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MILK SUBSTITUTES,

Powdered Skimmilk for Raising Calves

by

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Outline

	Page
I. Introduction	
II. Review of Literature	1
Skimmilk Feeding	1
Milk Substitutes for Raising Calves . .	2
III. Factors that Influence the Utilization of Various Feeds by Young Animals	16
Physiological (General discussion). .	16
Growth (General discussion) . . .	16
Normal Growth	17
Limits of Growth	18
Internal Secretions and the Ductless Glands	19
Nutrition (General discussion) . . .	23
Protein Metabolism (With a dis- cussion of the proteins and amino- acids)	25
Carbohydrates	31
Mineral Matter	32
The Newer Dietary Factors (A dis- cussion of accessories, vitamins, fats and oils	35

	Page
IV. Application of Present Knowledge of	
Nutrition to Milk Substitutes	44
V. Experimental Work	53
Object of Experiment	53
Preliminary Experiment	53
Plan of Main Experiment	55
Animals Used	56
Stabling	57
Method of Feeding	57
Weights and Measurements	59
Feeding Standard	60
Total Feed Consumed	60
Nutrients Received by Calves	61
Protein Consumed	62
Energy for Growth	63
Dry Matter	63
Gains in Weight	64
Height at Withers	64
Growth by Weight and Growth in Height, Shown in per cent of Normal	65
Utilization of Rations by the Calves of the Different Breeds	66
Cost of Ration	67
General Discussion of Results	68

	Page
VI. Conclusions	72
VII. Bibliography	

MILK SUBSTITUTES,

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Introduction

According to the United States census in 1910 there were 21,000,000 cows in the United States. Considering the average productive life of a cow five to six years, 4,000,000 of these animals have to be replaced each year. The average cow does not come into milk until she is at least two years of age, this necessitates the keeping of approximately 8,000,000 immature animals. One of the greatest problems of a successful dairyman is to obtain good cows each year to replace his discarded animals.

For the farmer selling cream this is comparatively easy on account of the skimmilk he has available. He feeds the calves whole milk for the first two or three weeks and then gradually changes to skimmilk with some grain supplement. By this method it costs approximately \$20.00 to raise a calf to six months of age.

A calf raised on whole milk would require at least 14 pounds per day for the first 120 days, a total of 1,680 pounds. At \$1.75 per hundred the milk alone would be

worth \$29.40 and in addition some hay and grain is required. The total cost when such a method is employed, exceeds the value of an ordinary heifer calf at this age. Under these conditions it is not surprising that the dairyman selling whole milk hesitates to raise his calves without some means of cheapening the ration.

About forty-five per cent of the dairy cows in the United States are found on the farms producing whole milk for the cheese factories, dried milk factories, milk condensaries and for market milk purposes. Such farms have no skimmilk for feeding purposes. The greater number of the cows on these farms, when they become unproductive, are replaced by purchase. However, every year it is becoming more and more difficult to buy really efficient producers and experience has taught that the only method of replenishing a herd and making for advancement in production is to raise the heifer calves.

The most common plan of raising calves in general use at the present, by the farmer selling whole milk, is to feed a minimum amount of milk along with grain, or to give the calf a good start and take the milk away after about two months putting it on a grain ration. The numerous attempts that have been made to find a "milk

substitute" have not been very successful.

Within recent years the preparation of dried skimmilk has become an important phase of the dairy industry. The "milk substitutes" for calf raising which have proven the most successful, with the exception of that prepared at the Purdue Experiment Station, have contained a small portion of this powdered skimmilk.

This thesis is a discussion, from the standpoint of our present knowledge of the fundamental principles of animal nutrition, of the possibility of raising calves on "milk substitutes". The experimental work, which consists of a trial of powdered skimmilk for calf raising, is to be the beginning of a systematic study of the question of raising the calves on those farms where whole milk is sold.

Review of Literature of Calf Feeding.

A large amount of work has been done at various experiment stations on calf raising. It may be classified in three divisions:

- (1). Skimmilk vs. whole milk.
- (2). Supplements to skimmilk feeding.
- (3). Milk substitutes.

Most of the early work had to do with the raising of calves on skimmilk as compared to whole milk. Along with this was the problem of determining the value of various substitutes for butterfat in skimmed milk. The substitutes used were of two kinds:

- (1) oils and fats, (2) various grains.

The oils and fats experimented with were cod liver oil, emulsion of peanut oil, cottonseed oil and oleomargarine. As a whole they were unsatisfactory.

The grains were more efficient. Curtiss⁸ in raising calves with skimmilk and supplementary grains concluded that, "a nitrogenous feed such as oil meal is neither necessary nor the most profitable as a supplement to a skimmilk ration for young calves". Further¹⁰ his results indicate pure corn meal to be superior to pure linseed meal for feeding calves in

combination with skimmilk and that carbonaceous grains should be more suitable for feeding with skimmilk than a highly nitrogenous product like linseed meal. Hooper³⁶, Otis⁹³, and Fain and Jarnagin¹⁶ obtained results similar to those of Curtiss's in their work with grains to supplement skimmilk. At present the greater per cent. of the calves of dairy breeds are raised on skimmilk with some grain supplement.

On account of economic conditions and the increased use of whole milk to supply the cities, milk condensaries and cheese factories the interest in "milk substitutes" is constantly increasing.

Hayward³³ published the first extensive report upon investigations of this subject. As a basis for his formula he used the following mixture, recommended by an Agricultural College in England:

Flour - - - - -	16 2/3 pounds
Flaxseed meal - - - - -	33 1/3 "
Linseed oil-cake meal - - - - -	50 "

With this as a foundation he conducted a number of trials using various combinations of feeds. Fairly satisfactory results were obtained with the following mixture:

Wheat flour - - - - -	30 pounds
Cocoanut meal - - - - -	25 "
Nutrium - - - - -	20 "
Linseed meal - - - - -	-10 "
Dried blood - - - - -	2 "

The calves used in the experiment were not selected but were taken just as they were born in the College herd. Each animal received whole milk for seven to ten days and was then gradually changed to the calf meal. The feed was given twice a day from a calf feeder. All the calves fed the meal seemed to grow as well as two calves which were raised on skimmed milk, hay and grain. In the opinion of Hayward, as good and as thrifty calves can be raised on calf meals as on skimmed milk.

Lindsey⁴⁴ compared the homemade mixture recommended by Hayward³³ with Blatchford's calf meal. He concluded that, "the commercial calf meal is hardly as satisfactory as the Hayward mixture during the first three months of the calf's life". Later Lindsey⁴⁵ tested several proprietary calf meals as "milk substitutes" and a number of calf meal preparations prepared by the Experiment Station. Those tested were as follows:

(1). Bibby's Cream Equivalent -- containing linseed, linseed cake, tapioca flour, sage flour, rice polish, locust bean, starch and salt.

(2). Hayward's calf meal.

(3). Schumacher's calf meal.

The calf meals prepared by the Experiment Station were as follows:

Lindsey's Calf Meal I

Fine corn meal	- - - - -	10	pounds
Flour middlings	- - - - -	10	"
Flaxseed meal	- - - - -	15	"
Cheap flour	- - - - -	10	"
Glucose sugar	- - - - -	5	"
Salt	- - - - -	1	"
Cost	- - - - -	3.2¢	per pound.

Lindsey's Calf Meal II.

Flaxseed meal	- - - - -	15	pounds
Cheap flour	- - - - -	8	"
Glucose sugar	- - - - -	2	"
Salt	- - - - -	1	"
Ground oat flakes	- - - - -	25	"
Cost	- - - - -	3.7¢	per pound.

Lindsey's Calf Meal III.

Fine corn meal	- - - - -	8	pounds
Flour middlings	- - - - -	10	"
Flaxseed meal	- - - - -	14.5	"
Cheap flour	- - - - -	10	"
Glucose sugar	- - - - -	7	"
Salt	- - - - -	$\frac{1}{2}$	"
Cost	- - - - -	3.4¢	per pound.

Lindsey's Calf Meal IV.

Fine corn meal	- - - - -	10 pounds
Flour middlings	- - - - -	10 "
Flaxseed meal	- - - - -	14.5 "
Cheap flour	- - - - -	15 "
Salt	- - - - -	.5 "
Cost	- - - - -	-3.0¢ per pound.

Lindsey's Calf Meal V.

Fine corn meal	- - - - -	11 pounds
Flour middlings	- - - - -	5 "
Flaxseed meal	- - - - -	10 "
Ground oat flakes	- - - - -	22 "
Prepared blood flour	- - - - -	1.5 "
Salt	- - - - -	.5 "
Cost	- - - - -	3.0¢ per pound.

Lindsey's Calf Meal VI.

Ground oat flakes	- - - - -	35 pounds
Prepared blood flour	- - - - -	1.5 "
Barley malt	- - - - -	12.5 "
Bicarbonate soda	- - - - -	.5 "
Salt	- - - - -	.5 "
Cost	- - - - -	-3.3¢ per pound.

Table 1. Summary of all Trials.

Massachusetts Experiment Station.

Kind of ration	No. of Calves	Days in trial	Daily gain pounds	Total food cost	Cost of food per lb. of gain (cents)
Skimmilk and Hayward's mixture	2	173	1.23	\$20.44	9.6
Skimmilk and Schu- macher's calf meal	3	150	1.00	12.27	8.2
Whole milk, skimmilk and Bibby's cream equivalent	3	148	1.21	13.08	7.5
Whole milk, skimmilk Lindsey's meal I	2	147	.97	14.54	10.4
Whole milk, skimmilk Lindsey's meal II	3	183	1.04	14.68	7.6
Whole milk, skimmilk Lindsey's meal III	1	148	1.70	15.24	6.1
Whole milk, skimmilk Lindsey's meal IV	1	148	1.50	14.49	6.5
Whole milk, skimmilk Lindsey's meal V	4	164	1.25	15.12	7.6
Whole milk, skimmilk Lindsey's meal VI	3	157	1.35	16.54	7.6

Lindsey in commenting on the results obtained states:- "Calf meals may be purchased or prepared that will take the place of considerable amount of whole milk or skimmilk and not interfere with 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. Holstein and Ayrshire calves are as a rule better able to utilize prepared foods than are the Jerseys and Guernsey, although we had no serious trouble in rearing calves of the

latter breeds with a minimum of milk".

Savage and Tailby⁹⁹ 1907-08 experimented with three lots of calves. They were fed respectively, skimmed milk, Schumacher's calf meal and Lactina Suisse. A summary of their work is given in Table 2.

Table 2. Substitutes for Skimmilk in Raising Calves

N.Y. Experiment Station (Cornell) 1907-08.

Lot	No. of calves	Average no. of days in Exp.	Cost of Feed	Average gain per day	Average cost of one pound of gain.
Skimmilk	5	120	\$10.21	1.76	\$.048
Schumacher's calf meal	6	120	12.14	1.25	.081
Lactina Suisse	5	105	8.60	.70	.116

In conclusion they state: (1) "while skimmed milk gives the best results as a substitute for whole milk, good strong calves can be raised without milk of any kind after the third or fourth week". (2) "Schumacher's calf meal does not appear from this feeding trial to be a complete substitute for skimmed milk, yet the gains from the use of this meal are good and the cost per pound of gain is fairly low". (3) Lactina Suisse did not give results nearly equal to skimmed milk or Schumacher's calf

meal at any corresponding periods of age.

The investigation was continued during 1908-1909. In this test four lots were used and the following feeds fed; skimmed milk, skimmed milk powder, Schumacher's calf meal and Blatchford's calf meal. A summary of their work for 1908-1909 is given in Tables 3 and 4.

Table 3. Substitutes for Skimmilk in Raising Calves.

N. Y. Experiment Station (Cornell) 1908-1909.

Lot	No. of calves	Total average gain	Average gain per day	Average cost of one pound of gain
Skimmed milk	7	229	1.53	\$.048
Skimmed milk powder	6	184	1.23	.064
Schumacher's calf meal	4	163	1.10	.090
Blatchford's calf meal	4	130	.87	.134

Table 4, gives the average amount of feed consumed by the calves of the different lots.

Table 4. Summary of Feed Consumed

Lot	Experi-mental food	Whole Milk	Hay	Dry Grain
Skimmed Milk	2,478	202	360.6	146.6
Skimmed milk powder	229.6	185	370.4	114.1
Schumacher's calf meal	220.2	226	328.8	108.7
Blatchford's calf meal	270.3	207	307.9	108.7

This is the only report found regarding the use of skimmed milk powder for raising calves. In the work reported the milk powder gave very good results. One pound of the milk powder was dissolved in nine pounds of water, this being practically the proportion of solids to water in ordinary skimmed milk. The powder was sifted to get out the lumps, then mixed with a little cold water and finely boiling water was poured on and the whole mixed. This method gave the best results, ensuring a liquid free from lumps, which served as skimmed milk in every way, the amount given at a feed being the same as of skimmed milk and fed at the same temperature. They state that, "the calves did very well and the raising of calves on this food was as easy as on skimmed milk, hay and grain."

These results show the third grade dried skimmilk powder to be the best substitute when skimmed milk is not at hand. A calf fed on this food should reach a weight of 250 to 260 pounds at five months of age, making an average gain of 1.25 pounds per day. The Schumacher's calf meal proved to be superior to the Blatchford's.

Somerville¹⁰² 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 for a calf. It should be gradually made to take the place of new milk after the first fortnight.

Crawford⁷ gives oil cake and oatmeal 1:1 cooked with hay tea and a little milk as a useful food for calves.

Dean¹¹ found Blatchford's calf meal to give no better results than a mixture of wheat bran, ground oats and a little oil cake when supplementing skimmilk. Blatchford's calf meal did not prove to be a good substitute when fed without skimmilk.

Michels⁷³ in an experiment lasting thirteen weeks compared cooked rolled oats with skimmilk as feed for calves. Nine calves fed the rolled oats made an average daily gain per head of 1.143 pounds whereas two calves fed the skimmilk made an average daily gain per head of 1.21 pounds. The value of such a feed would depend upon the price of rolled oats and the cost of preparation for the feed. The rolled oats he used

cost 4.4 cents per pound delivered in barrel lots.

Woodward and Lee¹⁰⁹ fed "Blackstrap" molasses to young calves to supplement skimmilk, it being the cheapest source of carbohydrates in the state. With them it proved laxative and produced undesirable fermentations and scours. Their opinion was that the results were due to the cane sugar it contained as cane sugar produced the same conditions. They gave a "milk substitute" which was employed by a farmer in that state. The ration fed consisted of bean-soup from 4 ounces of beans, 3 ounces shorts, 1 ounce blood meal and probably about half of the time 3 ounces of cottonseed meal. The calves were fed whole milk for the first five days. The milk was then reduced, adding the substitute, until at the end of ten days the calf was receiving one pint a day and the substitute. This amount of milk was fed until the calf was six weeks of age. Milk was then discontinued and only the ration fed until the calf was four months of age when it was weaned and put on dry feed entirely.

