gain in weight pounds
1	70	1.950	1.430
2	80	1.150	1.436
3	90	1.100	1.434
4	100	1.680	1.630
5	110	1.770	1.630
6	120	1.680	1.640
7	130	1.650	1.766
8	140	2.220	1.766
9	150	1.280	1.768
10	160	2.200	1.560
11	170	1.680	1.560
12	180	2.490	1.580
Total gain		208.500	192.000
Average gain		1.737	1.60

Table 26

Gains per Day

Compared to Normal

Calf 5

Ten day period	Age at end of ten day period days	Gain in weight pounds	Normal gain in weight pounds
1	70	1.017	1.430
2	80	.680	1.436
3	90	.986	1.434
4	100	.420	1.630
5	110	.624	1.630
6	120	1.040	1.640
7	130	1.930	1.766
8	140	2.136	1.766
9	150	1.764	1.768
10	160	1.120	1.560
11	170	1.410	1.560
12	180	1.500	1.568
Total Gain		146.270	192.000
Average Gain		1.218	1.60

Table 27

Gains per Day

Compared to Normal

Calf 21

Ten day period	Age at end of ten day period days	Gain in weight pounds	Normal gain in weight pounds
1	28	.517	1.100
2	38	1.350	1.180
3	48	.433	1.200
4	58	.517	1.200
5	68	.150	1.380
6	78	1.400	1.430
7	88	.966	1.430
8	98	.844	1.600
9	108	.570	1.630
10	118	.970	1.630
11	128	1.030	1.750
12	130	-.400	1.800
Total gain		86.67	158.90
Average gain		.773	1.418

Table 28

Gains per Day

Compared to Normal

Calf 23

Ten day period	Age at end of Ten day period days	Gain in weight pounds	Normal gain in weight pounds
1	28	.967	1.100
2	38	.983	1.180
3	48	.400	1.200
4	58	.417	1.200
5	68	.480	1.380
6	78	1.570	1.430
7	88	.850	1.430
8	98	1.130	1.600
9	108	.770	1.630
10	118	1.150	1.630
11	128	1.380	1.750
	130	— 1.500	1.800
Total Gain		97.970 99.470	158.90
Average Gain		.874 .888	1.418

Table 29

Gains per Day

Compared to Normal

Calf 25

Ten day period	Age at end of tenday period days	Gain in weight pounds	Normal gain in weight pounds
1	28	.617	1.10
2	38	1.383	1.18
3	48	.767	1.20
4	58	1.180	1.20
5	68	1.250	1.38
6	78	1.620	1.43
7	88	1.716	1.43
8	98	1.484	1.60
9	108	1.650	1.63
10	118	1.510	1.63
11	128	1.470	1.75
	130	.500	1.80
Total gain		147.470	158.90
Average gain		1.316	1.418

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Table 30

Gains per Day

Compared to Normal

Calf 531

Ten Day Period	Age at end of ten day period days	Gain in weight pounds	Normal gain in weight pounds
1	26	.733	1.10
2	36	1.214	1.16
3	46	.920	1.20
4	56	1.150	1.20
5	66	2.066	1.34
6	76	.714	1.43
7	86	1.430	1.43
8	96	1.240	1.56
9	106	1.850	1.63
10	116	1.500	1.63
	120	2.500	1.62
Total gain		138.20	143.28
Average gain		1.328	1.377

Table 31

Gains per Day

Compared to Normal

Calf 532

Ten day period	Age at end of ten day period days	Gain in weight pounds	Normal gain in weight pounds
1	26	.370	1.10
2	36	.836	1.16
3	46	1.034	1.20
4	56	.680	1.20
5	66	2.036	1.34
6	76	.850	1.43
7	86	1.600	1.43
8	96	1.290	1.56
9	106	1.600	1.63
10	116	1.310	1.63
	120	3.900	1.62
Total Gain		131.66	143.28
Average Gain		1.265	1.377

Table 32

Gains per Day

Compared to Normal

Calf 533

Ten day period	Age at end of ten day period days	Gain in weight pounds	Normal gain in weight pounds
1	26	-.220	1.10
2	36	.703	1.16
3	46	.483	1.20
4	56	.650	1.20
5	66	1.734	1.34
6	76	1.116	1.43
7	86	.894	1.43
8	96	1.250	1.56
9	106	1.440	1.63
10	116	1.280	1.63
	120	2.420	1.62
Total Gain		103.00	143.28
Average Gain		.990	1.377

