THE NEED OF A PHOSPHORUS SUPPLEMENT WITH ALFALFA HAY AS THE PRINCIPAL SOURCE OF PROTEIN IN THE RATION OF DAIRY CATTLE

THESIS FOR THE DEGREE OF M. S.

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Respectfully submitted to the Graduate School of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of Master of Science

by

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INTRODUCTION

"More Home Grown Dairy Feeds to Cut the Cost of Milk Production", is a slogan which might be accepted by all dairymen on farms in regions where alfalfa hay can be economically grown.

Because of its palatability and high protein content alfalfa hay is the most desirable roughage for dairy cattle. For this reason it is assuming a position of increasing importance in the rations of dairy cattle.

Several investigators have reported that rations consisting of alfalfa hay and the cereal grains furnish sufficient protein and total digestible nutrients for the production of from 35 to 40 pounds of milk a day. These reports have emphasized the importance of alfalfa hay as a source of protein. They have shown that for economical milk production less of the protein-rich concentrates such as cottonseed meal, linseed oil meal, corn gluten meal, and wheat bran need be fed with alfalfa hay to properly balance the ration.

Although alfalfa hay is the highest of the roughages in protein content, it like all roughages, is inherently low in phosphorus. The commonly used protein-rich concentrates, howerver, are rich in phosphorus. Corn Silage, and the cereal grains, however, are comparatively low in this element. With the lessened amounts of the protein-rich concentrates needed to balance rations consisting of alfalfa, corn silage and cereal grains, there follows a decrease in the amount of phosphorus supplied by rations composed of these home grown feeds.

In view of the low phosphorus content of rations composed of alfalfa hay, corn silage and cereal grains, a question has arisen as to the ability of such rations to meet the phosphorus requirements of growing dairy heifers and lactating dairy cows which demand this element in large amounts. This question seems an especially pertinent one for Michigan dairymen since analyses of samples of Michigan-grown alfalfa hay have revealed it to be comparatively low in phosphorus.

GENERAL DISCUSSION AND REVIEW OF LITERATURE

The dairy cow requires comparatively large amounts of the mineral elements, calcium and phosphorus, for body maintenance and milk production. It yields the greatest returns when a ration is fed which is composed, as far as possible, of home grown feeds.

The standard method of feeding dairy cows during the winter months is to give a dry roughage such as hay; a succulent roughage, the most common of which is corn silage; and a grain mixture.

With alfalfa hay as the dry roughage less of the protein rich concentrates need be fed to provide a balanced ration. These concentrates are high in phosphorus. The question has arisen, therefore, as to the ability of alfalfa hay to provide for the mineral requirements of growing dairy heifers and lactating dairy cows when home grown rations are used. This is especially true in regions where alfalfa is low in phosphorus.

Sources of Phosphorus in a Dairy Ration

All roughages are, as a class of feeds, comparatively low in the element phosphorus. Grains contain much larger quantities of phosphorus than roughages. Protein supplements are, however, rich sources of phosphorus in a dairy ration.

The phosphorus content of some of the more common feeds as given by Armsby (1a) are as follows:

Hays		Succulent Feeds	
Alfalfa	- 0.258 percent	Mangels	- 0.269 percent
Clover	- 0.183 "	Beet pulp	- 0.069 "
Timothy	- 0.123 "		
Soy Bean	- 0.237 "		
Cereal Grains		**Protein Concentrates**	
Corn	- 0.303 "	Wheat bran	- 1.233 percent
Oats	- 0.434 "	Linseed oil meal	0.786 "
Wheat	- 0.425 "	Cottonseed meal	- 1.479 "

Henry and Morrison (2) gave the phosphorus content of common barley and of corn silage as 0.371 percent and 0.007 percent, respectively.

The more common feeding stuffs were classified by Palmer (37) into phosphorus poor, medium phosphorus and phosphorus rich as follows:

Phosphorus Poor	Medium Phosphorus	Phosphorus Rich
Pearl Hominy	All Cereal Grains	Wheat Bran
Polished Rice	Alfalfa Hay	Wheat Middlings
Beet Pulp	Corn Stover	Red Dog Flour
Red Clover Hay	Corn Silage	Legume Seeds
Timothy Hay	Sweet Clover Hay	Cottonseed Meal
Cereal Straws	Vetch Hay	Linseed Oil Meal

It is admitted that the content of any element in any feed will vary from time to time. For this reason the above figures are not absolute. They do, however, present the accepted idea as to the value of the different feeds as sources of phosphorus in a dairy ration.

Alfalfa Hay as a Source of Phosphorus

From the foregoing tables it is seen that although all roughages are low in phosphorus alfalfa is the highest in this respect.

Figures from different investigators showed a wide variation in the amount of phosphorus contained in alfalfa hay obtained from different localities.

Huffman (3) reported an average phosphorus analysis for nineteen samples of Michigan-grown alfalfa hay as 0.178 percent. These samples were taken over a five year period.

Henderson (4) working with dairy heifers in an attempt to determine the effect of low phosphorus rations on growth, used alfalfa hay purchased in Michigan. It contained an average of 0.159 percent phosphorus.

Ames and Boltz (5) in a study of the nitrogen and mineral constituents of plants as affected by fertilizers reported a large number of samples of alfalfa hay to have an average of 0.254 percent phosphorus. These same investigators gave 0.2901 percent as the phosphorus content of alfalfa hay when comparing it to other farm crops.

Huffman (3) found a variation in phosphorus of from 0.120 percent to 0.250 percent.

Woll (74) studied alfalfa hay as the sole feed for dairy stock. He found that dairy heifers from one year to eighteen months of age, and carried through one and in some cases two lactations, made satisfactory growth, and reproduced satisfactorily. He also found that heifers fed alfalfa hay supplemented by a grain mixture were slightly heavier at freshening time, and produced more milk and more butterfat than those which did not receive grain. The increased milk and butterfat by grain feeding, however, barely paid for the grain. These results speak well for alfalfa hay as a feed for dairy cattle.

Fraser (75) is a great exponent of alfalfa as a feed for dairy cattle. He gave the phosphorus content of the hay as 0.20 percent. He reported satisfactory and economical production on alfalfa hay alone as a feed for dairy cows.

Meigs (76), after comparing alfalfa hay to timothy hay stated that alfalfa hay combined with a comparatively simple mixture of concentrates made a complete or nearly complete ration for dairy cows. In his grain mixture, however, he used corn meal, wheat bran, linseed oil meal and cottonseed meal.

Forbes and co-workers (77) reported the following analyses for alfalfa hay used in their experiments conducted while studying "the mineral metabolism of the

Milch cow": Percent phosphorus 0.169; 0.166; and 0.180.

Jones and Bullis (78) made a chemical study of legumes and other forage crops of western Oregon. They found that on an air dry basis alfalfa hay from the valley section contained 0.221 percent phosphorus and hay from Southern Oregon contained 0.224 percent phosphorus.

Forbes and co-workers (79) reported alfalfa hay as containing 0.221 percent phosphorus.

Eckles, Becker and Palmer (83), studying mineral deficiencies in the ration of dairy cattle found that less trouble was experienced when legume hay was fed in the place of commonly used prairie hay, but the use of home grown alfalfa hay by no means insured freedom from the trouble. They found one herd of cattle showing especially severe symptoms of phosphorus deficiency, including broken bones, which received alfalfa hay regularly.

Theiler and co-workers (49) in studying depraved appetite in range cattle stated that "supplementary foods such as maize and lucerne do not reduce osteophagia (bone chewing) unless relatively rich in phosphorus and fed in uneconomical amounts".

A review of the literature has not revealed a figure lower than the 0.120 percent reported by Huffman (3). His high figure, 0.250 percent, however, comes far from being the maximum percentage reported. Ames and Boltz (5) gave 0.3415 percent phosphorus as the amount contained in one of their series of samples.

It is therefore evident that the amount of phosphorus in alfalfa hay may vary within a wide range.

Thus, from a phosphorus standpoint at least, some alfalfa hay may be two or three times as valuable as some other hay made from the same plant.

Factors Affecting the Percentage of Phosphorus in Alfalfa Hay

Phosphoric acid content of the soil. Ames and Boltz (5) in showing the effect of phosphate fertilizers on the amount of phosphorus in hay grown on such fertilized soils, stated that hay from plots which received no fertilizer contained an average of 0.2276 percent phosphorus. Their data for hay sown on plots which had received phosphate fertilizer showed an average phosphorus percentage of 0.2601. In their work the amount of lime used with the phosphate affected the phosphorus content of the hay. From plots which received lime at the rate of 2500 pounds per acre the phosphorus content averaged 0.2578 percent. Those plots which received lime at the rate of 5000 pounds per acre yielded an alfalfa with 0.2518 percent phosphorus. These figures included plots which received no phosphate as well as those which received a liberal application of phosphate. The effect of lime on the phosphorus content of the alfalfa when used with and without phosphate fertilizer is as follows:

Lime	(2500	No Phosphate	0.2133
	(5000		0.2420
Lime	(2500	About 45 pounds phosphate per Acre	0.2665
	(5000		0.2538

Burke and co-workers (6) studied the effect of fertilizing alfalfa plots with phosphate. In their work the addition of 200 pounds of treble superphosphate per acre increased the yield three percent and increased the phosphorus content of the crop 10.41 percent in the first cutting. The increase for the second cutting was, yield 3.1 percent and phosphorus content 6.39 percent. They stated that their results showed clearly that phosphate fertilizer could increase the phosphorus content of alfalfa, clover, and timothy.

Price (7) fertilized alfalfa fields with limestone and acid phosphate with the result that the yields as well as the calcium and phosphorus contents of the hay were increased. His data is rather striking.