Fraser and Brand²² instead of working with "milk substitutes" tried to determine the minimum amount of milk necessary to insure to calves a satisfactory start in life. A series of three tests were conducted. The first test was preliminary and indicated that during

the first two weeks the calves must be fed a reasonable amount of whole milk. This to be gradually changed to skimmilk. The calves to receive practically all of their nourishment up to 8 weeks from milk. It showed in a very striking manner that the most important thing in raising calves is to give them a good start. The second test indicated that it was possible to raise calves on a moderate amount of milk. The average amount required being 152 pounds of whole milk and 435 pounds of skim milk. During the third test more milk was fed, but it was found to be unnecessary.

When the amount of both whole milk and skimmilk was limited the grain best suited seemed to depend to a considerable extent upon its palatability.

Hunziker and Caldwell⁴⁰ tested a home mixed calf meal by comparing it with skimmilk and Blatchford's calf meal. The rations fed are as follows:-

Lot 1. (skimmilk) received whole milk, skimmilk, ground corn and oats as a dry mash, alfalfa hay and corn silage.

Lot 2. (home-mixed calf meal) received whole milk, home-mixed calf meal (containing hominy feed, linseed meal, red dog flour and dried blood equal parts by weight), ground corn and oats as dry mash,

alfalfa hay and corn silage.

Lot 3. --(Blatchford's calf meal) received whole milk, Blatchford's calf meal, ground corn and oats as a dry mash, alfalfa hay and corn silage.

These rations were fed for a period of one hundred and eighty two days to three lots of ten calves each.

Tables 5 and 6 are a summary of their work.

Table 5 - Average Weight of Calves

Purdue University Experiments.

Lot	No. of calves	Average birth weight	Average final weight	Total average gain	Average daily gain
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
I	10	61.7	282.8	221.1	1.21
II	10	69.6	244.1	174.5	.95
III	8	68.2	200.2	133.4	.73

Table 6 gives the average amount of feed consumed by the calves of the different lots.

Table 6 - A Summary of Feed Consumed.

Lot	Experi- mental food,	Whole Milk	Dry Mash	Alfalfa hay	Corn silage
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
I	2,022.45	131.3	178.71	455.66	61.11
II	244.13	213.95	154.01	397.7	40.80
III	195.1	477.71	139.33	293.8	38.59

In their opinion "milk substitutes" for dairy calves are of comparatively limited value so long as skim milk is available as a feed. The results from feeding Blatchford's calf meal from the standpoint of gain in weight and growth in height do not warrant its recommendation as an absolute "milk substitute" for the growing of dairy calves. The home-mixed calf meal gave more favorable results, compared with the skimmilk lot, than did the lot receiving Blatchford's calf meal.

Carr, Spitzer, Caldwell, and Anderson⁵ carried on an experiment using a mixture of various vegetable proteins and mixtures of vegetable and animal proteins from various sources. The objects of the experiment were:--(1) to determine to what extent a calf meal made up of both animal and vegetable feeding material rich in protein could take the place of skimmilk; (2) to determine whether 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.

Five calves were used on the experiment and the following mixtures fed.

1. Vegetable meal

Linseed meal - - - - -
 Soy-bean meal - - - - - Equal parts
 Cottonseed meal - - - - - by weight
 Wheat middlings - - - - - Nitrogen = 4.97%

2. Home-mixed meal

Hominy feed - - - - -
 Linseed meal - - - - - equal parts by weight
 White swan flour - - - - - Nitrogen = 5.60%
 Dried blood - - - - -

3. Vegetable dried blood meal

Soy-bean meal - - - - -
 Linseed meal - - - - - Equal parts by weight
 Cottonseed meal - - - - - Nitrogen = 6.0%
 Wheat middlings - - - - -
 Dried blood - - - - -

4. Home-mixed casein meal

Hominy feed - - - - - -9 parts by weight
 Linseed meal - - - - - -9 " " "
 White swan flour - - - - - -9 " " "Nitrogen
 Casein - - - - - -8 " " " 5.02%

The linseed meal used was the old process.

The calf meals were mixed with water at the rate of 4 ounces of meal to 3 pounds of water and fed at same temperature as the skimmilk. They were fed in three periods of 29, 25 and 18 days respectively. The following shows the proportion of nitrogen consumed which was retained.

Skim milk ration - - - - - 40.7%
 Home-mixed meal - - - - - 32.0
 Home-mixed casein meal - - 30.0
 Vegetable meal - - - - - 27.3
 Vegetable dried blood meal 22.6

The home-mixed meal appeared to give results that compared the most favorably with the skimmilk ration. The gain in grams of body weight per gram of nitrogen consumed for different rations were:

Skim milk ration - - - - -	34.41	grams
Home-mixed casein meal ration - -	32.74	"
Vegetable dried blood meal - - -	26.85	"
Home-mixed meal ration - - - - -	26.17	"
Vegetable meal ration - - - - -	26.14	"

Many of the various calf meals are made, so far as the relative proportions of the several ingredients are concerned, to imitate dry skimmilk. Up to the present they have not proven satisfactory as absolute substitutes for skimmilk. Those which have proven the most successful seem to be those that contain a certain amount of dried skimmilk with the possible exception of the home-mixed meal used by Hunziker and Caldwell⁴⁰.

In all of the work cited at least some milk has been used during the early life of the calf. All workers upon the subject of calf feeding recognize that where skimmilk is available the value of "milk substitutes" is very limited. As the demand for whole milk increases the extensive use of such feeds must follow.

FACTORS THAT INFLUENCE THE UTILIZATION
OF VARIOUS FEEDS BY YOUNG ANIMALS.

Physiological.

In the preparation of a "milk substitute" one should take into consideration the different factors which influence the utilization of a ration. Recent work along physiological and nutritional lines has resulted in a rapid development of our knowledge with regards to the function and importance of certain organs of the body and the different constituents of the diet. Such factors may be classified as (1) physiological, i.e. the numerous processes of the body and (2) Nutritional such as the physical and chemical composition of the ration and the quality of the different constituents contained in the ration. In the study of the body mechanisms many questions arise, e.g. What are the functions of the parts of the body? What is the nature of living substance and how can it be studied?

Growth - The morphological unit of living tissue is the cell. Investigators have been able to study its nature only indirectly by observation of motion, irritability and growth or the multiplication of mass. The latter is of the most vital importance in the study of the young of a species. Just what is growth is very hard to define

but is generally understood to incorporate that series of physiological changes by which any individual of any species develops from the fertilized egg to maturity.

Normal Growth - The body of an animal increases rapidly in size. It is a popular idea that the rate of growth increases up to maturity and then declines. Howell³⁸ shows that the rate of growth decreases from birth to old age, although not uniformly and that the maximum rate is reached some time during the intra uterine period. Jackson³⁸ found the maximum rate of growth occurred during the first month of fetal life. As soon as the egg of the mother unites with the sperm of the father there is an "inherent tendency" to grow. The "inherent tendency" is fundamental. The part nutrition plays is secondary but there has to be an interrelationship between the two in order to bring about normal growth. The normal rate of growth for any species can be determined only by collecting data on a large number of apparently normal animals within that species and averaging the values found. The large number has a tendency to lessen the possibility for error.

At the present normal values are available for several species of animals. The only satisfactory values for dairy animals are those calculated by Burlingham and Gillette⁴ and by Swett¹⁰⁵. One of the most significant

and definite contributions to the subject of growth has been made by Rubner³⁸. He worked with man, horse, cow, sheep, dog, cat, rabbit and guinea pig. His work showed human growth to constitute a type of its own while for all of the rest it was the same. He formulated two general laws:- (1) the law of constant energy consumption. During the first period of growth the total amount of energy necessary for maintenance and growth, as expressed by the heat value of the food consumed, is the same for all mammals except man. (2) The law of the constant "growth quotient". In all the mammals considered the same fractional part, 34 per cent, of the entire food energy is utilized for growth. This is known as the "growth quotient".

Limits of Growth - "The rhythm of cell division is limited for every class of animals and for every individual, therefore, even with the greatest intake of food growth, will never exceed a certain limit".² Wilson⁴ says that, "all animals and plants have a limit of growth". Rubner³⁸ concluded that in some way the processes of growth contain the very source of maintenance of life. After the animal has reached the period of puberty or reproductive power, and provision is thus made for the perpetuation of the species the individual organism is

depleted of the power of growth and senescence and death become inevitable.

A summary of the work on growth as expressed by Kellicott⁴² is, "It seems quite likely that in organisms in general the normal growth of each tissue or each organ is controlled separately 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 and the Ductless Glands .-

The term "internal secretion" according to Howell³⁸ is used to designate those secretions of glandular tissue which, instead of being carried off to the exterior by a duct are eliminated in the blood or lymph. Experience has shown that not only the ductless glands but some of the typical glands provided with ducts may give rise to internal secretions, the pancreas for example. Some of the glands giving off internal secretions are thyroid, parathyroid, adrenals, pituitary, pineal, thymus, pancreas and the generative organs. According to Hutchison⁴¹ the secretions from these various glands seem to contain some specific chemical agent or agents which are passed into the blood stream and carried by it to influence distant structures in many of their involuntary physiological

functions. These chemical products which stimulate the activity of special organs Starling¹⁰¹ designates as "hormones". Schafer¹⁰¹ calls attention to the fact that some hormones inhibit functional activity while others act as a chemical stimulant. He suggests the use of the term "autacoid substances" to indicate their drug-like action and subdivides them into two groups.

Hormones--stimulating action.

Autacoid substances

Chalones--inhibitory action.

The active agents of external secretions are always of the nature of a ferment or an enzyme. The active materials of internal secretions are for the most part not rendered inactive even by prolonged boiling and are of a much simpler chemical constitution than enzymes.

As a proof that the secretions of these various glands are essential for the body processes of the individual, cessation of growth, poor physical condition and even death have been caused by the removal of certain ones of these organs, Mathews⁶⁷. Feeding the extract of the corresponding gland of another animal causes a rapid recovery. The same results are also obtained in working with certain glands by planting the corresponding gland

of another animal any place in the body of the animal being experimented upon.

What was formerly known as the thyroid gland is now divided into the thyroid and the parathyroid. They are located along the sides of the trachea near its junction with the larynx. Goitre in humans is a condition of enlargement of the thyroid. The function of these two glands as given by Howell³⁸ is distinct. When the parathyroids are removed the animal dies quickly with acute symptoms and muscular convulsions. Upon the removal of the thyroids alone the animal may live for a long period, but will develop a condition of chronic malnutrition. It may take the form of cretinism.

The pituitary is a small gland found at the base of the brain. Investigators, Schafer¹⁰¹, are of the opinion that it furnishes the autacoid principles to the blood which serve as chemical regulators of nutrition and growth. It is thought to be essential to life.

The thymus is essentially an organ of early life. Its functions as yet are rather obscure, but Howell³⁸ is of the opinion that the gland is concerned in some way with the process of growth.

The secretion from the adrenal gland has an in-

fluence upon many diverse organs and glands, including most of the other ductless glands. Schafer's¹⁰¹ impression is that this is probably due to the fact that the adrenalin, the secretion from the adrenals, activates the sympathetic nerve-endings throughout the body.

Schafer¹⁰¹ in discussing some of the other glands states, "As yet work on the pineal gland does not allow the making of any definite conclusions regarding its functions or the nature and mode of action of its autacoids".

The activities of the sexual organs seem to have a very important relationship to the development of the secondary sexual characteristics. This is shown by the modifications in the individual's development after castration, or spaying. Steinach³⁸ was able to get normal development by transplanting these glands from their normal position to other regions. They are also important in regard to the body metabolism in general.

Von Mering and Minkowski³⁸, from their work and the results of other investigators which were similar, believed that the pancreas forms an internal secretion which passes into the blood and plays an essential part in the metabolism of sugar in the body.

Work with the organs giving off internal secretions in their relation to metabolism has been, for the most part, with that of the carbohydrates. There seems, according to Schafer¹⁰¹ to exist a functional correlation between the pituitary, suprarenal, pancreas and liver. Any one of these organs may effect normal metabolism through its influence upon the others. The function of the thyroid along this line as yet is imperfectly understood. Noël Paton's¹⁰¹ view of the action of the principles of internal secretions is that, "A certain minimum of each seems to be essential and some proportion between the amounts of each must be maintained if the metabolism is to continue in its normal course----. It seems to me that such a conception is more in accordance with the facts which we possess than that of a series of hormones or excitors directly calling forth the activity of the various tissues".

Nutrition

In connection with the physiological functions of the various organs and glands of the body the amount and kind of food required by the animal must be taken into consideration, as food is essential for the continuation of life and growth. v The earliest belief was that the total amount of food consumed determined the amount of growth. Soon the total energy of the

ration came to be considered the most important factor. From this conclusion food was divided into its different constituents:- proteins, carbohydrates and fats. Following this phase of work in nutrition came the importance of the mineral matter. About this time investigators began to work with "purified foods". This resulted in the division of proteins into their amino-acids and recognized the fact that other things, vitamins and accessories to growth, beside the protein, carbohydrate, fat and mineral content of the ration had to be taken into consideration in order to produce normal growth.

According to Matthews⁶⁷ food fills two great functions:-

(1) It furnishes the material for the formation of new living matter or the replacement of the loss of this matter that is continually going on.

(2) It furnishes a supply of energy for the heat of the body and for the work done by the various cells, the contraction of the muscle, the secretion of the gland, the discharge of the nerve cells, etc..

For the first function protein (or its split products) is absolutely and perhaps is alone needed. The second function is met by any of the three energy yielding food-stuffs, carbohydrates, fats and proteins, especially by the carbohydrates. Rubner⁶⁹ speaking of the function

of protein says, "Growth is a function of the cell; it can be rendered latent by an insufficient supply of protein but protein cannot raise the rapidity of growth above the limits set by nature". He further states, "this behavior of protein during growth is a biological necessity; the relative importance of the physiological functions involved determines the order in which they are filled. First losses are replaced; next growth ensues; thirdly, the usual metabolism of protein for the production of heat occurs".