Table 33

Gains per Day

Compared to Normal

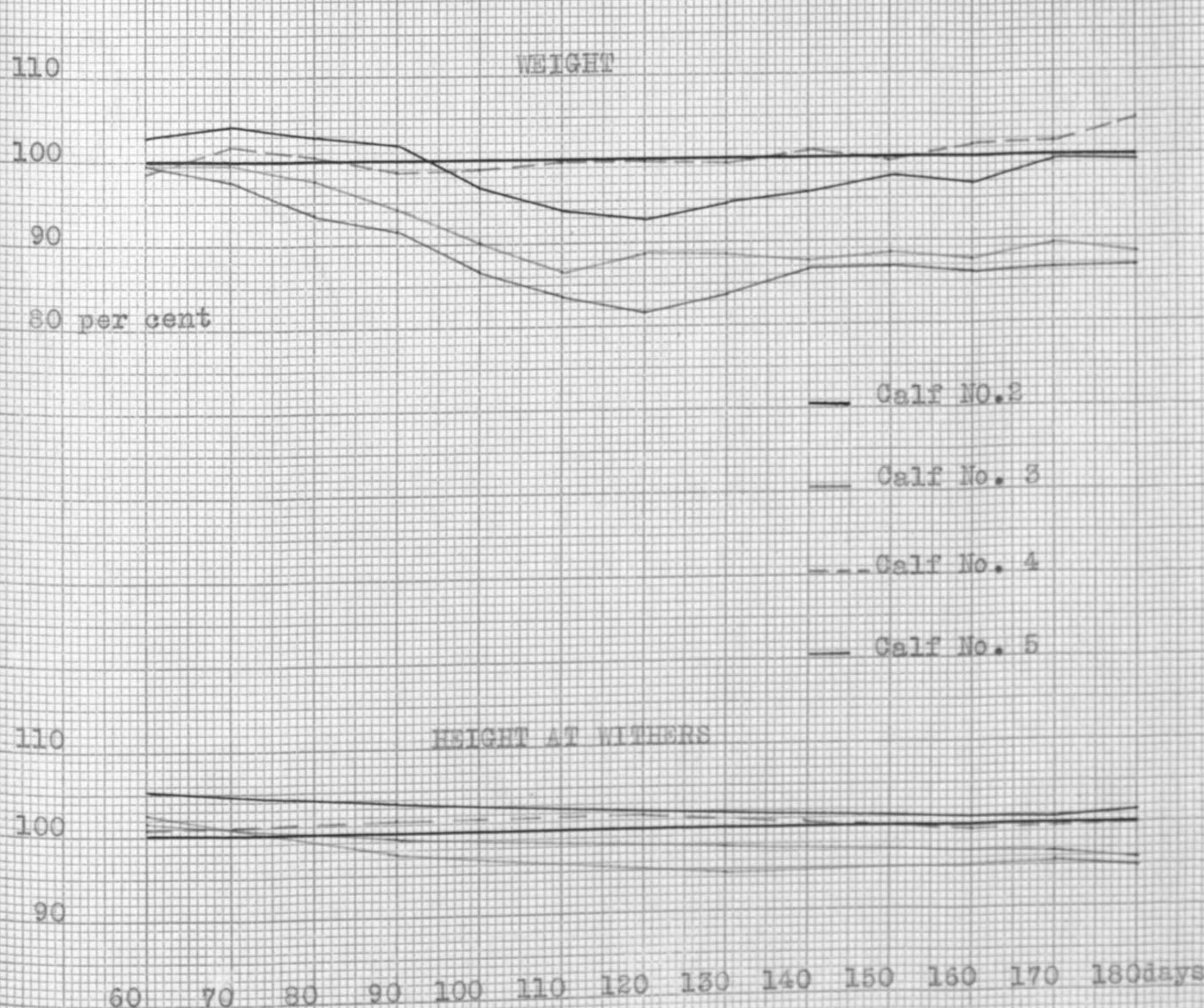
Calf 534

Ten day period	Age at end of ten day period days	Gain in weight pounds	Normal gain in weight pounds
1	26	.503	1.10
2	36	.800	1.16
3	46	.447	1.20
4	56	-.214	1.20
5	66	1.350	1.34
6	76	.434	1.43
7	86	1.450	1.43
8	96	1.480	1.56
9	106	.700	1.63
10	116	2.180	1.63
	120	1.970	1.62
Total Gain		99.200	143.28
Average Gain		.953	1.377