Treatment	First Cutting Yield per A.	% Ca.	% P.	Second Cutting Yield per A.	% Ca.	%P.
No treatment	728 pounds	0.56	0.054	500 pounds	1.52	0.259
2 tons limestone per acre	972 "	2.98	0.179	591 "	1.82	0.255
2 tons limestone and 250 pounds acid phosphate per acre	1149 "	2.63	0.205	933 "	1.63	0.310

Mather (8) analysed alfalfa hay from plots which had been fertilized with phosphate fertilizers to determine

the particular fraction of the phosphorus which was increased. His conclusions were that the increase in phosphorus in alfalfa hay following the application of fertilizers was practically all confined to the inorganic fraction.

Burke and co-workers (6) reported one case in Cascade County, Montana where the application of phosphate fertilizer increased the yield of alfalfa hay 12.5 percent and the phosphorus content of the hay 21.09 percent. His work with plots showed an increase of 41.9 percent phosphorus in alfalfa, 30.6 percent in clover and 24 percent in timothy. All plots yielded much greater growth than the unfertilized plots.

Ames and Boltz (5) stated that the phosphorus supply of the soil as increased by the addition of acid phosphate was reflected by the phosphorus content of the crop which followed the same order as the yields obtained.

Archibald and Nelson (80) found that fertilizing the soil with 55 pounds nitrogen, 55 pounds P_2O_5 and 67 pounds of K_2O per acre resulted in raising the phosphorus content of the dry matter 10 percent over the unfertilized check plot while the average total production of phosphorus in six plots was 42 percent more per acre.

Theiler and co-workers (49) reported the available phosphoric acid content of the soil in the area of severe phosphorus deficiency as 0.0005 percent. They stated after experimenting with fertilizers that acute bone chewing

practically disappeared when animals were turned on to plots fertilized with high grade superphosphate.

Crawford (53) observed that the district which showed the highest calcium and phosphorus soil contents produced the best animals.

Theiler, Green and duToit (38) stated that their experiments using plots for studying range vegetation indicated that the phosphorus deficiency of the soil and lack of rainfall were the two main factors limiting the carrying capacity of the ranges.

Rainfall

Fallon (9) stated as a result of studies on irrigated alfalfa fields that in Nevada irrigation increased the phosphorus content of alfalfa hay. Hay from fields which had not been irrigated for five years contained 0.175 percent phosphorus on a dry matter basis, while hay from similar fields which had been irrigated frequently contained 0.220 percent phosphorus.

Widtsoe and Stewart(10) studied the effect of different amounts of irrigation water on the chemical composition of crops. They stated that in general the more water applied resulted in crops with higher ash content. Their results were as follows:

Percent Ash in Alfalfa When Different Amounts of Water Are Used

Water in Inches	First Crop	Second Crop	Third Crop
10.00			8.16
20.00	7.48	8.62	8.55
25.00	8.62	8.58	8.15
30.00	8.37	8.56	--

Water in Inches	First Crop	Second Crop	Third Crop
35.00			8.79
50.00	12.28	9.16	8.53

Theiler and co-workers (49) reported a definite connection between the rainfall and symptoms of phosphorus deficiency. During May and June when these symptoms were at their height the grass was old and dry and showed but 0.017 percent to 0.034 percent phosphorus in the dry matter. During October and November after the rains had come the young grass showed from 0.24 percent to 0.274 percent phosphorus in the dry matter. Subsequent to these rains the bone chewing among the cattle ceased.

Comparing the composition of forage in areas in which phosphorus deficiency was prevalent, with unaffected areas, Scott (41) stated that soil analyses showed a high calcium content and an apparently adequate phosphorus content. He was at a loss to explain the fact that the forage crops grown on these soils were deficient in phosphorus. He inferred that the soil phosphorus was for some reason not readily available. He also stated that the amount of precipitation during the years of his investigation had no effect on the mineral content of the grasses.

Welch (43) stated that in very dry years soils containing plenty of minerals may produce forage deficient in mineral content as there is not enough moisture to dissolve the soil constituents so that the plants could take them up.

Neidig, McDole, and Magnuson (21) studied the effects of sulfur, calcium, and phosphorus on the yield and composition of alfalfa on six types of Idaho soils. They found that the addition of phosphorus in the form of treble superphosphate increased the yield on all but two soils. The arid soils gave greater response to applications of phosphate than did the humid soils. The equivalent of 200 pounds of treble superphosphate per acre was used. In some cases, particularly Moscow loam, the increase in yield was 71.5 percent.

Eckles, Becker and Palmer (83) found that in 1925 with 17.49 inches of rainfall the alfalfa hay contained 0.199 percent phosphorus, while in 1924 with 21.98 inches precipitation the phosphorus was 0.221 percent.

It was the observation of all the investigators studying phosphorus deficiency that the symptoms were usually much more pronounced in dry years.

<u>The Cutting</u>

Henry and Morrison (11) gave the percentage of phosphorus in the different cuttings of alfalfa hay as follows: first 0.256; second 0.256; third 0.232; fourth 0.214 percent.

The average percent of ash for the three cuttings reported by Widtsoe and Stewart (10) were as follows: first 9.19 percent; second 8.73 percent; third 8.40 percent. In discussing ash percentages it is assumed that within certain limits there is a correlation between the amount of total ash and the phosphorus in samples of alfalfa hay.

The California Station (12) reported the following figures of ash in the different cuttings: first 10.48 percent; second 7.99 percent; third 10.20; and fourth 9.57 percent.

Ames and Boltz (5) stated that the yields obtained from the first cuttings were always larger than the second cuttings and that the percentages of nitrogen, calcium and phosphorus and ptassium followed the yield. The average phosphorus content for first cutting samples was 0.2793 percent, while 0.2301 percent was the average for second cutting samples.

Maturity of the Plant at Time of Cutting

Swanson and Latshaw (13) found that alfalfa cut at the bud stage yielded hay with the highest ash and crude protein content. Widtsoe (14) analysed samples of the alfalfa plant at intervals of a week throughout the growing season and found it to be highest in the bud stage. They also found that the percentage of ash dropped quickly as the plant reached the stage of medium bloom. Dinsmore (15) reported findings similar to those of Swanson and Latshaw (13) and Widtsoe (14).

Henry and Morrison's (16) tables showed that the ash content of alfalfa decreased from 10.0 percent to 7.0 percent from the early bloom stage to the seed stage.

Orr (17) stated that young plants in the leafy stage were much richer than old plants in mineral content. Hence there was a seasonal variation, especially in the percentage of calcium and phosphorus. These mineral elements increased in the early part of the summer until the plants were at the stage of maximum leaf and most active growth. They then decreased as the plants approached maturity.

Ames and Boltz (5) found that alfalfa cut in bloom contained the largest amounts of the more valuable plant foods and nutritive constituents in the leaves.

Quality of the Hay

Quality of any kind of hay is influenced by many factors. To the average dairyman the most important of these factors are those which affect palatability; namely, color, leafiness and the absence of what is called "woodiness". The percentage of total digestible nutrients, digestible crude protein, and the mineral content are, however, probably of more importance in determining the quality and feeding value of the hay.

The total digestible nutrients and the mineral content of hay are affected by the maturity of the plant when cut according to Huffman (3), Orr (17), and many others who have studied this problem.

The quality of hay is affected by the curing process as shown by many investigators.

Damaged by Rain. Huffman (3), quoting findings of the Colorado Experiment St tion stated that whereas hay which was cured without being damaged by rain showed an ash content of 12.18 percent and a crude protein content of 18.71 percent, similar hay damaged by rain was found to contain 12.71 percent ash and but 11.01 percent crude protein.

Paturel (19) analysed damaged clover, alfalfa and common hay which showed a loss of from 15 to 35 percent in dry matter. Feeding tests also showed a proportionate loss in nutritive value for these roughages.

Leafiness of the Hay. The influence of the percentage of leaves on the quality of alfalfa hay is a point often unappreciated. Swanson and Latshaw (13) showed that stems and leaves differ in the content of ash and that leaves contain over two and one-half times as much crude protein as the stems.

Fonder (20), working on the influence of soil type on the magnesium and calcium contents of the alfalfa plant stated that the ratio of stems to leaves was about equal on the different soil types which he studied. The average of his ratio for six soil types was, leaves 60.81 percent to stems 39.19 percent by weight.

That the percentage of leaves saved in curing alfalfa hay may have a profound influence upon its mineral content was shown by the following figures as given by Henry and Morrison (16). Ash in alfalfa hay, 8.6 percent, in alfalfa leaves, 13.6 percent and in alfalfa stems 4.9. percent.

Ames and Boltz (5) stated that considerable care should be taken in harvesting the crop, since under most favorable conditions the loss of leaves may amount to about 15 percent of the crop. Their figures on the phosphorus content of the different parts of alfalfa plant were as follows: seed, 0.5170 percent, stems, 0.2790 percent, and leaves 0.3780 percent.

These same authors (5) stated that rain removed a considerable portion of the mineral and food elements which are not securely combined in the alfalfa plant. Results obtained by them in treating dried alfalfa with water showed that 50 percent of the nitrogen and 75 percent of the phosphorus were dissolved.

Hart and co-workers (81) found that the rate at which calcium was assimilated from hay depended very largely on the manner in which the hay was treated after being cut. They secured positive calcium and phosphorus balances in liberally lactating cows fed alfalfa hay cured under caps. The positive balances were increased when fresh green alfalfa replaced the dry hay. These workers suggested a relationship between calcium balances in lactating cows when fed alfalfa hay and the quality of the hay. By "quality" they referred to "the relative degree of destruction by curing process of the unknown factors affecting calcium assimilation".