Protein Metabolism - The food proteids are not identical with the body proteids. This is especially true of the vegetable proteids in the food of the herbivora. Armsby¹ says, "the food proteids must be changed to body proteids. The molecules of the food proteid must be broken down into their constituent atomic groupings^{so} as to permit of a rearrangement and repropotioning of the latter into molecules of body proteids". Following consumption the various food substances are digested or broken down into the building stones:- amino-acids, monosaccharides and fatty acids which are the common basis of all proteins, carbohydrates and fats.

Hawk³⁴ gives protein digestion as the breaking down of the protein molecule by means of cleavage and hydration into proteoses, peptones, polypeptids and amino-acids.

Hart, McCollum, Steenbock and Humphrey²⁹ showed that it was not the quantity but the quality of the protein fed which was the main factor in the protein supply.

Three lots of animals were fed rations balanced from restricted sources. The animals receiving their nutrients from the wheat plant were unable to perform normally and with vigor, all the physiological processes such as general vigor, size and strength of offspring and the capacity for milk secretion. Those receiving their nutrients from the corn plant were strong and vigorous, in splendid condition all the time and reproduced young of great weight. The animals receiving their nutrients from the oat plant were able to perform all the physiological processes of growth, reproduction and milk secretion with a certain degree of vigor but not in the same degree as manifested by the corn fed animals.

McCollum⁵⁰ found the value of some of the grains can be greatly increased by combining them with other grains in mixtures. In such a way the amino-acid shortcomings of the proteins of a certain grain are undoubtedly supplemented by the amino-acid content of the proteins from the others.

From such experiments the significance of the amino-

acids as the fundamental factors in all problems in which hitherto the role of proteins has been involved is evident. It was Folin and Denis¹⁸ that formulated the hypothesis that, "the blood promptly transports the proteins as amino-acids from the intestine to every tissue of the body".

McCollum⁴⁸ and Mendel and Osborne^{90 & 91} have shown that, not all of the known amino-acids need be furnished in the diet in order to secure maintenance or even growth. For example, it is recognized that the animal is capable of synthesizing glycocoll. Abderhalden⁸² has suggested that the organism may be able to synthesize proline from glutaminic acid. He also intimates that arginine may be replaced by ornithine, which readily unites with urea to form arginine. With respect to the possibility of a synthesis of such structural units as alanine, valine, leucine, etc. by the animal organism no positive statement can be made.

The "protein minimum" as expressed by Cathcart⁶ is "the quantity of protein which must be ingested in order to prevent loss of protein from the body". Osborne and Mendel⁸² call this the "maintenance protein requirement". They are of the impression that this is really a requirement for definite amino-acids in place of certain

proteins demanded to repair a hypothetical destruction of the protein molecule.

In respect to the nitrogenous requirements of the organism, growth sets a standard decidedly higher than that of maintenance for certain amino-acids which cannot be synthesized by the growing organism. These must not only be furnished for the maintenance but also for the construction of new tissue. Osborne and Mendel⁹⁰ state that an essential feature of the construction of new tissue is a synthesis of new protein. Growth will, therefore, be limited by any factor preventing this synthesis, such as the lack of any component amino-acid which cannot be manufactured directly in suitable amounts by the body. Lysin, tryptophane and cystin seem to have pronounced effects upon growth when added to an otherwise deficient ration.

Buckner, Nollau and Kastle³ interpreted the experimental data of Osborne and Mendel⁸² as showing that "lysine is primarily responsible for the stimulation of growth". They fed chicks the following mixture:- wheat, wheat bran, sunflower seed, hemp seed and skimmilk and contrasted the results with those obtained with a ration which consisted of barley, rice, hominy, oats and gluten flour. They concluded that the contrasted

difference between the two lots in rate of growth and development was due to the "difference in the amino-acid content of the two rations and in all probability to the difference in the lysine content".

McCollum, Simmonds and Pitz⁶⁶ in their work directed toward ascertaining the supplementary relationships among the naturally occurring foodstuffs have secured data which prohibits the generalization that any one amino-acid, as lysine, is present in the more common vegetable foods in amounts relatively smaller than are other essential amino-acids. From their work they also concluded that neither tyrosine, tryptophane nor cystine was the limiting amino-acid in a mixture of the oat kernel and the maize kernel. That the data supported the view (but did not prove it) that lysine is the amino-acid whose addition alone to the wheat protein mixture raises the biological value of the latter.

Up to the present the following proteins have proven sufficient for normal growth:-

<u>Proteins of animal</u> <u>Origin</u>	<u>Proteins of Vegetable</u> <u>Origin</u>
(1) Casein - - - - (Milk)	(1) Edestin -v- - - (hemp-seed)
(2) Lactalbumin - - (Milk)	(2) Globulin - - - (squash-seed)
(3) Ovalbumin - - (hen's egg)	(3) Excelsin - - - - (Brazil-nut)
(4) Ovotellin - - (hen's egg)	(4) Glutelin - - - - (maize)
	(5) Globulin - - - - (cottonseed)
	(6) Glutenin - - - - (wheat)
	(7) Glycinin - - - - (soybean)
	(8) Cannabin - - - - (hemp-seed)

Proteins known to be inefficient for normal growth:-

(1) Legumelin - - (soybean)	(6) Legumin - - - - (vetch
(2) Vignin - - - (vetch)	(7) Conglutin - - - (blue or yel- low lupin)
(3) Gliadin - (wheat or rye)	(8) Gelatin - - - - (horn)
(4) Legumin - - - (pea)	(9) Zein - - - - - (maize
(5) Hordein - - - (barley)	(10) Phaseolin - - (white kidney bean)

In summarizing Osborne and Mendel⁸⁷ state that when the content of any amino-acid group in a specific protein is relatively small, the comparative poverty in the amino-acid in question will not manifest itself so long as the diet contains a surplus of this amino-acid above either the maintenance or growth quota. If, on the contrary, the intake of the protein is kept low, a plane will ultimately be reached

where the yield of the amino-acid in question becomes so small that it cannot satisfy, first, the growth requirement and later the maintenance need for the nutrient unit, in question, even though the other amino-acids are still available in suitable quantity.

Carbohydrates - For the most part the carbohydrates of a food are considered as the energy portion. They are supposed to be eventually oxidized to carbon dioxide and water. The available carbohydrate material of the body consists of the glycogen found in the tissues, especially in the liver and muscles. From this the sugar of the blood is formed. The sugar content of the blood is kept astonishingly constant, not only during the conditions of ordinary living but under such an abnormal condition as prolonged starvation. The regulation of this supply of sugar to the blood is usually attributed to the liver. An excess of carbohydrates in a ration result in the storage of glycogen in the body. This storage is about equally divided between the liver and muscular tissue. Lusk³⁸ has shown that a number of amino-acids can yield sugar in the body. Glycin, alanin, aspartic and glutaminic acid are examples.

The general value of carbohydrate food as summarized by Howell³⁸ is as follows:-

(1) It furnishes a source of energy for the needs of the tissue cells and particularly for muscular work.

(2) The oxidation of the sugar furnishes an important part of the constant supply of heat needed by the body.

(3) The oxidation of the sugar protects the protein of the body.

(4) Any excess of carbohydrate, taken as food, beyond the power of the tissues to store as glycogen may be synthesized to form fat.

(5) To some extent carbohydrates may be utilized in constructive processes. Nucleic acid contains a carbohydrate group. McCollum⁴⁸ experimenting on growing rats showed that the body can make its own nucleic acid.

The ease with which carbohydrates are consumed and digested, combined with their cheapness, make them the most convenient and economical source of energy of the body.

Mineral Matter - The mineral elements such as calcium, magnesium, potassium, sodium, phosphorus, sulphur, iron and chlorine are required in varying proportions by all animals. According to Howell³⁸ these mineral constituents have very important functions.

"They maintain a normal composition and osmotic pressure in liquids and tissues of the body, and by virtue of their osmotic pressure they play an important part in controlling the flow of water to and from the tissues".

Forbes and Keith²¹ decided that without a doubt there is a certain interdependence of all of the constituents of the body in their metabolism. The less available the supply of any nutrient, compared with the demand for the same, the more definitely does it become the limiting factor in production and the more closely does its metabolism measure that of the body as a whole. Any element, therefore, might become the limiting factor in metabolism.

From numerous experiments made upon growing rats fed upon artificial diets Osborne and Mendel⁸³ showed that, if the necessary proteins, fats and carbohydrates are supplied but the inorganic salts are omitted the animal promptly loses weight and dies. In this case the mineral matter is the limiting factor as the accessories had been taken care of. McCollum and Davis⁵⁶ in their extensive feeding of wheat containing rations conclude that, "the addition of salts alone to a ration derived entirely from wheat or wheat and wheat gluten

gives a diet which is a wonderful improvement, over the grain alone, yet such rations give less than half normal growth and do not suffice for prolonged maintenance".

Those elements in the greatest demand during the growing portion of the life of the animal are calcium and phosphorus.

Waters¹⁰⁷ points out that growth of the skeleton and of the soft parts are independent of one another. He found no advantage in adding ash to a corn ration for swine.

Forbes¹⁹ in working with swine came to the conclusion, "It seems unlikely that, with grown or growing animals any ration composed from natural foods and supplying the nitrogen requirement will fail to furnish enough total phosphorus to maintain phosphorus equilibrium". He is also of the opinion that the effect, if there be any, from adding isolated compounds of phosphorus to the ration is probably limited to the density and strength of the bones.

Phosphorus appears to be independent of calcium to some extent because of its association with nitrogen in the soft parts. On the other hand calcium is closely dependent on phosphorus because it is not stored in considerable amounts except as combined with phosphorus.

Hart, Steenbock, and Fuller³¹ state that the grains are deficient in calcium but rich in phosphorus. The roughages vary widely in calcium content. The straws contain the least, while legume hays are very rich in calcium. They found that additional calcium supplied to the ration of growing swine increases the size of the shaft on the bone, but the length or the rate of growth is not influenced. Woodward¹¹⁰ was unable to draw conclusions from his work except that all functions, to some extent, appear to be dependent upon the mineral matter in the ration.

Our present knowledge is rather limited concerning the mineral requirement for growing animals. From the evidence given it appears that an excess of certain mineral elements have no effect on the length or the rate of growth of the bones in growing swine but they do appear to effect the size of the shaft and the density of them. However, it is evident that mineral matter is very essential for the normal functions of the animal.

Newer Dietary Factors - The question of the possible function of accessory diet factors or "Growth vitamins" in growth has been raised by the studies of Rohman, Hopkins, Hopkins and Neville, McCollum, McCollum

and Davis, Funk, Funk and McCallum, and Osborne and Mendel⁶⁸. They show that all attempts to grow animals on diets consisting of carefully purified and isolated foodstuffs, not the highly complex food mixtures such as constitute the familiar rations of every-day life, sooner or later result in failure.

Attention was first directed toward such factors in the study of the disease beri-beri among the rice eating people of the world. Funk³⁸ found this disease to be due to the eating of polished rice instead of the unpolished. When the unpolished rice was used no such symptoms appeared. He was able to obtain an unknown substance from the polishings of rice and from many other common foods which upon being administered to animals having the symptoms of beri-beri caused the disappearance of these symptoms. He gave the name "vitamine" to such a substance.

A number of investigators have tried to attach this factor of the diet to the fats and oils. As a consequence an immense amount of work has been done to determine the value of such substances as phosphorus, lecithin, cholesterol, cephalin, cerebrosides, glycerides and the phosphatides as the limiting factor of a ration.

In early work it was thought that the natural fats

were indispensable in a ration. Stepp⁷⁸ in working on the subject fed rations that had both the natural fats and lipoids removed. He found his mice to succumb in a few weeks. He concluded that the nutritive failure was due to a lack of certain "lipoid" substances as the addition of alcohol-ether extracts of materials known to be rich in this type of compound sufficed to keep the animals alive. Osborne and Mendel⁷⁸ in their experiments obtained evidence which pointed toward the possibility of lipoid-synthesis in rats, i.e. the "lipoids" in general. They also obtained positive evidence that the true fats are dispensable in growth.

McCollum and Davis⁵³ found that rats could be brought up on mixtures of isolated food substances to what they termed the "critical point". Here growth was suspended but it could be revived by the addition of certain ether-soluble substances to the diet. These were found to be supplied by the ether extract of egg or of butter. They did not believe that young animals could synthesize all the lipoid substances needed.

McCollum, Halpin and Drescher⁶⁰ in feeding experiments with poultry have shown that the hen is able to synthesize lecithin. From their results they conclude, "that the lecithins of the egg yolk are variable in

respect to the nature of the fatty acid radicals they contain and that their nature is influenced by the character of the lipoids of the diet".

Robertson⁹⁵ in his work with white mice found no noticeable difference in the build of his cholesterol-fed animals from the normal ones. Further⁹⁶ lecithin gave a very slight effect, if any, upon the growth of mice.

McArthur and Luckett⁴⁷ obtained results which clearly indicate that lecithin, cephalin, cerebrosides, cholesterol and fats are dispensable parts of a food for mice, but that a substance is present in egg yolk, insoluble in ether, soluble in cold alcohol, and probably easily destroyed by heat that needs to be added to a synthetic food containing casein, starch, lactose, lard and the salts of milk to make it a complete food.

Osborne and Mendel⁸⁸ give the following list of natural fats found to contain the factor efficient in facilitating growth.

1. Butter-fat	4. Kidney fat--(ether-soluble portion of kidney fat free from visible fat)
2. Egg-yolk fat	5. Beef-fat.
3. Cod-liver oil	
-

The natural fats found to give negative results are:-

1. Lard	4. Cottonseed-oil
2. Olive oil	5. Peanut oil
3. Almond oil	

They found the growth promoting factor to remain in the mother liquor of "oil" fractions when the butter-fat and the beef-fat were subjected to fractional crystallization from alcohol.

McCollum and Davis⁵⁵ conclude that, "certain fats occurring in the plant kingdom possess just as pronounced stimulating action on growth as do certain animal fats, although this is by no means true of the plant fats from all sources".

Work up to the present seems to indicate the association of some unknown dietary factor, which limits growth, with certain ones of the natural fats. However, many of the substances which were thought to have a very important function relating to growth have been proven to have an exceedingly minor role, if any.

Osborne and Mendel⁸⁹ found the growth-promoting substance in butter-fat to be very stable when kept under ordinary conditions of storage. However, in the butter "oil", in which the growth-promoting factor is in a more concentrated state than in butter, gradual

deterioration occurred.

McCollum and Davis⁵⁴ found the substance in butterfat which exerts a stimulating influence on growth to be sufficiently stable to withstand the conditions of saponification. By this procedure they were able to transfer this substance from butter to olive oil, getting positive results with olive oil thus treated.