GRAPH No. 1

A comparison of weights and heights on percentage

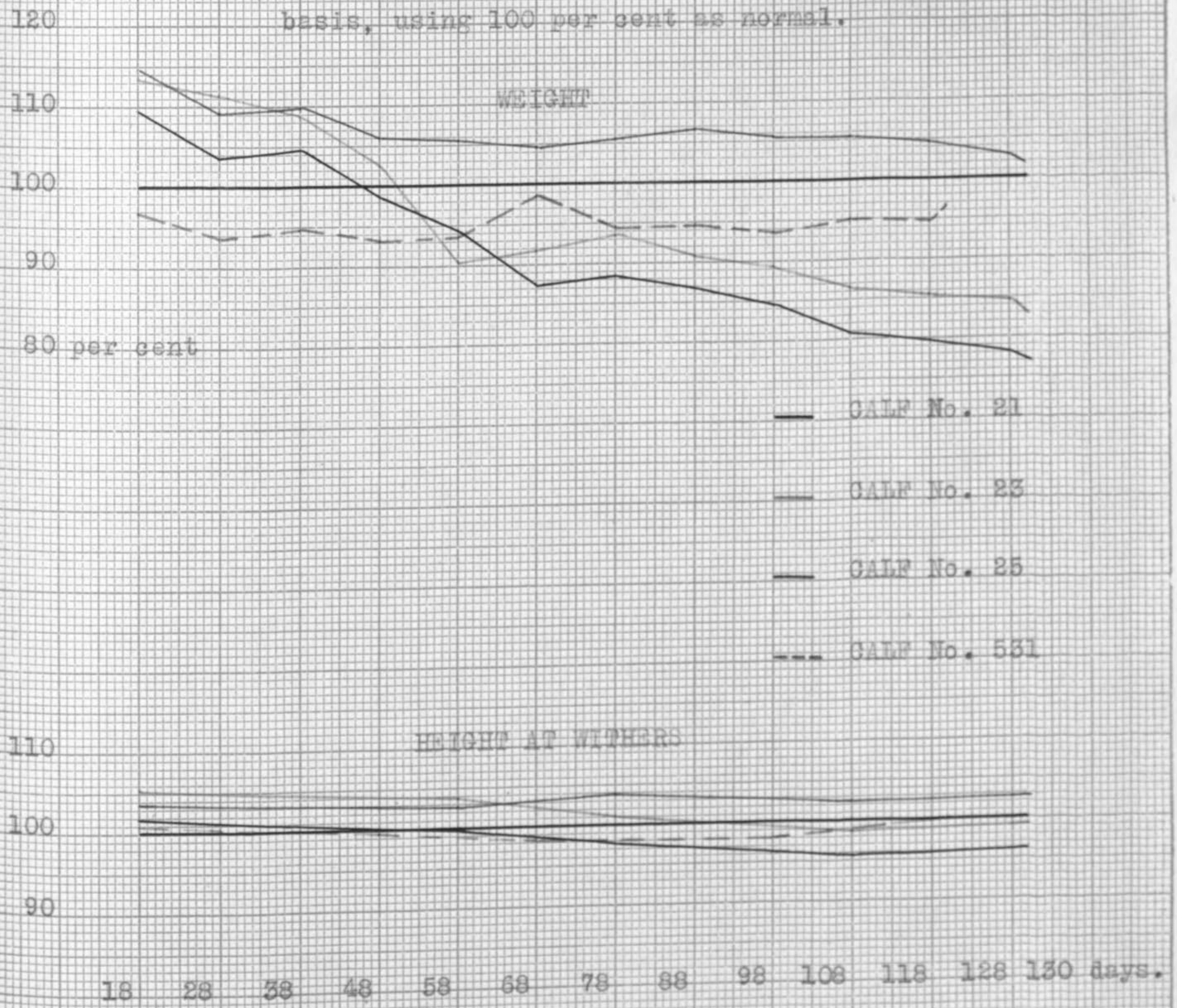
basis, using 100 per cent as normal.



These animals were weaned at seventy days of age. They were fed a grain mixture consisting of four parts corn meal, one part oil meal, one part bran; and cut alfalfa hay.

GRAPH No. 2

A comparison of weights and heights on percentage basis, using 100 per cent as normal.