Hart and associates (85) studied the influence of method of curing upon the anti-rachitic properties of hay by curing some hay in the dark and exposing other hay to ultra violet light during the curing process. They fed these hays to goats. These investigators found that the goats were in negative calcium balance when fed the hay cured in the dark, but that the balances were changed to positive when they were fed the hay which had been exposed to ultra violet light. Hart and associates (85)

suggested a relationship between curing hay in the sun and the value of the mineral elements in the hay.

Amount of Phosphorus Required for Normal Growth

The literature on the amount of phosphorus required for normal growth in dairy calves is very meager. The effects of feeding different amounts of calcium and of phosphorus to different classes of animals, however, have been the subject of countless investigations.

Armsby (1b) stated that growth involves the storage of matter in a body, minerals being no exception. These materials are not only combined into new tissue but also may be stored in reserve for future use. While discussing total retention of phosphorus and calcium during growth, he stated that the daily average retention was 0.071 grams calcium and 0.037 grams phosphorus per 1000 kilograms live weight the first year.

Soxhlet (96) stated that with calves the ash in milk was 53 percent digestible, calcium 97 percent and phosphorus 72.5 percent digestible. Neumann (97) working with somewhat older calves secured the following results: calcium was 45.3 percent and phosphorus 45.2 percent digestible. These figures were obtained with skim milk diets.

Lehmann (98) and Weiske (99) both worked with older calves on mixed rations. Their results showed a percentage availability of the phosphorus and calcium fully as great as Neumann (97) obtained with skim milk.

Armsby (1d) concluded that the cause of the lower assimilation of phosphorus and calcium reported by Neumann (97) was the lowered demand for these elements in the body rather than any lowered availability of the elements themselves.

Fingerling (100) has shown that a variety of organic phosphorus compounds may be quite completely assimilated from concentrated feeding stuffs. While from roughages he (101) observed an availability of approximately 50 percent.

Kellner (102) concluded that the feed should contain from two to three times the amount of mineral matter that would be stored. He came to this conclusion as a result of experiments which showed the phosphorus in the feed to be from one-half to one-third available.

McCollum and Simmonds (63b), working with low calcium rickets stated that the rations used contained "about an optimal amount of phosphorus (0.41 percent)".

Osborne and Mendel (22) have shown that the lack of sufficient phosphorus in the ration is promptly characterized by a cessation or a restriction of growth. They stated that a shortage of an essential inorganic element could be suitably remedied under ordinary conditions by the use of its salts.

McCollum and co-workers (23) in reporting on a study of the production of rickets in rats stated that the absolute amount of phosphorus was not so important as the ratio of calcium to phosphorus in the ration.

Henderson and Weakley (24) worked with dairy heifers in an attempt to show the effect of different amounts of phosphorus in the ration on the growth and development of the animals. They found 0.131 percent phosphorus in the ration the second year lowered the inorganic phosphorus of the blood below normal.

They also found that a ration below 0.20 percent phosphorus gave rise to bone low in ash and therefore low in calcium and phosphorus.

McCollum (25) as a result of his studies considers an optimal P_2O_5 content of the dry matter in a ration to be 0.95 percent. Converted to phosphorus this figure becomes 0.4148 percent.

That there is danger of a deficiency of phosphorus in the rations of cattle is shown by the researches of many investigators. The review of their findings will be made in the sections provided for discussing the diseases produced by a phosphorus deficiency.

Palmer (37) in a discussion of minerals for fram animals stated, "It is somewhat difficult to fix a limit for the phosphorus content of foods below which the food can be said to be deficient. Nevertheless, there seems to be good evidence that if the dry matter of the food contains less than 0.20 percent of the element, phosphorus, it may be classes as a phosphorus deficient food, and if more than 0.50 percent phosphorus it may be classed as phosphorus rich".

Theiler, Green and duToit (64) in studying the mineral requirements in cattle found that a ration supplying 2.23 grams of phosphorus and 4.99 grams of calcium per day was deficient. Animals from 12 to 18 months of age withstood this level of mineral intake for from three to six months. They then showed symptoms of mineral deficiency disease.

Theiler and co-workers (49) in discussing osteophagia, or bone chewing, in cattle grazed on South African veld stated that "in any given diet it is the percentage of phosphorus in relation to the total feeding value which is of importance in determing osteophagia. The better the pasture the higher must be the percentage of phosphorus in dry matter, and conversely the poorer the pasture the lower need be its percentage of phosphorus, since the cattle, by eating more of the poorer quality vegetation thereby raise their absolute daily phosphorus intake. For this reason cattle need not necessarily develop marked osteophagia on a veld containing as little as 0.07 percent phosphorus, in the dry matter, although where it falls below 0.043 percent osteophagia would be expected even when the nutritive value of the grass is so low that the grazing consumption approaches the limit of the digestive capacity of the cattle".

These same authors (49) found that with cattle grazing on the veld a daily consumption of about 11.79 grams of phosphorus was regarded as somewhere about the

point at which osteophagia could develop or disappear in grasing cattle of 1000 pounds live weight.

They stated that for old oxen the intake of 11.79 grams of phosphorus per 1000 pounds was probably more than enough to prevent osteophagia while for young cattle or milk cows this intake was certainly too low.

Amount of Phosphorus Required for Milk Production

The mineral metabolism of lactating dairy cows has been the subject of numerous investigations. Research workers, realizing the importance of minerals in the ration of the dairy cow have attempted, not so much to determine the exact phosphorus requirements for milk production, as to ascertain the value of certain feeds for maintaining lactating cows in phosphorus equilibrium.

Cases of cows on negative calcium and negative phosphorus balances have been reported by Meigs and associates (65), Hart and associates (81), Reed and Huffman (72), Forbes and co-workers (103) and a great many others. These investigators are agreed that such negative mineral balances cannot continue indefinitely. There is a certain point beyond which this depletion of mineral stores cannot proceed. Thus, accoeding to these authors, when a cow reaches this point in her mineral metabolism she must diminish her milk flow so as not to further deplete her own supply.

Mineral requirements for maintenance have been studied by several investigators. Armsby (1c) stated, "that a supply of the so-called mineral or ash ingredients, as well as of protein and the energy yielding materials, is necessary for the maintenance and growth of animals, has been fully recognized since the time of Liebig". Forster (104) in 1873 and Lunin (105) in 1881 demonstrated that animals could live longer without any food at all than when fed ash-free diets.

Reasons given by Armsby (1c) for the necessity of ash were, "their use in the skeleton and soft tissues; specific uses of such elements as iron, fluorin, and iodin; maintenance in the body fluids and tissues of (a) normal osmotic pressure, (b) relative concentrations of various irons, and (c) as a specific case of the latter, the preservation of neutrality".

Diakow's (106) and Cochrane's (107) experiments where each worked with a single steer are of interest. Diakow found that 52.2 grams calcium and 20.4 grams phosphorus in the feed per 1000 pounds live weight sufficied to support some gains by the body. Cochrane reported that a minimum of 66.67 grams calcium per 1000 pounds resulted in a gain while 17.6 grams was sufficient for maintenance. Henneberg's (108) results showed that smaller amounts of calcium and phosphorus would suffice. He reported that 40.8 grams calcium and 9.53 grams phosphorus were adequate for maintenance of a 1000 pound animal.

Kellner (102) computed the approximate requirements for calcium and phosphorus from the outgo in the milk. He accepted Henneberg's (108) estimate of 71.4 grams calcium and 21.8 grams phosphorus per 1000 kilograms live weight for maintenance and added to these three times the amount found in the milk, on the somewhat questionable assumption that only one-third to one-half the feed ash was available. Thus a 1000 pound cow giving twenty pounds of milk would require 61 grams of calcium and 25 grams of phosphorus for maintenance and milk production.

Theiler (49) believed that for old oxen an intake of 11.79 grams phosphorus per 1000 pounds was probably more than enough for maintenance.

Meigs and co-workers (65), in studying the calcium and phosphorus metabolism of dairy cows reported in the first of two experiments that they found the calcium assimilation of cows was apt to be greatly interfered with by any influence which tended to throw them even slightly off feed. From their two experiments they concluded that cows usually assimilated about 20 percent of the intake of the calcium from well cured hay.

Workers at the Vermont Agricultural Experiment Station (66) studied the maintenance requirements of dairy cows. Reporting on factors affecting these maintenance requirements they stated that heavily milking cows, losing both calcium and phosphorus on a ration of timothy hay,

corn silage and a grain mixture showed decided storage of both minerals when steamed bone meal and ground limestone were added. They found that dry cows on a winter maintenance ration also assimilated calcium and phosphorus when these minerals were fed. They also found that exercise or lack of exercise might prove a vital factor in the determination of mineral balances. In their trials the retention of calcium and phosphorus was reduced when the cows were not exercised.

Rose (67) worked with a single cow, varying the amounts of organic phosphorus in the ration. He fed straw, polished rice, wheat gluten and wheat bran (washed or not). In this experiment, as in previous work there was in all cases more inorganic phosphorus eliminated than had been given in the ration. This showed that the end product of phosphorus metabolism is inorganic phosphate, which in herbivava is excreted chiefly by way of the intestinal canal as salts of the alkali earths. He quoted Berg as saying that this is chiefly tri-basic calcium phosphate. He concluded that for maintenance of phosphorus equilibrium in this species of aniaml the requirement would seem to be the amount of phosphorus eliminated in the milk plus 26 milligrams per kilogram of body weight; an excess over this amount resulting in phosphorus retention, and smaller amounts resulting in loss of phosphorus from the organism.