McCollum and Davis⁵⁷ in later work, studying the dietary deficiencies in rice, found that, "there are necessary for normal nutrition during growth two classes of unknown accessory substances, one soluble in fats and accompanying these in the process of isolation of fats from certain foodstuffs and the other soluble in water but apparently not in fats". This water-soluble accessory is also soluble in alcohol. This accessory substance which is soluble in water and in alcohol has been found to be absent from milk fat, stable to heat and prolonged boiling does not injure it to a noticeable degree.

In their work⁵⁹ they conclude that the amount of the accessory substance of either class which is required for growth is small but that above this amount growth seems proportional to the amount of accessories present. As an explanation of the success which various

investigators, as well as themselves, obtained in feeding butterfat and "fat-free" diets they state it to be due to the fact that casein and lactose of good quality still retain amounts of both classes of accessories, which are sufficient to exercise a pronounced effect on growth in young animals.

To these two unidentified accessories McCollum and his assistants have given the names, fat-soluble A and water-soluble B. The working hypothesis----" the necessity of two dietary essentials as yet unidentified in the diet for growth or prolonged maintenance, viz. the fat-soluble A of butterfat and certain other food-stuffs and the water-soluble B" is now supported by nearly one thousand rat feeding experiments, McCollum, Simmonds and Pitz⁶⁴.

From their experiments⁶⁴ they state that these two constituents of the diet pass into the milk only as they are present in the diet of the mother, and that milks vary in their growth promoting power. However, McCollum⁵¹ says the forage portion of the plants is rich in these substances. Therefore, animals like the cow can produce milk of good quality, in respect to these substances as they consume large amounts of roughage. They are also of the opinion that the chemical natures of the fat-soluble A and water-soluble B, whether

these represent in each case a single substance or a group of substances, are of such a character that they cannot be formed within the animal body from any of the cleavage products of the proteins.

McCollum and Kennedy⁶¹ have shown that polyneuritis in birds can be produced by feeding rations deficient in these unknown dietary factors.

McCollum, Simmonds, and Pitz⁶² in a discussion of the earlier work state that, "If a single natural food product fails to nourish an animal adequately it may be due to:- (a) lack of sufficient protein, or proteins of poor quality; (b) an unsatisfactory mineral content due either to inadequacy of certain elements in amount, or to unsatisfactory proportions among them; (c) an inadequate supply of the fat-soluble A; (d) of the water-soluble B; (e) or some toxic substance contained therein. One, two, three, four or all of these factors may operate in inducing nutritive disturbances".

In their study of the wheat embryo they found that it needed the following modifications in order to serve as a satisfactory diet, (1) mineral content modified; (2) Deficient in fat-soluble A (3) toxicity must be removed.

The dietary deficiencies of the maize kernel appeared to be, (1) mineral content needs modification, (2) deficient in fat-soluble A, (3) certain ones of the amino-acids needs to be fortified.

The entire wheat grain, McCollum⁵¹, appears to be deficient as follows:- (1) proteins of poor quality; (2) mineral content; (3) Fat-soluble A; (4) seems to have a toxic principle.

Alfalfa hay appears to contain an abundance of water-soluble B, fat-soluble A and has a high mineral content. About twenty-five per cent., of its nitrogen is of the amide form, but Hart, Humphrey and Morrison²⁷ from their work state that, "On the basis of total nitrogen ingested the utilization of nitrogen for growth was as efficient when the source was from alfalfa hay as when it came from the corn kernel. The full value, at least for growth, can be given to the total nitrogen of alfalfa hay".

The vast knowledge of nutrition thus far gained should be of great value to the question of providing milk substitutes for calf raising if properly applied.

APPLICATION OF PRESENT KNOWLEDGE OF NUTRITION
TO MILK SUBSTITUTES

Recent additions to the knowledge of animal nutrition makes it clear why many attempts made to find a "milk substitute" for calf raising have not met with much success. Until recently it has been assumed that the entire problem was one of supplying a certain amount of digestible protein, carbohydrates and fat in a palatable form and not containing too much crude fibre. In preparing these "milk substitutes" no attention has been given to providing the accessories for growth, to getting the right combination of mineral matter, and the right quality of protein, all which are now known to be of great significance to growth.

Blatchford's calf meal, one of the well known proprietary "milk substitutes", contains 28 per cent of crude protein, 50 per cent carbohydrates, 5.47 per cent fat and 88.68 per cent of dry matter. From the standpoint of food nutrients supplied this calf meal would appear to be satisfactory and further its various ingredients are in similar proportion to that of the milk solids in dried skimmilk, but trials at the New York¹⁰⁰, Massachusetts⁴⁵, and Indiana⁴⁰ Experiment Stations have shown conclusively that it is not an efficient "milk

'substitute". It gave very poor results in all the trials where it was used. This is apparently an example of a ration that has been prepared for the purpose of supplying a sufficient amount of protein and other food nutrients but is deficient in some respect.

In preparing a calf meal it is evident that only those feeds should be included which are easily and highly digestible. The calf being an immature animal needs feed which it can digest and utilize readily. This necessitates keeping the fibre content at a minimum. The following feeds:- finely ground corn, barley malt, flour middlings, wheat flour, oat flakes, oil meal and blood flour have been used with more or less success in connection with the preparation of calf meals. Their actual value in such mixtures has not been determined. Cottonseed meal in any quantity is not to be recommended for young calves. Dry skimmilk is the most valuable substance, next to skimmilk, for feeding calves but its cost is likely to prevent its use.

The successful results obtained with a number of the calf meals may have been due to the fact that they contain a certain amount of powdered skimmilk. This not only contains complete animal proteins but also a

sufficient amount of the growth accessory water-soluble B and a small amount of the fat-soluble A. The mineral content is also a combination such as is desired.

In some of the experiments with "milk substitutes" the feeds given in addition to the calf meal may have been more of a determining factor in the results than was realized by the investigators. For example in all of the various experiments some legume, generally alfalfa hay, has been fed. This hay not only contains a high per cent. of nitrogen in both the protein and amide form but it also has a high mineral content, and contains both the fat-soluble A and water-soluble B in adequate amounts to promote growth. The leaves contain a higher percentage of these accessories to growth than do the stems. A good quality of this hay is also very palatable.

The success Hayward³³ attained in his investigations upon the use of calf meals was probably due largely to the nutrium, a commercial brand of powdered skimmilk, which was in the mixture he fed.

The results Lindsey⁴⁵ obtained can possibly be accredited for the most part to the portion of milk which he fed along with the calf meals.

Savage and Tailby¹⁰⁰ in their work fed whole milk at the first. This along with the legume hay and the grain mixture fed supplementing the calf meal were undoubtedly factors affecting the results.

Hunziker and Caldwell⁴⁰ in their work fed a meal in which there was no powdered milk but it contained animal proteins in the form of blood flour. They also fed legume hay for roughage and a grain mixture along with the calf meal. Table 7 gives the average ration fed to the calves in their three groups and the chemical composition of the same.

Table 7

Average amount of feed consumed and

Chemical composition of the same.

(Purdue University Experiments)

(Lot I, Skimmilk Group)

Feed Consumed	Dry Matter	Crude Protein	Carbo-hydrates	Fat	Ash
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Whole milk					
131.3	15.20	3.74	6.67	3.93	.85
Skimmilk					
2,022.45	203.25	80.08	107.18	.80	15.16
Dry Mash					
178.71	152.22	18.37	122.01	7.14	4.69
Alfalfa Hay					
455.66	418.25	64.74	317.23	6.74	29.52
Corn silage					
61.11	23.94	2.37	19.79	.69	1.09
Total	812.26	169.30	572.88	19.30	51.31

(Lot II, Home-mixed calf meal)

Whole milk					
213.95	24.77	6.09	10.86	6.41	1.39
Home-mixed calf meal					
244.13	218.71	88.99	111.56	11.19	6.96
Dry Mash					
154.012	131.18	15.83	105.15	6.16	4.04
Alfalfa Hay					
397.709	365.05	56.51	276.88	5.88	25.77
Corn Silage					
40.8	15.98	1.58	13.21	.46	.73
Total	755.69	169.00	517.66	30.10	38.89

(Lot III, Blatchford's calf meal)

Whole milk					
447.71	51.83	12.75	22.74	13.42	2.91
Blatchford's calf meal					
195.1	173.01	54.82	97.66	10.67	9.85
Dry Mash					
139.33	118.68	14.32	95.12	5.57	3.65
Alfalfa Hay					
293.88	269.75	41.76	204.59	4.34	19.04
Corn Silage					
38.59	15.12	1.49	12.49	.43	.69
Total	628.39	125.14	432.60	34.44	36.14

Table 7 shows that with the group receiving skimmilk alfalfa furnished 50 per cent of the total dry matter, 38.2 per cent of the protein and 57.6 per cent of the ash. The skimmilk furnished 47 per cent of the protein.

In the ration fed Lot II, receiving the home-mixed calf meal alfalfa furnished 48.3 per cent of the dry matter, 33.4 per cent of the protein and 66.3 per cent of the ash.

Lot III receiving Blatchford's calf meal was supplied with 42.92 per cent of the dry matter, 33.37 per cent of the protein and 52.69 per cent of the ash from the alfalfa.

This data shows that the alfalfa furnished as high a per cent of the various ingredients in the ration received by the different lots as did the calf meal or the skimmilk. In addition to this it supplies both of the accessories for growth, according to McCollum⁵¹. A chemical analysis gives no information as to the presence of these substances. The amount of mineral matter alfalfa adds to a ration is also of great importance. The actual value of alfalfa for feeding to young calves should be appreciated to a greater extent.

Fraser and Brand²² in their work on the minimum amount of milk necessary to insure to calves a satisfactory

start in life were working on one of the fundamental phases of the subject of calf raising.

The probable solution of the question of "milk substitutes" may be to find a combination of feeds, keeping in mind the economical phase of the work, that will produce the most satisfactory growth after discontinuing the use of milk. It is obvious, that in making up this ration for young growing animals we must take into account the dietary factors for growth, fat-soluble A and water-soluble B, mineral content of the right combination and protein of high quality as well as a sufficient amount of food nutrients.

McCollum⁵¹ states that, "Wheat and other grains contain without exception, the water-soluble B but always an inadequate amount of the fat-soluble A". In marked contrast to the dietary properties of the grains stand the forage of the plant. McCollum⁵¹ not only shows that, "The grains all lack an adequate content of the peculiar substance which is found in butterfat, without which growth of an animal cannot proceed, but there is an abundant supply of it in such a feedstuff as alfalfa hay. The other dietary essential, water-soluble B is likewise abundant in alfalfa hay.

In a ration that will produce the most satisfactory

growth after discontinuing the use of milk, alfalfa will undoubtedly be one of the principal parts. Finely ground corn, with probably a portion of ground oats and some blood flour should make a fairly satisfactory grain combination. The amount of these different feeds to put in a mixture would have to be determined experimentally, provided this proved to be a satisfactory combination of the many grains that could be used. When the calf is first changed to such a feed, the alfalfa might add to the efficiency of the ration if it be ground and put in the mixture. The hay which has the greatest proportion of leaves should be used for they contain more of the fat-soluble A and the water-soluble B than do the stems.

In such a mixture the alfalfa will furnish both accessories for growth, fat-soluble A and water-soluble B, mineral matter (calcium principally) and a high per cent of nitrogen, which Hart, Humphrey, and Morrison²⁷ has shown to be as efficient in promoting growth as nitrogen coming from the corn kernel. Alfalfa hay of good quality is also very palatable, but it has a rather laxative affect and must be fed with care in order to keep the calves from scouring. Corn will furnish energy, mineral matter (phosphorus mainly) and its content of water-soluble B.; the oats principally for variety of feed.

The oat grain is higher in crude protein than is corn and in fat it exceeds wheat and nearly equals corn. As oats are rather high in fibre it may be best to omit them from the ration till the calf is at least three months of age. For young calves the oats may be ground and sifted, thereby taking out the greater per cent of the hulls. The blood flour is of special benefit in three ways: It furnishes the fat-soluble A, a suitable mineral addition and adds proteins of high quality. Blood flour also furnishes an exceedingly cheap source of protein.

It would appear from the standpoint of our present knowledge of nutrition, that this combination should fill all of the requirements of a satisfactory ration for young calves.

EXPERIMENTAL WORK

Object of Experiment - The best grade of skim milk powder, which is ordinary skim milk dried, under normal conditions can be purchased at a price equivalent to approximately one dollar per hundred pounds for fresh skim milk. This powdered skim milk keeps indefinitely. Where milk is sold at a high price at retail or wholesale no skim milk is available and the problem is one of feeding some cheaper feed than the whole milk or fail to raise the calf. If dried skim milk is a satisfactory feed its use would make it possible to raise the best calves at a cost much less than would result from feeding the fresh milk. The object of this experiment was to test this possibility. The specific points to be determined were:- (1). The possibility of using powdered skim milk for feeding young dairy calves; (2) The economy of such a practice.

Preliminary Experiment - In starting this work it was decided that a preliminary test should be run and the results obtained used in formulating a plan of procedure for the main experiment. This preliminary test was made with a cross-bred calf from the dairy herd of the College. The ration was fed as follows:-

Period I - Changed gradually from skimmilk to skimmilk powder, feeding it in a liquid form. One pound of the powder skimmilk was mixed with nine pounds of water, giving approximately the composition of ordinary skimmilk.

Period II - Changed from feeding powdered skimmilk, dissolved in water to feeding it in the dry form, mixing it with the grain.

Period III - Changed back to skimmilk and possibly continue changing suddenly from one to the other.

The data for this preliminary work are to be found in Table 8. The amount fed daily was two and one-half pounds of the powdered skimmilk and one and one-half pounds of ground corn for the period when the powdered skimmilk was dissolved in water and fed in liquid form.

In Period II, two and one-half pounds of the powdered skimmilk and two pounds of ground corn were fed. The calf had access to all the alfalfa hay it cared to eat.

The outcome of this test showed that there was no danger from trying to raise calves on powdered skimmilk and that the calf will make ordinary gains when it is fed in liberal amounts.