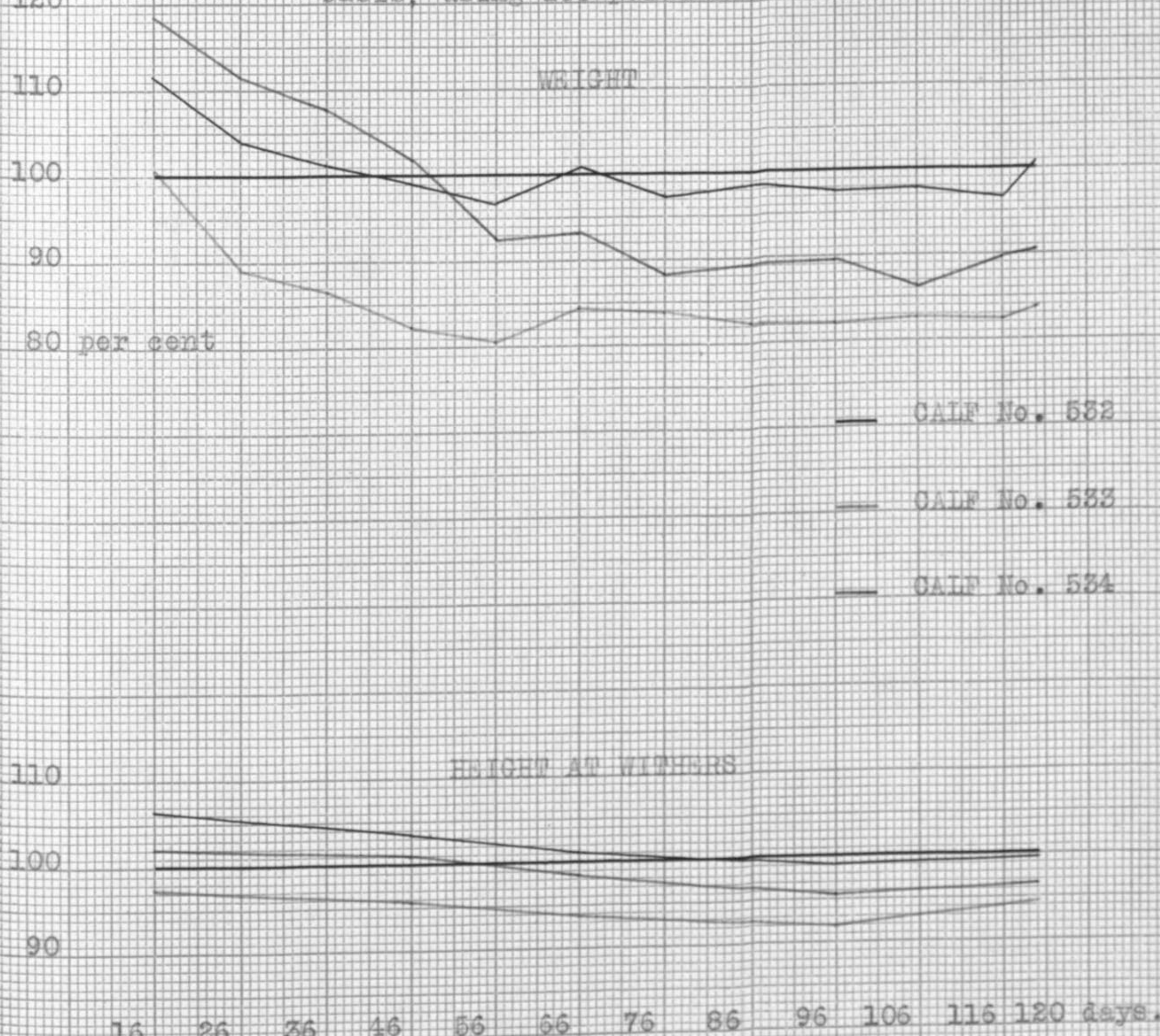


The amount of milk fed to these calves was reduced one-half at thirty days of age, and by the fiftieth day the calves were weaned. They received a grain mixture consisting of four parts corn meal, one part oil meal, one part bran; and cut alfalfa hay.

GRAPH No. 3

A comparison of weights and heights on percentage

basis, using 100 per cent as normal.



These calves were fed in the same manner as were calves No. 21-23-25-531, except that melted milk was made to take the place of raw whole milk after the first month.

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A C K N O W L E D G M E N T

The writer wishes to express his indebtedness and sincere gratitude to Dr. C. H. Eckles, for his many helpful suggestions during the preparation of this thesis.