Reed and Huffman (72) found that a ration consisting of timothy hay, corn silage and grain, with no mineral supplement other than common salt furnished sufficient calcium and phosphorus for normal growth, good reproduction and liberal milk production. Their cows which received a mineral supplement of bone flour were, however, reported to be in the best health of any of the animals in their experiment. These investigators reported that cows getting bone flour increased in milk production and produced larger calves as they became older.

Meigs and Woodward (70) believed from their studies that standard rations without mineral supplements did not supply sufficient calcium and phosphorus to maintain high milk yield year after year. In their experiments cows after having been fed in excess of the most liberal feeding standard responsed to phosphate feeding by increased milk production.

In discussing the mineral feed problem in Wisconsin, Hart, Steenbock and Morrison (73) stated that the use of wheat bran and certain other protein concentrates rich in phosphorus would generally solve the phosphorus feeding needs of growing and high producing livestock.

Forbes (103), Meigs and Woodward (70), and Hart and co-workers (81), reported negative calcium and phosphorus balance as nearly universal in milking cows receiving recognized standard rations without mineral supplements.

Huffman, Robinson and Winter (109), on the other hand found that their cows were much more frequently in

positive calcium and phosphorus balance than was reported by Forbes (103), Meigs and Woodward (70), Hart and co-workers (81). This apparent lack of agreement as to the mineral needs of heavily milking cows may be explained by the fact that Huffman and associates secured much better utilization of calcium and phosphorus than was reported by the other investigators.

Various authorities suggested different amounts of mineral supplements to use under varying conditions.

While these recommendations are really nothing more than opinions they reflect the beliefs of these workers. Maynard (68) suggested equal parts of bone meal and finely ground limestone when a mineral supplement was needed. He recommended from 2 to 5 ounces of this mixture per head a day.

Sotola and co-workers (69) recommended four parts bone meal to one of salt for dairy cows. They recommended from 2 to 5 percent of this mixture in the grain.

Huffman and Reed (71) recommended free access by cows getting a ration consisting of legumes and cereal grains which may be deficient in phosphorus, to a mixture of equal parts steamed bone meal and salt.

Calcium-Phosphorus Ratio for Normal Growth

The calcium phosphorus ratio in the diet has been the subject of many investigations.

McCollum and co-workers (26) showed the effect of varying the rations between calcium and phosphorus in the diet on the histological picture of the bones. Small deviations from the optimal composition of the food, in certain cases, produced profound changes in the manner of organization of the finer structures of the living tissues.

McCollum, Simmonds, Shipley and Park (23) observed that the ratio between the calcium and phosphorus in the diet, may within certain limits, be of greater significance to the welfare of an animal than the absolute amounts of these substances contained in the diet.

Haag and Palmer (27), after studying the effects of variations in the proportions of calcium, magnesium and phosphorus contained in the diets of rats, concluded that the general trend of their results left no doubt that a more or less balanced condition of calcium, magnesium and phosphorus salts of the ration was essential to normal growth and functioning.

Bethke and co-workers (28), working with chickens found that the optial, or near optimal, calcium phosphorus ratio lay between 3:1 and 4:1 and that requirements of chickens for the antirachitic factor were the lowest when this calcium-phosphorus ratio was maintained. They observed as did McCollum (26) that within certain limits of concentration, the ratio of calcium to phosphorus was of greater significance in calcification and growth than the absolute amounts of the elements in the ration. Bethke

and co-workers presented data which showed that phosphorus may be as much of a limiting factor as calcium in growth and bone formation.

Turner and Hartman (29) made a study of an adequate ration for high producing cows and the effect of exercise upon calcium, phosphorus and nitrogen balances. Two cows giving from 27 to 29 killograms of milk daily were fed an excellent dairy ration with a calcium-phosphorus ratio which varied from 1.09 to 1.19. Both cows remained in negative calcium and negative phosphorus balances during seven weeks on metabolism test.

Turner, Harding and Hartman (30), working with two cows found a better assimilation of calcium from alfalfa hay than from clover. Their metabolism data suggested a better assimilation of calcium and phosphorus when the value of the calcium-phosphorus ratio was 1.25 than when it was 2.5.

Shohl and Bennett (31) worked with rickets-producing rations and studied their effects on dogs fed a high calcium-low phosphorus diet. The calcium-phosphorus ratio was 0.66. This diet produced rickets in less than 10 weeks. The fastest growing dogs developed the most severe rachitic lesions. They quoted Boas as saying that the normal ratio between calcium and phosphorus retention in the rat is 1.58. They also stated that data from many published articles on the normal ratio for calcium phosphorus retention in the infant is the same. It was their opinion that higher ratios represented

excess calcium retention while lower ratios represented excess phosphorus retention. Shohl's rachitic dogs showed a calcium-phosphorus retention ratio of from 9.0 to 2.4 and 9.8 to ∞. The ratio between the two elements in his mildly rachitic dogs was from 2.7 to 1.9 and for his normal dogs from 1.7 to 1.4.

Sherman and Quinn (32) demonstrated the interdependence of calcium and phosphorus in the diet of white rats by limiting the calcium intake. With deficient calcium intake the percentage of phosphorus in the body of the rats was the same regardless of whether cod liver oil was, or was not, supplied. They concluded that in this work calcium was the limiting factor, for as soon as it was increased in the food the storage of both minerals increased.

Shelling and co-workers (33) made studies upon calcification in vitro by using rachitic and non-rachitic human bodies. They found the ratio between calcium and phosphorus to be very near that in Tri-calcium phosphate or 1.93. They also found that when calcification did occur the type of calcium-phosphorus compound laid down appeared to be independent of the inorganic phosphorus concentration of the blood serum. In their work, the ratio of calcium phosphate to calcium carbonate was higher, however, the greater the inorganic phosphorus concentration of the serum.

Meigs, and co-workers (34) using four lactating cows, two in each of two experiments, concluded that

phosphorus assimilation may be interfered with by an excess of calcium in the ration and that two parts or more by weight of calcium to one of phosphorus constituted an excess.

McCollum and Simmonds (63a) found that for rats the most favorable relationship between calcium and phosphorus was "a considerable excess of calcium over phosphorus in percent of the diet".

Scott (41) found that the proportion of calcium to phosphorus in the food supply was a factor in regulating the amount of phosphorus retained by the growing animal. He drew attention to the fact that on a tricalcium-phosphate basis the legumes have a large excess of calcium over that required for chemical combination with phosphorus. He also found that wild grasses from areas from districts free from phosphorus deficiency showed an excess of phosphorus over calcium, but that corresponding samples from districts in which phosphorus deficiency occurred showed an excess of calcium. He made these calculations to show that there is more possibility of the phosphorus than of the calcium content of forage from affected areas falling short of a combining proportion.

Phosphorus Deficiency in the Ration

Several workers have reported cases of phosphorus deficiency in the diets of nearly all classes of animals. There are apparently two types of phosphorus deficiency,

one being insufficient phosphorus in the diet, and the other being an unbalanced condition existing between the calcium and the phosphorus in the ration.

Types of Phosphorus Deficiency

Phosphorus Content Below Minimum. Just what is the minimum content of phosphorus in the ration which will give satisfactory results with dairy cattle is still somewhat of an enigma.

Reports have come from all over the world of certain "diseases" which have been attributed to a deficiency of phosphorus in the rations of cattle in those sections. These so-called "diseases" have been cured by various methods, all of which included the use of some phosphorus-carrying substance. Theiler and associates (49) fed bone meal, Eckles, Becker and Palmer (83) used mono sodium phosphate.

Calcium - Phosphorus Ratio Upset. Cases of phosphorus deficiency caused by a lack of balance between the calcium and the phosphorus in the ration of cattle were not observed.

Concerning the mineral elements in animal nutrition, Orr (35) states that "excess or deficiency of one mineral element may interfere not only with the absorption, but also with the utilization of another. So the ratios of the different minerals to each other and to the organic constituents are almost as important as their absolute amounts".

Evidences of Phosphorus Deficiency

Depraved Appetite. A depraved appetite is defined as a craving or liking for substances not ordinarily classed as foods. Cattle exhibit this symptom under varying conditions. Taylor (36) observed that depraved appetite developed in calves fed on concentrates alone.

Since his grain mixture contained what would ordinarily be considered an abundant supply of phosphorus this condition obviously could not have been caused by a deficiency of phosphorus. In cases of animals developing depraved appetite while being fed concentrates alone he found that cravings could be cured by feeding roughage. In some cases the roughage used was timothy hay - in others alfalfa. He ascribed the cure of the depraved appetite to some "unknown factor" carried by the hay. He also stated that this factor was probably not a mineral since a mineral mixture similar to the mineral combination found in hay failed to relieve the depraved appetite.

Cattle with depraved appetite chew sticks of wood, bones, old pieces of leather, sacks or anything available according to Palmer (37).

Environments causing depraved appetite to develop in cattle under conditions other than those of the laboratory are, according to Theiler, Green and duToit (38), a low phosphorus content of the soil which results in a low per-

centage of phosphorus in the herbage growing on that soil. Such forage fails to meet the needs of the animal with the result that it starts to chew bones, wood, etc.

Reed and Huffman (39) attributed depraved appetite to a deficiency of phosphorus in the ration.

Tuff (40) observed that it was only in certain areas that cattle exhibited depraved appetite. Upon analysing the soils in these areas he found them to contain but 0.002 percent phosphorus, whereas in the unaffected areas the soil contained 1.21 percent phosphorus. The hay taken from the affected areas contained 0.065 percent phosphorus contrasted to 0.19 percent phosphorus in the hay from the unaffected areas.

Scott (41), studying phosphorus deficiency in forage feeds of range cattle in Montana found that in areas of depraved appetite in cattle the phosphorus content of the forage was lower than in similar forage from unaffected areas. He found that wet, marshy meadows were responsible in a great many cases for mineral nutrition disorders. In unaffected areas alfalfa hay contained 0.18 percent phosphorus while in affected areas it contained 0.109 percent phosphorus.