There was very little difference between Period I, when the powdered skimmilk was fed in liquid form, and

TABLE 8

Preliminary Experiment

Powdered Skimmilk food in Liquid and Dry
form and Results of Sudden Changes

Date	Weight	Total Gain	Daily Gain
	Lbs.	Lbs.	Lbs.
Period I - Liquid Form			
July 11	137.5		
July 18	152.5	15.0	2.14
July 25	162.5	10.0	1.43
August 1	172.5	10.0	1.43
August 9	185.0	12.5	1.78
Average			1.64
Period II - Dry Form			
August 16	197.5		
August 23	202.5	5.0	.71
August 30	220.0	17.5	2.50
September 6	232.5	12.5	1.78
September 13	250.0	17.5	2.50
Average			1.87
Period III - Results of sudden changes.			
September 13	250.0		
September 14	Fed Po. Skimmilk (dry)		
September 15	Fed Skimmilk		
September 16	Fed Po. Skimmilk (wet)		
September 17	Fed Skimmilk		
September 18	Fed Po. Skimmilk (dry)		
September 19	Fed Skimmilk		
September 20	Fed Po. Skimmilk (wet)		
September 20	265.0	15.0	2.14

Period II, when it was fed dry. The results are slightly in favor of feeding powdered skimmilk in the dry condition. This may be due probably to the extra amount of grain the animal received during this period. The wet feeding showed no noticeable advantage over the dry feeding.

In Period III the calf seemed to be very little effected by the sudden changing from feeding the dry to the wet substance. No trouble was experienced with scours and more than average gains were even made with such treatment. Too much stress cannot be laid upon these results as this calf was getting to an age where calves are not easily affected by changing the feed. Whether these results would hold good with a month old calf is very doubtful.

Plan of Main Experiment - With the preliminary test as a guide the following plan was outlined:-

Have three lots of three calves each. A complete record to be kept of the feed consumed and of their growth for the first 180 days of their life.

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 the place of ordinary skimmilk. The powdered skimmilk to

be fed in the dry form mixed with ground corn, equal parts by weight. The calves are to receive this ration until they are 120 days of age. The calves to be then placed upon 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 skim milk and ground corn until they are 90 days of age. The data from this group is expected to indicate to some extent at least the minimum amount of powdered skim milk required.

The feed is to be weighed to these calves and records kept of the weights of the animals together with measurements of growth as represented by height at the withers. The question of the economy of raising calves in this manner is to be studied from the data taken and feed records available of animals raised in the ordinary manner.

Animals used - The greater number of the calves used are from the dairy herd of the College. A few were obtained from local dairymen. The detailed statistics in regard to the number of the calf, breed, sex, date of birth and weight at birth may be found in Table 9. The nine calves used are evenly divided among the three breeds, Ayrshires, Jerseys and Holsteins. Each lot contained an

TABLE 9

Detailed Statistics of Calves Used

Lot	Calf No.	Breed*	Sex**	Date of Birth	Weight at Birth
Lot I	326	Ayrshire	H	Nov. 13, 16	52 Lbs.
	235B	Holstein	B	Nov. 7, 16	77
	105B	Jersey	B	Dec. 3, 16	50
Lot II	301B	Ayrshire	B	Sept. 29, 16	50
	200B	G. Holstein	B	Sept. 29, 16	90
	1B	G. Jersey	B	Nov. 2, 16	52
Lot III	325	Ayrshire	H	Oct. 16, 16	65
	201	G. Holstein	H	Oct. 19, 16	102
	87B	Jersey	B	Nov. 8, 16	77

* G. Before the breed stands for a grade, all others are pure bred animals.

** H. - - Heifer.

B. - - Bull

an animal from each breed.

Stabling - It was impossible at the time to house all of the animals under the same conditions. The calves of Lot I, the skimmilk group, were housed in the main barn in individual pens. They were allowed exercise during the day with other calves of the herd, not on experiment. The calves in Lot II and Lot III were kept in individual pens in a shed open on the south but well protected from the north, west and east. As the weather was very severe at times during the experiment these calves were probably affected to some extent by their environment. They were allowed to exercise in a lot adjoining the shed on the south.

Method of Feeding - All of the calves were fed twice a day from the time they were taken from their mother. They had access to salt and water during the time they were out to exercise, which included the greater portion of the day, when the weather permitted. The calves in Lot I were left with the cow for the first two days. They received their mother's milk for the first week and were then gradually changed to mixed whole milk from the dairy herd. Skimmilk was gradually substituted in place of whole milk, beginning at an age between 2 and 3 weeks. The animals received varying amounts of

ground corn to supplement the skimmilk and alfalfa hay ad libitum.

The calves in Lot II remained with the cow for the first four to six days. They were then fed whole milk for the first five weeks. This was gradually changed to a mixture consisting of powdered skimmilk and ground corn, equal parts by weight. They received from one pound to two and four-tenths pounds of this mixture daily until they were 120 days of age. At this age they were changed to a ration of the following grain mixture:- ground corn 2 parts, ground oats 2 parts, and linseed meal one part by weight. Alfalfa hay was fed ad libitum throughout the experiment.

The calves in Lot III received the same treatment as those in Lot II only they were changed from the mixture of powdered skimmilk and ground corn to the grain mixture at 90 days of age instead of 120 days.

The powdered skimmilk was fed in the dry form as this would be the most practical method for use by the dairyman. It was supplemented with ground corn, for the greatest need, when feeding alfalfa hay and powdered skimmilk is for energy in the ration. No matter how high the price of feeds, corn nearly always remains the cheapest source of energy among the grains. Such a ration contains a sufficient amount of protein of the right kind, contains

enough energy, plenty of mineral matter and has both of the accessories for growth.

The grain mixture used in the later part of the experiment in the feeding of Lot II and Lot III was found by McCollum⁵¹ to give the highest per cent retention of nitrogen of any of the grains or combination of grains used.

The feed records were kept in 10 day periods for economy of time in calculation of results.

Weights and Measurements - The calves were weighed at birth or the beginning of the experiment and at 10 day intervals until 180 days of age. Only one weight was taken. On account of such short periods it was impractical to take the weights for three successive days and determine the average. The use of only one weight, instead of the average of three, causes some rather abrupt variations due to the condition of the animal, but on the whole they show a rather uniform increase.

The height of each calf was taken at birth and at 30 day intervals thereafter. It was not taken as often as the weights, for calves do not grow as fast in height. The height measurement used is an average of three measurements taken at the withers. These measurements are taken the same day, to do this the calf is moved so as to be in a different position for each measurement.

Table 10

Average Dry Matter, Digestible Crude Protein, and
Net Energy Values per 100 pounds for Ruminants*

Feed	Dry Matter	Digestible Crude Protein	Net En- ergy Value
	Lbs.	Lbs.	Therms.
Cow's Milk	13.6	3.3	29.01
Skimmilk (Separator)	9.9	3.6	14.31
Skimmilk (dried)	91.7	34.4	103.91
Alfalfa Hay	91.4	10.6	34.23
Corn (ground)	89.5	7.5	89.16
Oats (ground)	90.8	9.7	67.56
Oil Meal (Old Process)	90.9	30.2	88.91

* Bulletin 142, Pennsylvania Ag. Exp. Sta. 1916.

H. P. Armsby and J. A. Fries.

TABLE 11

FEED CONSUMED, - WEIGHT AND HEIGHT

CALF 326

LOT I

10 da. Periods	Whole Milk	Skim- milk	Ground Corn	Alfalfa Hay	Height	Weight
	Lbs.	Lbs.	Lbs.	Lbs.	Cm.	Lbs.
					61.33*	52*
1	80.0					60
2	96.0	4.0				66
3	9.0	91.0	2.50	4.20	66.16	73
4		71.0				81
5		94.5	2.50	5.00		85
6		105.0	7.25	13.00	70.75	105
7		120.0	6.75	12.25		106
8		126.5	6.25	14.00		121
9		140.0	10.00	16.25	75.83	132
10		140.0	11.75	11.50		142
11		147.0	2.75	20.50		155
12		160.0	14.75	10.25	80.83	170
13		160.0	16.75	27.50		193
14		160.0	17.50	35.75		205
15		158.0	11.25	21.80	86.00	215
Total	185.0	1,677.0	110.00	192.00		

*Height and Weight at Birth.

TABLE 12

NUTRIENTS CONSUMED

CALF 326

10 da. Periods	Dry Matter	Digestible Crude Protein	Energy
	Lbs.	Lbs.	Therms
1	10.88	2.64	23.21
2	13.46	3.31	28.42
3	16.30	4.22	19.30
4	7.03	2.56	10.16
5	16.17	4.12	17.46
6	28.77	5.70	25.94
7	29.12	6.13	27.38
8	30.91	6.50	28.46
9	37.66	7.51	34.51
10	34.89	7.14	34.45
11	35.75	7.67	30.51
12	38.41	7.96	39.56
13	55.97	9.94	47.24
14	64.18	10.86	50.74
15	45.64	8.84	40.10
Total	465.14	95.10	457.44

TABLE 13
FEED CONSUMED - Weight and Height
CALF 235 B

LOT I

10 da. Periods	Whole Milk	Skim- milk	Ground Corn	Alfalfa Hay	Height	Weight
	Lbs.	Lbs.	Lbs.	Lbs.	Cm.	Lbs.
					71.00*	77*
1	96.0					85
2	120.0					94
3	84.0	36.0	.80	2.75	76.25	101
4		70.0				94
5		73.0	2.20	3.25		105
6		78.0	2.00	7.00	78.16	110
7		102.0	7.25	6.00		130
8		120.0	5.50	12.00		131
9		134.5	10.75	18.75	83.66	152
10		147.5	11.50	13.25		165
11		149.4	10.00	17.50		181
12		158.0	15.00	23.00	88.83	195
13		160.0	20.00	26.25		180
14		160.0	19.00	36.00		225
15		158.0	20.00	29.50	93.66	247
Total	300.0	1,546.4	124.00	195.25		

*Height and Weight at Birth.

TABLE 14
NUTRIENTS CONSUMED

CALF 235B

10 da. Periods	Dry Matter	Digestible Crude Protein	Energy
	Lbs.	Lbs.	Therms
1	13.05	3.17	27.85
2	16.32	3.96	34.81
3	18.21	4.42	31.16
4	6.93	2.52	10.02
5	12.17	3.14	13.52
6	15.91	3.70	15.34
7	22.07	4.85	23.11
8	27.77	6.00	26.18
9	40.08	7.64	35.25
10	37.00	7.57	35.90
11	39.74	7.99	36.29
12	50.09	9.26	43.85
13	57.73	10.04	49.72
14	65.74	11.01	52.16
15	60.50	10.32	50.54
Total	483.31	95.59	485.70

TABLE 15
FEED CONSUMED -WEIGHT AND HEIGHT
CALF 105B
LOT I

10 da. Periods	Whole Milk	Skim- milk	Ground Corn	Alfalfa Hay	Height	Weight
	Lbs.	Lbs.	Lbs.	Lbs.	Cm.	Lbs.
					66.75*	50*
1	69.0					60
2	75.5					66
3	83.5				69.66	80
4	80.0	20.0	2.00	3.50		88
5		120.0	3.50	10.00		100
6		122.5	5.00	10.60	76.50	112
7		140.0	10.00	17.90		122
8		139.0	5.75	12.00		129
9		147.0	11.75	13.25	82.00	152
10		160.0	20.75	18.50		169
11		160.0	19.00	32.00		193
12		160.0	30.00	23.25	87.66	200
13		158.0	11.00	15.05		220
14		160.0	12.30	25.55		243
15		160.0	17.70	28.45	92.00	255
Total	308.0	1,646.5	148.75	210.05		

*Height and Weight at Birth.

TABLE 16
NUTRIENTS CONSUMED
CALF 105B

10 da. Periods	Dry Matter	Digestible Crude Protein	Energy
	Lbs.	Lbs.	Therms
1	9.38	2.28	20.02
2	10.27	2.49	21.90
3	11.36	2.76	24.22
4	17.85	3.88	29.05
5	24.15	5.64	23.71
6	26.30	5.91	25.62
7	39.17	7.69	35.08
8	29.88	6.70	29.13
9	37.18	7.57	36.06
10	51.32	9.28	47.73
11	62.09	10.58	50.79
12	63.94	10.47	57.60
13	39.25	8.12	37.57
14	50.20	9.39	42.62
15	57.68	10.11	48.42
Total	530.02	102.87	529.52

TABLE 17FEED CONSUMED - WEIGHT AND HEIGHTCALF 301 BLOT II

10 da. Periods	Whole Milk	Po.Skim Milk	Ground Corn	Alfalfa Hay	Grain Mixt.	Height	Weight
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cm.	Lbs.
						64.66*	50*
1	57.0						65
2	91.0						67
3	83.5	2.40	2.40			66.83	77
4	68.0	5.00	5.00				75
5	65.5	3.45	3.45	1.70			82
6	10.0	7.05	7.05	4.50		69.08	89
7		8.90	8.90	12.30			95
8		10.00	10.00	24.40			100
9		10.00	10.00	24.40		70.80	123
10		10.00	10.00	22.40			125
11		10.00	10.00	26.60			142
12		10.10	10.10	29.00		74.83	137
13		4.20	4.20	34.60	15.6		160
14				30.60	24.0		167
15				33.19	25.9	78.00	173
16				35.70	31.3		185
17				34.50	32.0		198
18				53.30	32.0	84.66	213
Total	375.0	81.1	81.1	367.19	160.8		

* Height and Weight at Birth.

TABLE 18NUTRIENTS CONSUMEDCALF 301 B

10 days Periods	Dry Matter	Digestible Crude Protein	Energy
	Lbs.	Lbs.	Therms
1	7.75	1.88	16.54
2	12.38	3.00	26.40
3	15.71	3.77	28.85
4	18.32	4.34	29.39
5	16.71	3.79	26.24
6	18.24	3.77	18.06
7	27.37	5.03	21.40
8	40.42	6.78	27.66
9	40.42	6.78	27.66
10	38.59	6.56	26.98
11	42.43	7.01	28.42
12	44.80	7.30	29.42
13	53.27	7.46	32.42
14	49.57	6.36	29.67
15	53.65	6.89	32.08
16	60.80	7.85	37.26
17	60.33	7.82	37.41
18	77.52	9.81	43.84
Total	678.28	106.20	519.70

TABLE 19

FEED CONSUMED - WEIGHT AND HEIGHT

CALF 200 B

LOT II

10 da. Periods	Whole Milk	Po.Skim Milk	Ground Corn	Alfalfa Hay	Grain Mixt.	Height	Weight
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cm.	Lbs.
						72.00*	90*
1	52.5						95
2	77.0						99
3	75.0	2.40	2.40			74.66	97
4	62.0	5.00	5.00				108
5	56.0	5.20	5.20	5.6			115
6	4.0	10.90	10.90	15.2		78.25	134
7		12.00	12.00	20.2			138
8		12.00	12.00	29.8			141
9		12.00	12.00	35.8		81.33	170
10		10.50	10.50	27.0			157
11		9.05	9.05	34.2			182
12		10.10	10.10	37.7		82.50	175
13		4.20	4.20	43.7	14.4		185
14				43.7	22.8		202
15				36.0	25.9	85.50	202
16				56.4	31.3		228
17				51.5	32.0		238
18				59.2	32.0	90.00	255
Total	326.5	93.4	93.4	496.0	158.4		

*Height and Weight at Birth

TABLE 20

NUTRIENTS CONSUMED

CALF 200 B

10 da. Periods	Dry Matter	Digestible Crude Protein	Energy
	Lbs.	Lbs.	Therms
1	7.14	1.73	15.23
2	10.47	2.54	22.34
3	14.55	3.49	26.39
4	17.50	4.15	27.65
5	22.16	4.62	28.21
6	34.27	6.33	27.50
7	40.20	7.17	30.08
8	48.98	8.19	33.37
9	54.46	8.82	35.42
10	43.71	7.26	29.51
11	47.66	7.42	28.88
12	52.76	8.23	32.40
13	60.51	8.26	34.58
14	60.46	7.59	33.20
15	56.21	7.19	33.04
16	79.72	10.05	44.35
17	75.87	9.62	43.23
18	82.91	10.44	45.86
Total	809.54	123.10	571.24

TABLE 21

FEED CONSUMED - WEIGHT AND HEIGHT

CALF 1B

LOT II

10 da. Periods	Whole Milk	Po.Skim Milk	Ground Corn	Alfalfa Hay	Grain Mixt.	Height	Weight
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cm.	Lbs.
						65.33*	52*
1	32.0						53
2	62.0						60
3	60.0					67.00	64
4	51.0	.95	.95	6.00			67
5	19.0	4.25	4.26	6.00			73
6		6.00	6.00	11.40		68.00	76
7		6.00	6.00	14.40			88
8		5.70	5.70	16.00			89
9		8.90	8.90	20.80		70.75	93
10		10.40	10.40	11.70			99
11		8.80	8.80	15.20			97
12		12.10	12.10	20.00		72.16	115
13		3.80	3.80	24.80	20.7		125
14				29.50	24.8		137
15				54.60	26.9	78.50	145
16				33.30	28.0		160
17				39.85	28.0		187
18				29.20	28.0	82.83	191
Total	224.0	66.90	66.90	332.75	156.4		

*Height and Weight at Birth.

TABLE 22

NUTRIENTS CONSUMED

CALF 1B

10 da. Periods	Dry Matter	Digestible Crude Protein	Energy
	Lbs.	Lbs.	Therms
1	4.35	1.06	9.28
2	8.43	2.05	17.99
3	8.16	1.98	17.41
4	14.14	2.72	18.69
5	15.76	3.05	15.77
6	21.29	3.72	15.48
7	24.03	4.04	16.51
8	24.95	4.09	16.48
9	35.14	5.93	24.31
10	29.54	5.60	24.08
11	29.84	5.30	22.19
12	40.20	7.19	30.21
13	48.18	6.92	32.39
14	49.28	6.35	29.94
15	74.11	9.29	40.21
16	55.64	7.17	33.80
17	61.62	7.86	36.04
18	51.89	6.74	32.40
Total	596.55	91.06	433.18

TABLE 23

Feed Consumed - Weight and HeightCALF 325LOT III

10 da. Periods	Whole Milk	Po.Skim- milk	Ground Corn	Alfalfa Hay	Grain Mixt.	Height	Weight
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cm.	Lbs.
						66.91*	65*
1	42.0						68
2	77.0	1.20	1.20				73
3	60.0	2.95	2.95			68.33	75
4	27.0	4.62	4.62	2.7			83
5		6.25	6.25	5.4			85
6		7.75	7.75	20.4		70.16	88
7		8.00	8.00	19.0			104
8		8.00	8.00	19.6			105
9		8.00	8.00	26.6		73.33	113
10		4.20	4.20	26.6	5.8		110
11				30.0	19.6		118
12				21.0	24.0	76.58	132
13				26.1	24.4		133
14				39.7	30.4		145
15				19.7	32.0	79.00	155
16				30.1	32.0		165
17				44.9	32.6		175
18				51.3	34.0	84.33	192
Total	206.0	50.97	50.97	383.1	234.8		

* Height and Weight at Birth.

TABLE 24

NUTRIENTS CONSUMEDCALF 325

10 da. Periods	Dry Matter	Digestible Crude Protein	Energy
	Lbs.	Lbs.	Therms
1	5.71	1.39	12.18
2	12.64	3.04	24.66
3	13.51	3.21	23.11
4	14.51	3.04	17.67
5	16.26	3.19	13.91
6	32.70	5.41	21.94
7	31.87	5.36	21.94
8	32.41	5.43	22.15
9	38.81	6.17	24.55
10	37.14	5.33	21.85
11	45.06	5.73	25.95
12	40.79	5.35	26.39
13	45.82	5.94	28.45
14	63.65	8.16	37.91
15	46.81	6.25	32.34
16	56.31	7.35	35.90
17	70.38	9.00	41.45
18	77.49	9.86	44.76
Total	681.87	99.21	477.11

TABLE 25FEED CONSUMED - WEIGHT & HEIGHTCALF 201LOT III

10 da. Periods	Whole Milk	Po.Skim Milk	Ground Corn	Alfalfa Hay	Grain Mixt.	Height	Weight
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cm.	Lbs.
						76.33*	102.0
1	84						107.5
2	121						115.0
3	88	1.62	1.62	4.20		79.25	128.0
4	4	8.60	8.60	7.00			139.0
5		9.85	9.85	11.60			147.0
6		12.00	12.00	20.80		81.25	150.5
7		12.00	12.00	27.40			183.0
8		12.00	12.00	32.00			192.0
9		12.00	12.00	36.00		86.16	205.0
10		2.55	2.55	36.40	18.9		198.0
11				41.80	22.4		220.0
12				42.00	22.0	88.16	237.0
13				32.30	24.5		240.0
14				46.70	31.3		260.0
15				56.70	32.0	92.00	270.0
16				56.30	32.1		286.0
17				71.55	35.2		302.0
18				37.90	36.0	95.66	323.0
Total	297.0	70.62	70.62	560.65	254.4		

*Height and Weight at Birth.

TABLE 26NUTRIENTS CONSUMEDCALF 201

10 da. Periods	Dry Matter	Digestible Crude Protein	Energy
	Lbs.	Lbs.	Therms
1	11.42	2.77	24.37
2	16.46	3.99	35.10
3	18.75	4.03	20.09
4	22.53	4.48	20.17
5	28.45	5.36	22.99
6	40.75	7.23	30.29
7	46.78	7.93	32.55
8	50.99	8.42	34.12
9	54.64	8.85	35.49
10	54.90	7.39	32.50
11	58.36	7.34	32.23
12	58.19	7.31	31.98
13	51.57	6.61	30.66
14	70.85	9.02	41.03
15	80.62	10.17	45.01
16	80.34	10.14	44.95
17	97.07	12.16	52.65
18	67.04	8.70	41.77
Total	909.71	131.90	617.95

TABLE 27

FEED CONSUMED - WEIGHT AND HEIGHTCALF 87 BLOT III

10 da. Periods	Whole Milk	Po.Skim Milk	Ground Corn	Alfalfa Hay	Grain Mixt.	Height	Weight
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cm.	Lbs.
1	70.0					73.16*	77*
2	100.0						78
3	99.0	.10	.10	2.50		78.92	95
4	40.0	4.60	4.60	8.50			100
5		7.00	7.00	11.80			123
6		7.00	7.00	20.00		80.41	125
7		6.80	6.80	20.00			126
8		8.80	8.80	20.20			131
9		10.65	10.65	25.80		81.16	132
10		3.50	3.50	28.00	7.2		140
11				29.20	19.3		143
12				40.30	26.2	83.00	160
13				37.60	32.0		175
14				42.80	32.1		185
15				36.35	34.0	88.16	197
16				34.95	34.0		213
17				29.55	34.0		216
18				48.10	34.0	94.00	245
Total	309.0	48.45	48.45	435.65	252.8		

*Height and Weight at Birth.

TABLE 28

NUTRIENTS CONSUMEDCALF 87B

10da. Periods	Dry Matter	Digestible Crude Protein	Energy
	Lbs.	Lbs.	Therms
1	9.52	2.31	20.31
2	13.60	3.30	29.01
3	15.93	3.59	29.77
4	21.55	4.15	23.39
5	23.48	4.19	17.55
6	30.97	5.06	20.36
7	30.61	4.97	19.98
8	34.41	5.83	23.90
9	42.88	7.19	29.40
10	38.41	5.37	22.10
11	44.06	5.61	25.44
12	60.41	7.68	34.75
13	63.17	8.15	38.47
14	68.01	8.71	40.33
15	63.82	8.27	39.64
16	62.54	8.12	39.16
17	57.61	7.55	37.31
18	74.56	9.52	43.66
Total	755.54	109.57	534.53

TABLE 29

Summary of Total Feed Consumed*180 days

No. of Calf	Whole Milk	Skim-milk	Ground Corn	Alfalfa Hay	Grain Mixture	Digestible C. Protein	Energy
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Therms
Lot I ¹							
326	185	1,677.0	110.00	192.00		95.10	457.44
235B	300	1,546.4	124.00	195.25		95.59	485.70
105B	308	1,646.5	148.75	210.05		102.87	529.52
Lot II							
301B	375.0	81.1**	81.1	367.19	160.8	106.20	519.70
200B	326.5	93.4	93.4	496.00	158.4	123.10	571.24
1B	224.0	66.9	66.9	332.75	156.4	91.06	433.18
Lot III							
325	206	50.97	50.97	383.10	234.8	99.21	477.11
201	297	70.62	70.62	560.65	254.4	131.90	617.95
87B	309	48.45	48.45	435.65	252.8	109.57	534.53

* The data on Lot I is for only 150 days.

** Powdered skimmilk.

1 Lot I - Skimmilk

Lot II - Powdered Skimmilk for 120 days

Lot III - Powdered skimmilk for 90 days.

Feeding Standard - No feeding standard was followed. The calves were fed all they would consume and still keep in good physical condition. The total dry matter, digestible crude protein and energy were calculated from the analyses, given in Table 10, taken from the Pennsylvania Bulletin 142 by Armsby and Fries.

Total Feed Consumed - The total feed consumed by the calves of the different lots is shown in Table 29. The individual calf in each lot which made the best gains and looked the most thrifty was the one which consumed the largest amount of feed of any calf of that group. The calves on the powdered skimmilk, grain and hay consumed a larger amount of alfalfa hay than did those which were fed skimmilk.

Data on Lot I are only reported for 150 days instead of 180 since the calves were not available at a date early enough to allow for a six month feeding period to be completed before the date set for the completion of thesis. In five months the calves of Lot I consumed an average of 264 pounds whole milk, 1,629.3 pounds of skimmilk, 127.6 pounds of corn and 199.1 pounds of alfalfa hay.

The calves of Lot II received an average of 308.5 pounds of whole milk, 80.5 pounds of powdered skimmilk, 80.5 pounds of ground corn, 398.7 pounds of alfalfa hay and 158.5 pounds of the grain mixture.

The calves of Lot III used an average of 270.7

pounds of whole milk, 56.7 pounds powdered skim milk, 56.7 pounds of ground corn, 459.8 pounds of alfalfa hay and 247.3 pounds of the grain mixture.

Nutrients Received by Calves - The total feed consumed and the nutrients contained is shown in Tables 11 to 28 inclusive. The height of the calves at withers and the weights are also shown in the same tables. Table 30 gives the average amount of nutrients received by the calves in the different lots, also what portion of the nutrients is furnished by the different feeds. In Lot I the Jersey 105B received the largest amount of nutrients for the lot, the Holstein calf 235B next, and the Ayrshire 326 last. In Lot II the Holstein 200B received the most nutrients, the Ayrshire 301B next and the Jersey 1B last. In Lot III the Holstein 201 received the most nutrients, the Jersey 87B next, and the Ayrshire 325 last.

The calves in Lot I received 59.7 per cent of their digestible crude protein from the skim milk and 21.6 per cent from the alfalfa hay. They received 47.3 per cent of their energy from the skim milk, 23 per cent from the ground corn and 13.8 per cent from the alfalfa.

For Lot II the powdered skim milk furnished 25.9 per cent of the digestible crude protein and 16.4 per cent of the energy. Alfalfa furnished 39.5 per cent of the

TABLE 30

Average Nutrients Consumed - 180 days*

Average feed Consumed		Dry Matter	Digestible C. Protein	Energy
Lbs.		Lbs.	Lbs.	Therms
Lot I¹				
Whole Milk	264.00	35.95	8.72	76.68
Skimmilk	1,629.30	160.70	58.44	232.29
Ground Corn	127.58	114.19	9.57	113.76
Alfalfa Hay	199.11	181.98	21.11	68.15
Total		492.82	97.84	490.88
Lot II				
Whole Milk	308.50	41.95	10.18	89.50
Po. Skimmilk	80.46	73.79	27.68	83.61
Ground Corn	80.46	72.02	6.04	71.75
Alfalfa Hay	398.65	364.36	42.26	136.46
Grain Mixture	158.50	142.68	20.61	126.83
Total		694.80	106.77	508.15
Lot III				
Whole Milk	270.70	36.81	8.93	78.52
Po. Skimmilk	56.68	51.98	19.50	58.90
Ground Corn	56.68	50.73	4.25	50.53
Alfalfa Hay	459.80	420.25	48.74	157.39
Grain Mixture	247.30	222.60	32.15	197.86
Total		782.37	113.57	543.20

* The data on Lot I is for only 150 days.

¹ Lot I - Skimmilk

Lot II - Powdered Skimmilk for 120 days

Lot III- Powdered Skimmilk for 90 days

digestible crude protein and 26.8 per cent of the energy. The grain mixture furnished 19.3 per cent of the digestible crude protein and 24.9 per cent of the energy.

For Lot III the powdered skimmilk furnished 17.1 per cent of the digestible crude protein and 10.8 per cent of the energy. The alfalfa furnished 42.9 per cent of the digestible crude protein and 28.9 per cent of the energy. The grain mixture furnished 28.3 per cent of the digestible crude protein and 36.4 per cent of the energy.

The calf in each lot that showed the largest gains in weight, as well as being in the best of condition, was the one which received the greatest amount of nutrients.