Schmidt (42) found that osteophagia (bone chewing) could be prevented or cured by feeding a mixture of three parts bone meal and two parts salt to range cattle of Texas.

Welch (43), studying bone chewing in cattle found that cattle confined to limited range and especially those fed "wild hay" and usuallythat grown on low ground, were observed to chew bones. This condition developed in the winter and lasted until well into the summer. He stated that this tendency to chew bones was the first sign of a mineral deficiency and that it was a deficiency of phosphate of lime in soils and grasses.

Hedlund (44) pointed out that depraved appetite tended to develop in cattle fed on hay characterized by low alkalinity, the proportion of alkaline material to the dry matter content of the plant being little larger and sometimes even smaller than the proportion of chlorine and sulfur. A high degree of alkalinity and a low crude fiber content were regarded by this author as determining the quality of hay.

Murray (45), describing depraved appetite in cattle stated, "they have a capricious and variable appetite as regards their ordinary feed, but evidence strong desire to lick and eat substances for which healthy cattle have no inclination". He also stated, "this condition frequently precedes the condition in which the bones of cattle become brittle and fracture easily, known as oesteomalacia".

Orr (46) was inclined to regard depraved appetite, or "pica", and "osteomalacia" not as two separate "diseases", but as different manifestations of the same disease. He considered the pica as merely the outward manifestation of an instinctive craving for some substance, the deficiency of which was the cause of the lesions in the bones and the

accompanying symptoms of malnutrition found in osteomalacia.

Cauis and Bharucha (47) were inclined to think after investigating the subject of earth eating and salt licking among men and animals in India, that these habits were due to a deficiency of one or more of the following elements, calcium, phosphorus or iron. They stated that salt licking was not due to a lack of sodium chloride.

According to Hart and co-workers (48), the symptoms of animals used insstudying phosphorus deficiency were, extreme emaciation, stiffness intthe hind quarters, and at times, in the front quarters, swollen joints, harshness of coats, dull eyes, unthrifty condition and depraved appetites.

Marcq (50) stated that osteophagia (chewing of bones) was proof of lack of phosphorus in the food.

Theiler and co-workers (49), after a thorough investigation of conditions of phosphorus deficiency existing in South Africa stated that the immediate cause of bovine osteophagia was shown to be a deficiency of phosphorus in the veld vegetation of soils very low in phosphorus content. They also stated that the main importance of osteophagia lies in the fact that it is the precusor of the dreaded lamziekte. Discussing the subject of osteophagia they made the following observation - "although it has never been observed to pass over independently into a disease with an incidence of mortality of its own, it is probably of importance in relationship to the rate of growth of young stock and to the milk yield of cows".

These same authors (49) produced osteophagia experimentally by feeding cattle upon a phosphorus deficient ration, and again removed it by the simple addition of phosphoric acid to the diet. Continuing their discussion they stated, "the relationship between the minimum phosphorus requirements for prevention of osteophagia and the irreducible minimum physiological requirements for life and health has not been worked out. But the fact that cattle can show osteophagia for ten months of every year of their lives, and still remain in good health and reproduce their kind suggests that osteophagia is manifested before the point at which continuous draining of the phosphorus from the tissues begins".

Effects of Phosphorus Deficiency

The effects of a phosphorus deficiency in the ration may be divided into two classes, the visible effects and the invisible effects. One of the first of the visible effects, depraved appetite, has already been discussed.

That pica, or depraved appetite, is the first outward manifestation of a phosphorus deficiency was stated by Orr (46), Theiler and co-workers (49) and Marcq (50).

Among the unnoticed effects of phosphorus deficiency may be the poorer utilization of their feed by animals on a phosphorus deficient ration. Eckles and Gullickson (84) used cows taken from a region where a phosphorus deficiency in the forage was known to exist. These cows were continued on the same ration and fed hay purchased from the deficient region. This ration consisted of good quality prairie hay and oats. On the basal ration the animals remained in an unthrifty condition and in most cases barely maintained their weight. Under these conditions six to fifteen pounds of digestible nutrients was required per pound of gain. When phosphorus in the form of $Ca_3(PO_4)_2$ or NaH_2PO_4 was added the animals showed improvement in condition within a week. Within three weeks the lameness, creaking of joints and abnormal appetites disappeared. Under these conditions it required from one to three pounds of digestible nutrients to produce a pound of gain. They reported no improvement in their animals when fed $CaCO_3$ in the ration. As a result of their experiment they concluded that with phosphorus on this level cows required at least 20 percent more digestible nutrients than when a phosphorus supplement was fed.

<u>Calcium and Phosphorus Content of the Blood.</u> According to Robinson and Huffman (86) the amount of inorganic phosphorus contained in 100 c.c. of normal beef blood is 5.98 milligrams. The amount of calcium in 100 c.c. was given by them as 11.00 mg. These figures are the average

of over 100 samples.

Since the blood is the medium by which the food elements are carried to the body tissues, any abnormality in the blood should affect the tissues accordingly. Various factors which might affect the composition of the blood have been the subject of much study. In this study the concentration of calcium and of inorganic phosphorus have been of main interest.

Meigs, Blatherwick and Cary (87) stated that normal blood plasma contained no phosphorus compounds at all except phosphatides and inorganic phosphates, which certainly comprised more than 97 percent of all the phosphorus that existed in the plasma. They stated that the concentrations of these fractions were highly variable, that both could be made to vary by changing the amount of phosphorus supplied by the rations though the inorganic phosphorus showed the most marked variation. Both calcium and phosphorus underwent variations as the animal grew older and during the later stages of pregnancy.

Malan, Green and duToit (88) found that the outstanding characteristic of the blood of cattle grazing on phosphorus deficient pasture was the low content of inorganic phosphorus with a corresponding reduction of the total phosphorus. In their work a normal content of inorganic phosphorus was secured when a "small ration" of bone meal was addâd. Heifers supplied with bone meal showed a normal phosphorus of 5 mg per 100 c.c. of blood, while control animals showed only 2.3 mg. per 100 c.c. They stated that in general low inorganic phosphorus con-

tent of the blood was associated with poor condition.

Palmer, Cunningham and Eckles (89) observed that the inorganic blood phosphate in individual cattle might vary markedly from day to day even when the blood was drawn under apparently identical conditions. They also found that exercise caused marked changes in the blood phosphorus. There was at first a rise followed by a marked fall which persisted for several hours.

Harvard and Reay (90) also studied the influence of exercise on the inorganic phosphate of the blood. They worked with the adult men whose exercise consisted of running for varying lengths of time. Their results for human blood corroborated the findings of Palmer and associates (89).

Bethke and associates (90) found that in the absence of normal growth there was shown a general tendency for reduced calcium content of the blood and ash content of the bones. The phosphorus content of the blood was found more constant, but apparently as the calcium increased there was a tendency for the phosphorus to be depressed.

These results are in contrast to those of Palmer and associates (89), and to those of Meigs, Blatherwick and Cary (87) who found that the concentration of calcium was quite constant in the blood plasma of the cow.

In an experiment to determine the effects of phosphorus deficient rations on the blood composition in cattle, Palmer and Eckles (92) worked with animals reared in a phosphorus deficient region and under experimental observation for at least 75 days before the first analysis. The calcium content of the ration was not high, but apparently adequate. The ration of a dry cow contained 0.08 percent phosphorus and 0.36 percent calcium. Cows giving 12 pounds of milk received a ration containing 0.13 percent phosphorus and 0.30 percent calcium. Dry cows getting a phosphorus supplement received a ration containing 0.28 percent phosphorus and 0.35 percent calcium. Their animals showed low inorganic phosphorus but normal calcium throughout. The product of calcium times phosphorus, or the calcium phosphorus area, for the low phosphorus animals was rarely above 30 and sometimes below 20. This was in contrast to the area for the group receiving NaH_2Po_4 which was from 50 to 75.

Reproduction on Phosphorus Deficient Rations. Orr (17a) stated that in areas where there was a general poverty of minerals the rate of growth of the young animals was slow, the milk yield of cows was low, and the fertility of the females was also low.

Lindsey and Archibald (93), in studying the value of calcium phosphate as a supplement to theration of dairy cows, divided their whole herd into two groups as much alike as possible. They fed one group steamed bone meal as a supplement to a low calcium - low phosphorus ration.

They found no difference in the amount of breeding troubles in the two groups. They reported, however, that the group receiving no bone meal dropped a higher percentage of weak or delicate calves.

Eckles, Becker and Palmer (83) found that cows in the areas of phosphorus deficiency in Minnesota showed a decided retardation of oestral period, some not showing oestrum until a year after freshening. They gave this as the cause of poor calf crops in phosphorus deficient areas. They found that in some cases after dry seasons the calf crop was often not more than fifty percent.

Theiler and associates (94), after studying the breeding of cows on phosphorus deficient pasture for two years, found that in one lot not receiving any phosphorus supplement to the veld only 51 percent of the cows calved normally, as compared to 80 percent in the lot receiving bone meal. Calves from cows receiving bone meal and themselves fed bone meal were far superior at one year of age to those from control cows and themselves not receiving bone meal after weaning.

Osteoporosis. Osteoporosis is defined by Dorland (51) as abnormal porousness or rarification of bone by the enlargement of its canals or the formation of abnormal spaces.

Dr. Bitting (52) called a disease of horses locally known as "big head", "osteoporosis". It affected both native and imported horses in Florida. It was evidenced by a swelling of the jaw bones. Other bones in the body

were often misshapen. The shoulders and legs were often swollen and stiff. The bones were enlarged and cancellated. Their surfaces covered by hard brittle emanences or proliferations. The entire bone became porous, the marrow of an albuminous consistency, cartilages reduced or worn away. The roughening of the bony surface seemed to give the bones strength.