Protein Consumed - Tables 31, 32 and 33 gives the amount of protein received by the different calves and the amount fed daily by thirty day periods.

The calves in Lot I received an average of 0.32 pound of digestible crude protein per day at the beginning of the test. This was gradually increased to the fifth month when they received an average of 0.99 pounds per day.

The calves in Lot II received an average of 0.24 pound of digestible crude protein at the beginning of the test. This was gradually increased until the sixth month, when they received an average of 0.86 pound per day.

The average amount of digestible crude protein received by the calves in Lot III during the first part of the

TABLE 31
Protein and Energy Received
by 30 Day Periods
Lot I (Skimmilk group)

Period	Total Dig. C. Protein Lbs.	Total Energy Therms	Dig.C.Protein Aver. per day Lbs.	Energy Aver.per da. Therms
Calf 326				
1	10.17	70.93	.34	2.26
2	12.38	53.56	.41	1.79
3	20.14	90.35	.67	3.01
4	22.77	104.52	.76	3.48
5	29.64	138.08	.99	4.60
Total	95.10	457.44		
Average	19.02	91.49	.63	3.05
Calf 235B				
1	11.55	93.82	.39	3.13
2	9.36	38.88	.31	1.30
3	18.49	84.54	.62	2.82
4	24.82	116.04	.83	3.87
5	31.37	152.42	1.05	5.08
Total	95.59	485.70		
Average	19.12	97.14	.64	3.24
Calf 105B				
1	7.53	66.14	.25	2.20
2	15.43	78.38	.51	2.61
3	21.96	100.27	.73	3.34
4	30.33	156.12	1.01	5.20
5	27.62	128.61	.92	4.29
Total	102.87	529.52		
Average	20.57	105.90	.69	3.53

TABLE 32
Protein and Energy Received
by 30 Day Periods
Lot II (Po.Skimmilk,120 days)

Period	Total Dig. C. Protein	Total Energy	Dig. C. Protein Aver. per day	Energy Aver. per da.
	Lbs.	Therms	Lbs.	Therms
Calf 301B				
1	8.65	71.79	.29	2.39
2	11.90	73.69	.40	2.46
3	18.59	76.72	.62	2.56
4	20.87	84.82	.70	2.83
5	20.71	94.17	.69	3.14
6	25.48	118.51	.85	3.95
Total	106.20	519.70		
Average	17.70	86.62	.59	2.89
Calf 200B				
1	7.76	63.96	.26	2.13
2	15.10	83.36	.50	2.78
3	24.18	98.87	.81	3.30
4	22.91	90.79	.76	3.03
5	23.04	100.82	.77	3.36
6	30.11	133.44	1.00	4.45
Total	123.10	571.24		
Average	20.52	95.21	.68	3.17
Calf 1B				
1	5.09	44.68	.17	1.49
2	9.49	49.94	.32	1.66
3	14.06	57.30	.47	1.91
4	18.09	76.48	.60	2.55
5	22.56	102.54	.75	3.42
6	21.77	102.24	.73	3.41
Total	91.06	435.18		
Average	15.18	72.20	.50	2.41

TABLE 33
Protein and Energy Received
by 30 Day Periods
Lot III (Po.Skimmilk, 90 days)

Period	Total Dig. C.Protein	Total Energy	Dig.C.Protein Aver,per day	Energy Aver.per da.
	Lbs.	Therms	Lbs.	Therms
Calf 325				
1	7.64	59.95	.25	2.00
2	11.64	53.52	.39	1.78
3	16.96	68.64	.57	2.29
4	16.41	74.19	.55	2.47
5	20.35	98.70	.68	3.29
6	26.21	122.11	.87	4.07
Total	99.21	477.11		
Average	16.52	79.52	.55	2.65
Calf 201				
1	10.79	89.56	.36	2.99
2	17.07	73.45	.57	2.45
3	25.20	102.16	.84	3.41
4	22.04	96.71	.73	3.22
5	25.80	116.70	.86	3.89
6	31.00	139.37	1.03	4.65
Total	131.90	617.95		
Average	21.98	102.99	.73	3.43
Calf 87B				
1	9.20	79.09	.31	2.64
2	13.40	61.30	.45	2.04
3	17.99	73.28	.60	2.44
4	18.66	82.29	.62	2.74
5	25.13	118.44	.84	3.95
6	25.19	120.13	.84	4.00
Total	109.57	534.53		
Average	18.26	89.09	.61	2.97

TABLE 34
Energy Received for Growth
180 Days*

No. of Animal	Average Weight	Total Energy	Energy for Main- tenance	Energy for Growth	Total Gain	Growth, Energy for a lb. gain.
	Lbs.	Therms	Therms	Therms	Lbs.	Therms
Lot I ¹						
326	133.5	457.44	235.80	221.64	163	1.36
235B	162.0	485.70	267.45	218.25	170	1.28
105B	152.5	529.52	256.89	272.63	205	1.33
Lot II						
301B	131.5	519.70	279.28	240.42	163	1.47
200B	172.5	571.24	334.66	236.58	165	1.43
1B	121.5	433.18	264.93	168.25	139	1.21
Lot III						
325	128.5	477.11	275.01	202.10	127	1.59
201	212.5	617.95	384.58	233.37	221	1.06
87B	161.0	534.53	319.62	214.91	168	1.28

* The data on Lot I is for only 150 days.

1 Lot I Skimmilk

Lot II Powdered skimmilk for 120 days

Lot III Powdered skimmilk for 90 days

test was 0.31 pound per day. This was gradually increased to 0.91 pound during the sixth month of the test.

There is no apparent relation between the amount of protein received and the gains in weights made by the calves of the different lots.

Energy for Growth - Table 34 shows the total energy available for growth above maintenance. This is calculated on the basis that six therms of energy are the daily requirements for the maintenance of 1,000 pounds of live weight. The requirement at the given weight of the animal was found by the following formula: $\text{Therms} = 6 \times \text{No. of days} \times \left(\frac{\text{live wt.}}{1,000} \right)^{2/3}$. In growth in weight the calves in each lot showed a relation between the amount of energy received above maintenance and their gain in weight. The calf that received the largest amount of energy for growth in each lot made the largest gain.

The calves in all the lots required an average of 1.33 therms of energy for a pound gain with a variation of from 1.06 therms to 1.59 therms. The calf that made the largest gain required the 1.06 therms while the calf that made the smallest gain required the 1.59 therms.

Dry Matter - The total amount of dry matter consumed and its proportion to the live weight of the calf is shown in Table 35. Lot I shows a marked contrast in the amount of dry matter consumed, to that consumed by Lots II and III. This lot received a large portion of its nutrients from skimmilk. A larger per cent of these nutrients are

TABLE 35

Total Dry Matter Consumed

180 Days *

No. of Animal	Average Weight Lbs.	Total Dry Matter Lbs.	Total Gain Lbs.	Dry Matter per lb. Live Weight Lbs.
Lot I ¹				
326	133.5	465.14	163	3.48
235B	162.0	483.31	170	2.98
105B	152.5	530.02	205	3.48
Lot II				
301B	131.5	678.28	163	5.20
200B	172.5	809.54	165	4.70
1B	121.5	596.55	139	4.91
Lot III				
325	128.5	681.87	127	5.30
201	212.5	909.71	221	4.30
87B	161.0	755.54	168	4.70

* The data for Lot I is for only 150 days.

1 Lot I Skimmilk

Lot II Powdered Skimmilk for 120 days

Lot III Powdered Skimmilk for 90 days.

utilized than are those found in the hay and grain. The amount of dry matter per pound of live weight for Lots II and III varied from 4.3 to 5.3 pounds with an average of 4.9 pounds. The dry matter for Lot I ranged from 2.98 to 3.48 pounds with an average of 3.3 pounds.

Gains in Weight - Tables 36 gives the weight of the calves at birth, their weight at the end of the feeding period and the daily gain made. The calves in Lot I show more uniform gains, all being over a pound a day with an average of 1.20 pounds. Those in Lot II show an average of 0.86 pounds while those in Lot III made an average daily gain of 0.95 pounds. The individuality of the calves is a factor that has a very important part in determining the growth which they make. Calf 325 in Lot III averaged only 0.71 pounds per day while calf 201 in the same lot made a daily gain of 1.23 pounds. All of the calves in Lots 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.

Height at Withers - The total growth in height at withers, measured in centimeters is shown in Table 37. The actual gains are compared with the normal gains for the same period of time in the life of calves. The normal gain for Ayrshires is that given by Burlingham and Gillette⁴

TABLE 36
Gains in Weight
180 Days*

No. of Animal	Birth Weight	Final Weight	Total Gain	Daily Gain
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I ¹				
326	52	215	163	1.09
235B	77	247	170	1.13
105B	50	255	205	1.37
Lot II				
301B	50	213	163	0.91
200B	90	255	165	0.91
1B	52	191	139	0.77
Lot III				
325	65	192	127	0.71
201	102	323	221	1.23
87B	77	245	168	0.93

* The data on Lot I is for only 150 days.

¹ Lot I Skimmilk

Lot II Powdered skimmilk for 120 days

Lot III Powdered skimmilk for 90 days.

The weights of these calves increase in a rather uniform proportion to the normal. The calf fed skimmilk approaches nearest the normal with the calf on powdered skimmilk for 120 days next and the one on powdered skimmilk 90 days farthest below the normal.

These weights show the calf fed powdered skimmilk for only 90 days to be nearest the normal with the calf fed fresh skimmilk next and the calf from Lot II, fed powdered skimmilk 120 days farthest below the normal.

Fig. 3- Limits of Variations in Weights from which the normal was calculated and the Weight of the Holstein in Lots I, II, III.

The Holstein fed powdered skimmilk 90 days is within the limits of variations of the normal weights throughout the trial while both the calf fed fresh skimmilk and the one fed powdered skimmilk for 120 days are slightly below the lower limit.

These weights show the calf fed skimmilk to be above normal. The calf fed powdered skimmilk 120 days has been far below normal but gained rapidly near the end of the trial. The calf fed powdered skimmilk 90 days was above normal at birth but is below at the end of the trial.

The Figure shows the Jersey in each of the Lots to be within the range of the variations of the normal weight. The calf fed skimmilk is at the upper extreme while the calf fed powdered skimmilk 120 days is on the lower extremity.

TABLE 37

Height at Withers

From 1 mo. - to 6 mo. of age*

No. of Animal	Gain cm.	Normal Gain cm.	Difference cm.**
Lot I ¹			
326	19.84	20.5	-0.66
235B	17.41	19.7	-2.29
105B	22.34	19.0	3.34
Lot II			
301B	17.83	24.5	-6.67
200B	15.34	24.1	-8.76
1B	15.83	23.4	-7.57
Lot III			
325	16.00	24.5	-8.50
201	16.41	24.1	-7.69
87B	15.08	23.4	-8.32

* Data on Lot I is only from 1 mo. to 5 mos.

The sign (-) indicates below normal

¹ Lot I Skimmilk

Lot II Powdered Skimmilk for 120 days.

Lot III Powdered Skimmilk for 90 days.

The Ayrshire in each group is below the normal height but the calf fed skimmilk is following the normal curve more closely than the others.

Fig. 7.--Height at withers of the
Holstein in Lots I, II, III.
Plotted directly in centi-
meters. Tables 13, 19, 25.

The Holstein in each lot is below the normal curve.
The calf fed skimmilk approaches nearest with the calf
fed powdered skimmilk for 90 days next.

The calf fed fresh skimmilk was within the limits of the normal at the end of the trial. The calf fed powdered skimmilk for 90 days was just slightly below while the calf fed for 120 days was below, except at the beginning.

Fig. 9.-Height at withers of the
Jersey in Lots I, II, III.
Plotted directly in centi-
meters. Tables 15,21,27.

Days

The Jersey fed skimmilk has been above normal in height throughout the trial, except at beginning. The calves on powdered skimmilk do not show such a rapid increase in height as, 105B, the one on skimmilk.

Days

Fig. 10.-Limits of variation in height measurements from which the normal height for Jerseys was calculated and the height of the Jersey in Lots I, II, III.

— Normal Height 105
 - - - Variations.
 — 105B Lot I
 — 1B Lot II
 — 87B Lot III

The calf fed fresh skimmilk and one of those on powdered skimmilk are within the limits of variations of the normal height.

in their thesis, "Standard Growth". The normal gains for the Jersey and Holstein are those given by Swett¹⁰⁵ in his thesis, "Growth of Dairy Animals". It is shown in this Table that those calves fed skimmilk were nearest the normal gain. The Holstein 201, in Lot III, started at a much higher plane from birth than, 235B, the one fed skimmilk. However, it did not gain as much in height during the period covered by the test as did the calf 235B.

Growth by Weight and Growth in Height, shown as per cent of Normal Tables 38, 39 and 40 give the weights and heights of the calves of the different lots and compares them with the normal values by thirty day periods. The normal values for the Ayrshires are those given in the thesis by Burlingham and Gillette⁴ on "Standard Growth" and those for the Jersey and Holstein are the ones given in the thesis by Swett¹⁰⁵ on "Growth of Dairy Animals".

The calves in Lot I varied from 81.7 per cent to 114.9 per cent of the normal in weight and from 97.1 per cent to 103 per cent of the normal in height at withers at the age of five months.

The calves in Lot II showed a variation from 71.8 per cent to 74.2 per cent of the normal in weight and 88.4 to 91.5 per cent of the normal in height at withers at the age of six months.

TABLE 38

Growth by Weight and Growth in Height of Calves
in Lot I shown as per cent of Normal
by 30 day periods

Period	Weight of Calf lbs.	Normal Weight lbs.	Per Cent of Normal	Height of Calf cm.	Normal Height cm.	Per cent of Normal
Calf 326						
Birth	52	69.9*	74.3	61.33		
1	73	90.0	81.1	66.16	68.0*	97.3
2	105	130.0	80.8	70.75	73.5	96.3
3	132	173.0	76.3	75.83	79.0	96.0
4	170	210.0	81.0	80.83	84.5	95.7
5	215	248.0	86.7	86.00	88.5	97.2
Calf 235B						
Birth	77	90**	85.6	71.00		
1	101	121	83.5	76.25	76.8**	99.3
2	110	157	70.1	78.16	82.0	95.3
3	152	200	76.0	83.66	86.8	96.4
4	195	249	78.3	88.83	92.0	96.6
5	247	302	81.7	93.66	96.5	97.1
Calf 105B						
Birth	50	55.2**	90.6	66.75		
1	80	76	105.3	69.66	70.3**	99.1
2	112	105	106.7	76.50	74.7	102.4
3	152	140	108.6	82.00	79.3	103.4
4	200	174	114.9	87.66	83.9	104.5
5	255	222	114.9	92.00	89.3	103.0

* Thesis by Burlingham and Gillette (4)

** Thesis by Swett (105)

TABLE 39

Growth by Weight and Growth in Height of Calves
in Lot II shown as per cent of Normal
by 30 day periods

Period	Weight of Calf Lbs.	Normal Weight Lbs.	Per cent of Normal	Height of Calf cm.	Normal Height cm.	Per cent of Normal
Calf 301B						
Birth	50	70*	71.4	64.66		
1	77	90	85.6	66.83	68.0*	98.3
2	89	130	68.5	69.08	73.5	94.0
3	123	173	71.1	70.80	79.0	89.6
4	137	210	65.2	74.83	84.5	88.6
5	173	248	69.8	78.00	88.5	88.2
6	213	287	74.2	84.66	92.5	91.5
Calf 200B						
Birth	90	90**	100.0	72.00		
1	97	121	80.2	74.66	76.8**	97.2
2	134	157	85.4	78.25	82.0	95.4
3	170	200	85.0	81.33	86.8	93.7
4	175	249	70.3	82.50	92.0	89.7
5	202	302	66.9	85.50	96.5	88.6
6	255	255	71.8	90.00	100.9	89.2
Calf 1B						
Birth	52	55**	94.2	65.33		
1	64	76	84.2	67.00	70.3	95.3
2	76	105	72.4	68.00	74.7	91.0
3	93	140	66.4	70.75	79.3	89.2
4	115	174	66.2	72.16	83.9	86.0
5	145	222	65.3	78.50	89.3	87.9
6	191	260	73.5	82.83	93.7	88.4

*Thesis by Burlingham and Gillette (4)

**Thesis by Swett (105)

TABLE 40

Growth by Weight and Growth in Height of Calvesin Lot III shown as per cent of Normalby 30 day periods

Period	Weight of Calf Lbs.	Normal Weight Lbs.	Per cent of Normal	Height of Calf Cm.	Normal Height Cm	Per cent of Normal
Calf 325						
Birth	65	69.9*	92.8	66.91		
1	75	90.0	83.3	68.33	68.0*	100.5
2	88	130.0	67.7	70.16	73.5	95.5
3	113	173.0	65.3	73.33	79.0	92.1
4	132	210.0	62.9	76.58	84.5	90.6
5	155	248.0	62.5	79.00	88.5	89.3
6	192	287.0	66.9	84.33	92.5	91.2
Calf 201						
Birth	102	90**	112.1	76.33		
1	128	121	105.8	79.25	76.8	103.2
2	150	157	95.9	81.25	82.0	99.1
3	205	200	102.5	86.16	86.8	99.3
4	237	249	95.2	88.16	92.0	95.8
5	270	302	89.4	92.00	96.5	95.3
6	323	355	91.0	95.66	100.9	94.8
Calf 87B						
Birth	77	55	139.5	73.16		
1	95	76	125.0	78.92	70.3	112.3
2	125	105	119.0	80.41	74.7	107.1
3	132	140	94.3	81.16	79.3	102.3
4	160	174	92.0	83.00	83.9	98.9
5	197	222	88.7	88.16	89.3	98.7
6	245	260	94.2	94.00	93.7	100.3

* Thesis by Burlingham and Gillete (4)

** Thesis by Swett (105)/

Fig. 11.-Comparison of growth by weight
to growth in height of the Ayrshire
in Lots I, II, III. Normal is con-
sidered 100 per cent. Tables 38, 39, 40.

Centimeters

100
90
80
70
60
50
40

Days

Normal-100 per cent.
Weight Height
326 Lot I
301B Lot II
325 Lot III

There appears to be some relation between weight and height. The changes in weight are more pronounced.

There are greater variations in the increase in weight of all the animals than in height. All the Holsteins are below normal.

The Jersey fed fresh skimmilk is above normal in both weight and height while both calves fed powdered skimmilk are below the normal.

TABLE 41
Variations in Data from which the Normals
were calculated*

Age in Months	Maximum	Normal **	Minimum
Jerseys			
Weight in pounds			
1	88	76	63
2	118	105	85
3	158	140	107
4	206	174	133
5	251	222	168
6	298	260	197
Height in centimeters			
1	72.0	70.3	68.5
2	77.5	74.7	71.0
3	83.0	79.3	74.5
4	89.0	83.9	77.0
5	93.5	89.3	86.3
6	97.0	93.7	89.5
Holsteins			
Weight in pounds			
1	137	121	114
2	164	157	145
3	221	200	173
4	269	249	216
5	330	302	258
6	410	355	305
Height in centimeters			
1	81.0	76.8	73.0
2	85.5	82.0	79.0
3	90.5	86.8	84.5
4	95.5	92.0	89.0
5	99.5	96.5	92.0
6	105.5	100.9	96.7

* Unpublished data at Mo. Agr. Exp. Sta.

** Thesis by Swett (105)

The calves in Lot III showed a variation from 66.9 per cent to 94.2 per cent of the normal in weight and 91.2 per cent to 100.3 per cent of the normal in height at withers at six months of age.

The data in these Tables show the growth of the calves as represented by weight to be much more affected than the growth as measured in height, but there appears to be some relation between the two. The height approaches the normal more closely than the weight. Other investigators have also found under extreme conditions that the influence on skeleton growth is less marked than it is on the weight of the animals.

Utilization of Rations by the Calves of the Different Breeds - Very little work has been done to compare the utilization of feeds by calves of the various breeds, Lindsey⁴⁵ from his work concluded that, "Holstein and Ayrshire calves are as a rule better able to utilize prepared foods than are the Jerseys and Guernseys, altho we had no trouble in rearing calves of the latter breeds with a minimum of milk".

The question appears to be one of size and ruggedness of the calf at birth. The larger calf should make the larger gains for it should be able to consume more feed. Table 34 shows that one breed is able to make a pound of gain from about the same amount of energy, above

maintenance, as the others. The Holstein being the largest of the dairy breeds will necessarily require more energy for maintenance but is able to handle more feed so should make a larger daily gain than calves of the other breeds.

The amount of data on this subject is so small that no definite conclusions can be drawn.

Cost of the Ration - The total cost of the feed consumed by the calves of the different lots, according to the values assumed for the different feeds, is shown in Table 43. The assumed values of the feeds used may be found in Table 42.

Any values assumed for different feeds is only temporary. Prices change so sudden that any values assumed are soon apt to be above or below the current prices. The most feasible way is to have the amounts of the different feeds required to raise a calf to six months of age. From these one can determine readily the cost of such a method of feeding by applying the current prices of the feeds used.

Table 43 shows that it cost an average of \$14.55 to raise the calves in Lot I to five months of age. The calves in Lot II cost \$23.10 to be raised to six months of age and those in Lot III \$21.15.

The total feed required by the different calves

TABLE 42

Assumed Cost of Feeds

Whole Milk per cwt. - - - - -	\$2.00
Skimmilk per cwt. - - - - -	.35
Powdered Skimmilk per cwt. - - - - -	12.00
Alfalfa hay per cwt. - - - - -	.90
Ground corn per cwt. - - - - -	1.40
Ground oats per cwt. - - - - -	1.60
Oil meal per cwt. - - - - -	2.10

TABLE 43
Cost of Raising Calves.
Calves on Experiment .
180 Days*

No. of Animal	Whole Milk	Skim- milk	Po. Skim- milk	Corn	Grain Mixt	Alfalfa Hay	Total for Animal	Total for Group
Lot I ¹								
326	\$3.70	\$5.87		\$1.54		\$1.73	\$12.84	
235B	6.00	5.41		1.74		1.76	14.91	
105B	6.16	5.76		2.08		1.89	15.89	\$43.64
Lot II								
301B	\$7.50		\$9.73	\$1.14	\$2.60	\$3.30	\$24.27	
200B	6.53		11.21	1.31	2.57	4.46	26.08	
1B	4.48		8.03	.94	2.53	2.99	18.97	\$69.32
Lot III								
325	\$4.12		\$6.11	\$.71	\$3.80	\$3.45	\$18.19	
201	5.94		8.47	.99	4.12	5.05	24.57	
87B	6.18		5.81	.68	3.92	4.09	20.68	\$63.44

*The cost of raising calves in Lot I is for only 150 days.

1 Lot I Skimmilk

Lot II Powdered skimmilk for 120 days

Lot III Powdered skimmilk for 90 days.

may be found in Table 29.

General Discussion of Results - The aim of this work was to determine the possibility of using powdered skimmilk for feeding young dairy calves and the economy of such a practice. The main source of data used is an experiment with nine calves conducted by the writer.⁵ This was a project of the Missouri Experiment Station and is to be the beginning of a systematic study of the question of raising the calves on those farms where whole milk is sold.

The calves used were divided into three lots of three calves each.

Lot I - to receive whole milk, skimmilk, all the alfalfa hay they would eat and ground corn.

Lot II - To receive whole milk, powdered skimmilk in dry form and ground corn, equal parts by weight, until they are 120 days of age, all the alfalfa hay they would eat and a grain mixture - 2 parts ground corn, 2 parts ground oats and 1 part linseed meal by weight - after the discontinuance of the powdered skimmilk and ground corn.

Lot III - Cared for in the same manner as Lot II except they be fed the powdered skimmilk and ground corn until they are 90 days of age.

It was found to require 264 pounds of whole milk, 1,629.3 pounds of skimmilk, 127.6 pounds of corn and 199.1 pounds of alfalfa hay to raise the calves in Lot I to five months of age.

The calves of Lot II required an average of 308.5 pounds of whole milk, 80.5 pounds of powdered skimmilk, 80.5 pounds of ground corn, .398.7 pounds of alfalfa hay and 158.5 pounds of the grain mixture until they were six months of age.

The calves of Lot III required an average of 270.7 pounds of whole milk, 56.7 pounds powdered skimmilk 56.7 pounds of ground corn, 459 pounds of alfalfa hay and 247.3 pounds of the grain mixture until they were six months of age.

The nutrients in these amounts of feed were calculated from the analyses given in Pennsylvania Bulletin 142 by Armsby and Fries.

The calves in Lot I made an average daily gain of 1.2 pounds for the first 150 days of their life. Lot II 0.86 pounds for 180 days and Lot III 0.92 pounds for 180 days.

The amount of protein received by the different calves gave no index of the gain in weight of the calf which resulted from the feeding trial. This would indicate that the protein in no case was the limiting factor in the growth

secured.

The calf in each group that received the largest amount of energy for the group made the largest gains, but there is no comparison between the gains made by the different lots and the amount of energy they received. This indicates that something other than the amount of protein and energy received is instrumental in the gains made.

The ration fed Lot I appeared to have a more pronounced influence on the growth of the animals than those fed to Lots II and III. The calves in Lot III consumed more nutrients than did those in Lot II. This may have been due to the palatability of the ration. The powdered skimmilk probably should have been fed in the wet form to get the most favorable results. The powdered skimmilk gave just as good results when fed in the dry as the wet form in the preliminary test but this may have been due to the short duration of the test, one month, as compared to three and four months in the main experiment.

The amount of dry matter consumed by the calves in Lot I is in marked contrast to that consumed by those in Lots II and III. The calves in Lot I consumed the smallest amount of dry matter for they received a large per cent of their total food nutrients from the skimmilk,

which is easily digested and much higher per cent of its constituents can be utilized by the young calf. Where skimmilk is not fed one of the most important factors is that of having the ration as palatable as possible. The calf on calf meals must consume as large amount of nutrients as it would if it were fed skimmilk. Such a ration must also be prepared so that it will meet the requirements of growth as they are now known in our present knowledge of nutrition.

By assuming the prices in Table 42 for the feeds used, 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 five months while that for Lots II and III is for six months.

Judging from both the gains in weight and the total cost of the ration fed Lot I is the most economical. This partly due to the low market value which skimmilk brings altho from the feeding standpoint it should be much higher, especially to be given the same value as the various feeds bring. That fed Lot III would rank second while Lot II would be third.

Conclusions

1. The best substitute for whole milk, in the raising of calves, is a ration of skimmilk, hay and grain.
 2. When skimmilk is available and its value for other purposes is not excessive, "milk substitutes" for raising dairy calves have a very limited use and are seldom practical or desirable.
 3. Many attempts have been made to find a substitute for milk in calf raising but the results, in most cases, have not been satisfactory. In the light of recent additions to the knowledge of animal nutrition it is believed these failures may be attributed to the poor quality of the protein, the lack of the accessories to growth or to the improper balance of mineral constituents.
 4. The "milk substitutes" which have given the most satisfactory results up to the present date, have contained either powdered skimmilk or blood flour and have been supplemented with alfalfa hay for roughage.
 5. The essential characters of a "milk substitute" are:
 - (1) It should supply all of the constituents necessary for growth as they are now recognized in our present knowledge of nutrition.
-

- (2) It must be palatable and of such a character that the calves, to which it is fed, will consume as much energy and protein as calves fed on skimmilk, hay and grain.
6. Good, strong, and healthy calves can be raised on dried skimmilk with results which compare favorably with those obtained from feeding skimmilk in the ordinary form.
 7. The feeding of powdered skimmilk to the age of 90 days gave equally as satisfactory results as when continued to the age of 120 days.
 8. If the price is not prohibitive, powdered skimmilk may be used successfully for the raising of dairy calves by those dairymen who market whole milk.
 9. The growth of calves as measured by increase in height at withers can be retarded to some extent for the first six months of age by the character of the ration fed, but judging from other investigations if a liberal ration is fed later this retardation is only temporary and no permanent bad effects result.
-

Plate I

No. 326 Ayrshire 5 months of age.

Lot I - Skimmilk

Plate II

No. 235B Holstein 5 months of age.

Lot I - Skimmilk

Plate III

No. 105B Jersey 5 months of age

Lot I - Skimmilk

Plate IV

No. 301B Ayrshire 6 months of age.
Lot II - Powdered Skimmilk for 120 days.

Plate V

No. 200B Holstein 6 months of age.
Lot II - Powdered Skimmilk for 120 days.

Plate VI

No. 1B Jersey 6 months of age.
Lot II - Powdered Skimmilk for 120 days.

Plate VIII

No. 325 Ayrshire 6 months of age.
Lot III - Powdered Skimmilk for 90 days.

Plate VIII

No. 201 Holstein 6 months of age.
Lot III - Powdered Skimmilk for 90 days.

Plate IX

No. 87B Jersey 6 months of age.
Lot III - Powdered Skimmilk for 90 days.

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