Crawford (53) blamed mineral deficiencies in the pasture of Ceylon for stunted growth, poor milkproduction, sterility and poor development of tooth and horn in cattle, for osteoporosis in horses, and for the inability of imported animals to develop on pasture without supplementary feeding.

McCollum and co-workers (23) stated that when both calcium and phosphorus were low but in the correct proportion to each other osteoporosis, and not rickets developed.

Osteomalacia. Another disturbance following a period of mineral deficiency is osteomalacia according to Orr (17b). He gave the results of 22 investigations in discussing hay which caused "brittle bone" or "osteomalacia". The average phosphorus content of these hays was 0.09 percent. He averaged the results of eleven investigators working with hay fed to cattle which showed no symptoms of mineral deficiency. The average was 0.229 percent. These figures were on a dry matter basis. He stated that after comparing the figures for calcium and phosphorus that they showed a more definite correlation between low phosphorus ration and osteomalacia than between low calcium ration and osteomalacia.

Dorland (51a) defined osteomalacia as a softening of the bones. A disease marked by increasing softening of the bones so that they become flexible and brittle. It is attended by rheumatic pains. The patient becomes weak and finally dies from exhaustion. It occurs chiefly in adults.

This softening of the bones is accomplished by a resorption of their mineral content whenever the food supply is inadequate in minerals according to Armsby (1f), who regards the skeleton of the animal as a storehouse in which, during periods of super abundance of calcium and phosphorus, these elements are stored up for use during periods of inadequate supply of these elements.

Carry (54) reported a "deficiency disease" occuring among cattle grazing on the coastal plains in Southern Alabama. When grass became old and dry cattle exhibited depraved appetite, chewed old bones, and some were said to eat slugs or grasshoppers. Milking cows came down first. They got very weak and lay down most of the time. Their bones became soft and flexible. Pressure on the nerves produced paralysis. In rare cases the bones of the limbs and pelvis were fractured. They recovered quickly when rains came and the grass began to grow or if turned into good fields of velvet beans or peas.

Styfziekte. The term styfziekte was found frequently in the literature. It is, according to Theiler, Green and duToit (64) a South African term which, when translated, means stiff sickness. It showed itself in retardation of growth and abnormal skeletal development, the most obvious

features of which were the thickening of the epiphyses of the leg bones, most pronounced at the metacarpus and first phalangeal joints of the fore limbs. The head and horns were sometimes disproportionately long and the skeleton was light. The disease resembled that referred to in European Veterinary literature as osteomalacia.

These workers (64) produced two cases of typical styfziekte by diets high in calcium but low in phosphorus. They found that they could cure the naturally occurring disease by supplementing the grazing areas in which it was prevalent with phosphorus compounds only. The authors concluded as a result of these investigations that it was definitely established that the styfziekte of South Africa was a straight aphosphorosis.

They stated further (64) that they had produced aphosphorosis, or clinically recognizable phosphorus deficiency experimentally and had shown it to be identical with the naturally occurring South African disease "styfziekte".

Lamziekte. According to Dorland (51c) lamziekte is a disease affecting cattle, characterized by lameness, humping of the back, and paralysis of the muscles of deglutition.

Theiler and co-workers (49) stated that lamziekte is the name originally given by the South African pioneering farmers to a fatal disease of cattle, characterized by symptoms of paralysis and paresis, principally of the locomotor system, but in many cases also of the muscles of mastication and deglutition. Translated, lamziekte

means lame sickness. Hence there is an intimate connection between the symptoms of the disease and its name.

Theiler and co-workers (49) gave the etiology of the disease as follows. (1) Phosphorus deficiency of the soil. (2) Consequent phosphorus deficiency of the herbage growin thereon. (3) Pica and more especially osteophagia in cattle. (4) Eating carcass debris. (5) This debris infested with a toxicogenic soprophite (parabotulinus bovis) which formed a toxin. (6) Toxin caused lamziekte. He stated that all six links in the chain must be present to produce lamziekte. Low phosphorus herbage could be prevented by phosphate manuring the soils deficient in that element. Osteophagia could be cured by feeding bone meal or other phosphorus rich substances. Still lamziekte could be prevented by removing carcass debris from the veld.

Theiler (49) made it plain that this disease is specifically caused by the saprophyte, parabotulinus bovis.

Marcq (50) stated that lamziekte can only be contracted by osteophagy; that osteophagy is certainly caused by lack of phosphorus in the food; that it is more marked on old grass and less accentuated on new grass richer in phosphorus.

Schmidt (55) investigated a disease occurring among the range cattle grazing on the costal plains of Texas. The animals, apparently in good state of nutrition, would suddenly show a complete breakdown of the organs of locomotion. The disease was prevalent from May to September and attacked animals over 18 months of age. The animals lost control of the loin muscles, went down and were unable to rise. They seldom recovered if once down. He ascribed (tentatively) the cause to toxins produced by bacterial action in carcass material on the prairie and the consumption of such putrid material by cattle. Sir Arnold Theiler visited this region and stated that he considered this disease as identical with lamziekte.

Rickets. Dorland (51c) defined rickets as a constitutional disease of childhood in which the bones become soft and flexible from retarded ossification, due to deficiency of the earthly salts. The disease is marked by bending and distortion of the bones under muscular action, by the formation of nodular enlargements on the ends and sides of the bones, by delayed closure of the frontenals, pain in the muscles, sweating of the head and degeneration of the liver and spleen. There are often nervous affections, feverishness and convulsions.

The foregoing symptoms of rickets are manifested by rachitic infants. In calves rickets give somewhat the same outward manifestation of the disease. There is a swelling of the joints, bending of the bones, softening of the skeleton in general according to Huffman and coworkers (56) who produced a rachitic condition in a bull on a low calcium ration.

According to Huffman rickets may be produced in calves when fed on concentrated alone. He found that the calves appeared to be in an excellent state of nutrition. The legs bent forward and outward. There was swelling at the joints. The eyes protruded. The head appeared too large for the rest of the body. The animals were irritable.

If allowed to remain on the rickets-producing ration the animals finally lost the ability to get up from the lying position.

Bergeim (58) stated that rickets could be produced experimentally by a low calcium, high phosphorus ration or by a low phosphorus, high calcium ration, this condition involving a loss of calcium or phosphorus or both from the body by way of the intestinal tract.

The relation of vitamin D to the prevention and cure of rickets was proven by McCollum and co-workers (59) when they used oxidized cod liver oil in their studies with rats. The oxidized oils would not prevent nor cure xerophthalmia but would aid in the deposition of calcium salts thereby preventing and curing rickets. They stated that this evidence demonstrated the existance of a fourth vitamin whose specific property "as far as we can tell is to regulate the metabolism of the bones".

To go into an exhaustive review of the literature on rickets is impossible in this thesis. There is, however, a relationship between rickets and mineral nutrition. Hess and Gutman (60) demonstrated the rickets curing properties of sunlight with infants by placing babies showing symptoms of rickets in direct sunlight for from thirty minutes to several hours. They found that the normal phosphorus content of infants blood was approximately four mg. per 100 c.c. By placing infants in direct sunlight as described they were able to raise the phosphorus of the blood in five infants from an average of 3.12 mg. per 100 cc. to 4.12 mg. per 100 c.c. in three months. This showed, according to

the authors, that the sunlight not only brought about a cure of the rachitic lesions but also occasioned chemical changes in the blood similar to those brought about by cod liver oil.

McCollum and co-workers (23) in 1921 produced rickets with diets low in phosphorus and vitamin A. These investigators showed that when a deficiency of phosphorus was insufficiently supplied with vitamin A rickets developed only when calcium was present in a ratio considerably higher than the optimal ratio for ossification.

Hart, McCollum and Fuller (62) in 1909 produced rickets in a lot of hogs on a low phosphorus ration (1.12 g in 2.2 pounds feed). These hogs developed stiffness in the hind legs and partial loss of their control. They became stupefied in actions and finally could not get to the feed trough. They appeared to be in good flesh in spite of their inability to carry their weight. The bones from one slaughtered animal were soft and spongy and appeared combed almost to the outer surface. The authors called it a case of extreme osteoporosis. They stated that the skeleton lost its calcium and phosphorus probably as $Ca_3 (Po_4)_2$ while the muscles and soft parts retained their normal percentage of phosphorus.

McCollum and Simmonds (63a) drew attention to the relationship between rickets and the proper balance of calcium and phosphorus in the ration when they stated "the experimental studies on rickets and related conditions have brought to light the great importance of having a proper quantitative relationship between the calcium and

the phosphorus in the diet since such a relationship greatly safeguards the developing skeleton".

Hart, Steenbock and Morrison (82) found that the mere supply of calcium or phosphorus in the ration was not enough to prevent rickets, and stated that bone formation required not only an ample supply of each of these minerals but also a vitamin which assists in assimilating calcium and phosphorus. They stated further that without this vitamin only a limited use was made of the calcium and phosphorus in the ration.

Huffman (57) found no beneficial effect of sunlight on calves which received roughage in their ration. He did find, however, that when calves were fed on a rachitic ration rickets developed when the calves were deprived of sunlight. A check group of calves on the same ration but turned into sunshine showed no signs of rickets. This suggested to Huffman (57) a relationship between roughage (in this case timothy hay) and vitamin D.

Summary of the Review of Literature

The importance of the mineral elements in the nutrition of animals has been appreciated since the time of Liebig. It was only within the past fifty years, however, that the mineral requirements of the dairy cow was made the object of extensive study.

An appreciation of the importance of phosphorus in the mineral nutrition of dairy cows resulted from the studies of calcium. Early investigators considered calcium the limiting factor in milk production.

All roughages are, as a class of feeds, comparatively low in phosphorus. Thecereal grains,however, contain much more of the element. The protein concentrates, such as bran, cottonseed meal, and linseed oil meal are the feeds richest in phosphorus.

Alfalfa hay ranks first among the roughages in phosphorus content. Different investigators showed that it may vary within a wide range in this respect. Factors influencing such variations were shown to be; the phosphoric acid content of the soil, the rainfall, the stage of maturity of the plant at time of cutting, the cutting and the quality of the hay as determined by such factors as leafiness, brightness, rain damage, and irradiation. during the curing process.

The phosphorus requirements of growing dairy heifers and lactating cows have not been definitely determined by modern methods of investigation. The quantitative relationship between the calcium and the phosphorus was studied and found to be optimal near, or greater than, the ratio found in bone which is 1.93.

For cattle, a deficiency of phosphorus in the ration depends, to a certain extent, upon the characteristics of the ration itself. The absolute, irreducible amount of phosphorus that the dairy cow requires has not been determined.

Phosphorus deficiency has been observed by research workers in practically every country in the world. The first noticeable symptom of such a deficiency is a craving on the part of the animal for bones, wood, old rags, and in fact, anything available. These symptoms were exhibited by dairy cows grazing on the best of sweet clover pasture, and while being fed alfalfa hay.

The diseases, or conditions, which result from a continued deficiency of phosphorus, are progressively; depraved appetite, and more specifically osteophagia, osteoporosis and osteomalacia if the animal is unable to gain access to carcass debris or other putrifying, toxin-infested material. If animals with osteophagia have access to carcass debris they will eat it. Theiler has demonstrated such debris to be infested with a toxin resulting from the presence within such debirs of a saprophyte, parabotulinus bovis which causes the dreaded lamziekte.

Another disease associated with the mineral metabolism of young animals is rickets. This disease was demonstrated to be of little importance to cattle because of the nature of their feed. Hay apparently carries enough vitamin D to insure proper calcification.

A review of the literature reveals the fact that little is known regarding the phosphorus requirements of dairy cattle. In view of the low phosphorus content of Michigan alfalfa hay more knowledge of the phosphorus needs of dairy cattle is desirable in order that no mistake may be made in utilizing Michigan's alfalfa crop.

EXPERIMENTAL WORK

Object of the Experiment

Reports of depraved appetite in certain sections of Michigan among cattle receiving alfalfa hay and a grain mixture containingno phosphorus supplements have been quite numerous. These reports point to a phosphorus deficiency in these sections.

Data on the mineral composition of several samples of Michigan alfalfa hay show it to be lower in phosphorus than hay reported from other states.

In view of the low phosphorus content of alfalfa hay grown in certain parts of Michigan, and of the prevalence of depraved appetite among cattle consuming this roughage, it was deemed advisable to conduct an experiment to ascertain the effect of adding phosphorus supplement to alfalfa hay as the main source of protein in a dairy ration.

An attempt will be made to secure alfalfa hay as low as possible in phosphorus. The object will be to determine the effect of such a ration upon the growth, health, and breeding ability of dairy heifers, and the effect upon the health, development and milk production of these animals after freshening.

Original Plan of the Experiment

Choice of Animals

For this experiment ten high grade Holstein heifer calves will be used. They will be from similar ancestry, and will be put on the experiment at ninety days of age. They will be divided into two lots of five animals each. An effort will be made to equalize the lots as to size of animals, and as to their apparent inheritance for milk production.

Choice of Rations

The rations to be used will consist as largely as practicable of alfalfa hay. An effort will be made to secure hay of good quality so that it will be consumed readily. It will be ground to insure accuracy in weighing as well as to aid in preventing waste. Corn silage will be fed as the remainder of the roughage since it is a common feed and relatively low in phosphorus. Corn will be the only concentrate in the ration. It willbe used largely to supply the required energy. Lot I will receive enough steamed bone meal to bring the phosphorus content of the ration up to McCollum's Optimum. Lot II will receive no mineral supplement other than common salt.

Care and Feeding Methods

The heifers will be cared for by the herdsman in charge of the experimental herd. Milk feeding will be discontinued as soon as possible after the animals are

put on the experiment in order to keep at a minimum the intake of phosphorus. Silage will be fed early in the morning. The corn will be given later in the morning and the hay will be fed in the evening.

The animals will be housed in individual stalls in the Experimental Dairy Barn. Bedding will consist of wood shavings. Each animal will be fed separately. The feed will be weighed on scales accurate to a tenth of a pound. A feed record will be kept in a book provided for that purpose. The animals will be turned into a dry lot for exercise. In summer they will remain in this lot the entire time except for feeding when they will be put into their stalls.

Collection of Experimental Data

Weighing

The animals willbe weighed at the end of each ten day period. At the end of each thirty day period they will be weighed three days in succession. The average of these three weights will be taken as the true weight of the animal in each case. These weights will all be taken early in the morning before the animals are fed.

The weights so secured will, in all cases, be compared to the Eckles Normal to determine the value of the ration for growth. These weights plus ten pounds, in each case, will be used as the basis for computing the rations for the animals. The ten pounds will be added each time to make sure that the animals are receiving sufficient feed to meet their requirements throughout the entire ten day period

Feeds

<u>Chemical Analysis.</u> Each feed will be analysed for calcium, phosphorus and nitrogen. An attempt will be made to secure alfalfa hay as low in phosphorus as possible.

<u>Nutrients Required and Nutrients Consumed.</u> The nutrients required by the animals will be ascertained at each weighing period and the feeds will be calculated accordingly. A record will be kept of the nutrients consumed and this figure will be compared to the requirements.

Feeding

<u>Plane of Nutrition.</u> The Armsby Feeding Standard will be used in the experiment. The rations will be adjusted at the close of each ten day period if the growth of the animals warrants it. Due to the variation in the phosphorus content of the alfalfa hay the average of the Michigan Experiment Station analyses will be used in computing the amount of bone meal to supplement the ration. The average protein content and net energy values as given by Henry and Morrison will be used in the ration.

<u>Mineral Supplement.</u> The mineral supplement will be Odorless Steamed Bone Meal. It will be fed in amounts sufficient to bring the phosphorus content of theration up to McCollum's Optimum. It will be weighed on gram balances.

<u>Salt.</u> Salt will be supplied to both lots. It will be placed in boxes so that it can be licked at will.

A record of the amount of salt fed will be kept.

Water. During cold weather water will be offered to the animals once per day in pails. During the time the outdoor water tank is used they will get their water from this tank.

Measurement of Growth

At the first of each month the following measurements will be taken; height at withers and at rump; depth of chest; width of chest, barrel, hooks, and thurls; length of rump; length from point of shoulders to hook bones; circumference of chest and of barrel.

Withers. The height of withers will be used to compare the skeletal growth of the two groups. It will also be used to compare the growth of each animal with the Eckles Normal.

Health Observations

General Appearance. Note will be taken from time to time of any peculiarities in the general appearance of the animals in the two groups.

Appetite. Any failure to eat their feed as well as any abnormalities of appetite will be recorded.

The herdsman in charge will make note of any abnormalities that may develop.

Heat Periods

An accurate record of the heat periods shown by all animals will be kept.

Metabolism of Feeds

The calcium, phosphorus and nitrogen balances of all the animals will be ascertained by seven day tests. These determinations will be conducted after the animals have become one year of age.

Blood Analyses

To determine the effect of the two rations upon the calcium and phosphorus of the blood, samples will be taken each month. These samples will be drawn from the jugular vein. They will be analysed by the staff of the Chemistry Section of the Agricultural Experiment Station.

After the heifers reach eight months of age they will be bled once each month for blood tests for B. Abortus infection. These tests will be made bythe Department of Animal Pathology.

Photographs

Pictures will be taken of the animals against a neutral back gound at the time they are placed on the experiment and at fifteen months of age.

Autopsy of Dead Animals

Any animals which may die on the experiment will be autopsied by the Department of Animal Pathology.

Method of Procedure

It was originally planned to write this thesis at the end of one year's time. That would have made it possible to include only the data on the animals up until the time the older nine were fifteen months of age.

Due to a change in plan, the writer was unable to write this thesis at the intended time. It has been possible, therefore, to include the data on the animals up to March 1, 1931. This necessitated the inclusion in the thesis of data not orginally provided for. Hence it was thought best to give an outline of the method of procedure.

Choice of Animals

The animals used in the experiment were high grade Holstein heifers taken from the experimental dairy herd of this station. They were daughters of the cows used on the Long Time Mineral Feeding Experiment then in progress. They were apparently normal in every respect at the time they were placed on experiment. They were all sired by the senior Holstein herd sire, Michigan College Mutual Johan 421266, then in service in the College dairy herd.

The first animal placed on the experiment developed a severe lameness, the cause of which could not be definitely diagnosed. It was considered that this lameness was a result of an injury to her left hind leg apparently received at birth. For this reason it was

dropped from the experiment.

A year after the work was started five more heifers were added, making seven animals in each group.

Choice of Rations

The feeds used were as planned. The alfalfa hay varied in phosphorus content more than was desired due to the difficulty of securing sufficient quantities, of the quality of hay desired, to last for any considerable length of time. In all cases the hay used was analysed before purchase and revealed a phosphorus content below the average of the samples analysed at this station in connection with the Long Time Mineral Feeding work.

Previous History of the Animals

These heifers were fed on whole milk for forty-five days. At forty-five days of age they were changed to skim milk. They received equal parts of whole corn and whole oats as soon as they would eat it. Ground alfalfa hay was given from the time they first started to eat it. They were continued on this ration of skim milk, corn and oats, and alfalfa hay until they were placed on the experiment at ninety days of age. In addition each animal received ten c.c. of cod liver oil each day to ninety days of age.

Care and Feeding Methods

The heifers were cared for as planned. On August 1, 1929, however, they were moved into what had previously

been the main dairy barn. At this time the nine older heifers were put in stanchions. The five younger ones were put in individual box stalls and kept in these stalls until they were about eleven months of age. At this time they were changed to the stanchion stalls, but tied with chains. On September 18, 1930 the entire experimental herd was moved to the new experimental barn. Here all the heifers were put in stanchions.

Milk was decreased at the end of ten days on the experiment, and discontinued after twenty days. Thus, from the age of 110 days the animals in Lot I received, until calving time, nothing but alfalfa hay, corn silage, corn, bone meal and salt. Lot II received the same ration without the bone meal. The bone silage was introduced into the ration at the time the milk was discontinued.

After the first freshening blood meal was added to the ration to supply the necessary protein without appreciably increasing the phosphorus intake.

It was found that the bone meal was eaten more readily when stirred into the hay at time of feeding. It was fed in this manner throughout the experiment.

As the animals reached ten months of age ground corn was gradually substituted for the whole corn. Some difficulty was experienced in getting the heifers to eat the corn meal - approximately one week being required to complete the change.

Water was offered as planned, except that when the animals were placed in the stanchions they could drink water at will, as the stalls were provided with drinking cups. Water meters were installed on the drinking cups and the water consumption was recorded in gallons.

Collection of Experimental Data

Weighing

Weights were taken each ten days as planned until the animals became fifteen months of age. After this time they were weighed for three consecutive mornings at the end of each thirty day period. In all cases the weighing was done in the morning before feeding.

The weights were compared to the Eckles Normal.

Feeds

Chemical Analyses. The feeds were analysed for calcium, phosphorus, and nitrogen as planned.

Nutrients Required and Nutrients Consumed. An accurate record was kept of the amounts of feeds consumed. The nutrients consumed were compared to the requirements according to the Standard used.

Feeding

Plane of Nutrition. The Armsby Feeding Standard was used in computing the rations until the animals freshened. After this time the lower limits of the Morrison Feeding Standard were used. In some cases it was necessary to supply some excess protein in order to provide sufficient net energy during the growing period. The rations were not always changed, as planned, at the end of each ten, or thirty day period because of the failure of some of the animals to gain sufficient weight to require it.

Mineral Supplement. Bone Meal was used as the phosphorus supplement as planned.

Salt. Salt was provided as planned while the animals were in the box stalls. After they were changed to the stanchions salt was mixed with the corn, one pound of salt per hundred pounds of corn.

Blood Meal. After the heifers freshened it was deemed advisable to furnish a protein supplement to balance the ration. This was done by adding blood meal as this feed would supply the necessary protein without appreciably increasing the phosphorus intake. It was added to the corn and mixed with it at the time of each feeding.

Measurement of Growth

Growth measurements were made as planned. Only the height at withers, however, was used in this thesis as a measurement of growth.

Comparisons of the height at withers to the Eckles Normal were made as planned.

Health Observations

General Appearance. Notes were made from time to time of the general appearance of the animals. These observations are given for each animal in the section provided for that purpose.

Appetite. The observations concerning the appetite of the animals were made as planned. These notes will be found for each animal in the individual sections.

Reproduction

Age at first Oestrum. The age of each animal at the first observed heat period was recorded.

Heat Periods. The heat periods were observed and note made of each. It is felt that some of these periods must have escaped observation since in some cases they were so irregular.

Number of Services for Conception. Record was made of the number of services required for conception. In some cases the animals were bred after having conceived. These services were not taken into consideration.

Gestation Periods. The length of the gestation period for each animal was computed.

Metabolism of Feeds

Seven day calcium, phosphorus and nitrogen metabolism tests were determined on the animals at various times. Animals D 2 to 12 were placed on metabolism prior to first freshening. All the heifers except D14 were placed on metabolism during high milk production. Metabolism tests were also made on D 2, D 8, and D 9 during medium production.

Blood Analyses

It was decided that once each month was not often enough to take blood samples so samples were drawn each two weeks. Calcium, and phosphorus determinations were made on these samples, as planned.

Blood samples for B. Abortus infection determinations were taken each month after the animals became eight months of age, as planned.

Milk Production

The milk production was recorded in pounds for each animal starting the fourth day after calving.

Butter Fat Production

Monthly Tests. Monthly determinations of the butterfat content of each animal's milk were made by the Babcock Method from two day composite samples.

The percentage of butterfat in the milk for each month was applied to that month's milkproduction to determine the butterfat production for that month.

Photographs

Photographs were taken as planned. In addition pictures were made of each animal at two years of age, and at freshening time for those that have freshened.

Autopsy of Dead Animals

None of the animals died.

Experimental Data

The similarity of inheritance for milk production of the animals used in this experiment is shown in Table I. They were all daughters of one sire, and out of cows of similar breeding.

The analyses of feeds used in the rations are shown in Table II.

Tables II to XVI inclusive, show the average weight of each animal for each thirty day period previous to calving, the feed consumed, the nutrients required and nutrients received, salt consumption, water consumption, percentage of phosphorus in the dry matter of the ration, and the average daily intake of phosphorus.

The monthly milk and butterfat production, feed consumed, nutrients received, nutrients required, percentage of phosphorus in the ration, and average daily intake of phosphorus are given in Tables XVII to XXVI, inclusive.

Table No. XXVII shows the reproduction data, including age at first oestrum, number of services for first conception, gestation period, age at first calving, weight, sex and health of calf and the recovery of the cow.

The metabolism of calcium, phosphorus and nitrogen before first calving appear in Table XXVIII.

The metabolism of calcium, phosphorus and nitrogen during high milk production appear in Table XXIX. This table includes data on D 11, D 12, D 13, and D 15 which

was secured after the taking of other data for this thesis was discontinued. This data is included in order to give a more accurate comparison between the two lots of animals. D 14 had not freshened at this time. For that reason this animal does not appear in this table.

It was planned to secure metabolism data on all the animals during medium milk production. Due to unavoidable hindrances this was not possible for all the animals. For that reason Table XXX includes data on but three animals.

Height at withers compared to Eckles' Normal and body weight compared to Eckles' Normal appear in Graphs I to VII, inclusive.

Graph No. VIII shows body weights during the first lactation period for animals D 2 to D 10, inclusive, which had been in milk for any considerable length of time.

Graphs IX to XVI, inclusive, show the blood calcium and inorganic blood phosphorus from the time the animals were placed on experiment until the data was compiled.

Health observations, appetites of the animals and detailed reproduction data are shown for each animal in the sections provided for each animal for that purpose.

Tests for B. Abortus infection are not shown because of the fact that all the animals remained negative throughout the experiment.

D-2

This heifer, born January 20, 1928 weighed 93 pounds at birth. It was a vigorous, thrifty calf when put on the experiment at ninety days of age. It weighed 195 pounds and was placed in Lot I.

Notes and Observations. On June 24, it was observed chewing wood in its stall. This was not observed again until November 28 and December 9, and again on March 7, 1929. At no time did it chew as ravenously as did the animals in the low phosphorus group.

It continued to be nearly normal throughout the course of the experiment.

Reproduction Record

			Oestrous Cycle
Age at first heat period	318 days		
" " second " "	339 "		21 days
" " third " "	367 "		28 "
" " fourth " "	488 "	Bred	121 " *

Services for first conception - 1.

Gestation period - 282 days.

Ease of Parturation - calved normally.

Health of Calf - strong - weight 93 pounds.

Recovery of cow - satisfactory - cleaned normally

Days until first heat period after freshening - 77.

		Oestrous Cycle
" " second " " " "	- 98 Bred	21

Services for second conception - 1.

*Intervening heat periods escaped notice.

D-8

This heifer was born on January 26,1928 and placed on experiment at ninety days of age. It weighed 84 pounds at birth and 165 pounds when started on the experiment in Lot II.

<u>Notes and Observations.</u> Throughout the experiment this heifer was a poor feeder. From the time milk was taken from the ration it never ate the alloted amount of feed. It exhibited a slight depraved appetite by chewing wood and hair and by chewing bone placed in its stall. It also was observed to eat dirt. The observation was made on June 15, 1928 that the low phosphorus group did not eat as well as the others. As shown by photographs it was a small underfed looking individual throughout the experiment. This is solely because of its poor appetite which became particularly pronounced shortly after calving.

Reproduction Record

			Oestrous Cycle
Age at first heat period	376 days		
" " second " "	441 "		65 days*
" " third " "	480 "	Bred	39 " *
" " fourth " "	502 "	"	22 "

Services for conception - 2.

Gestation period - 270 days.

Ease of parturation - calved normally.

Health of calf - strong - weight 69 pounds.

Recovery of cow - satisfactory - cleaned normally.

Days until first heat period after freshening — 29 days

Days until second heat period after freshening	48 days		19 days	
Days until third heat period after fresheing	71 "		25 "	
Days until fourth heat period after freshening	131 "	bred	60 "	*
Days until fifth heat period after freshening	187 "	"	56 "	*
Days until sixth heat period after freshening	207 "	"	20 "	

Services for second conception - 3.

* One or two heat periods apparently unnoticed.

D-4

D-4 was born January 31,1928. It weighed 82 pounds at birth and 186 pounds when placed on experiment at ninety days of age in Lot I.

Notes and Observations. It was observed chewing wood in its stall on several occasions. This did not seem to persist continually. D-4's appetite was good all the time and there was nothing in its record to indicate any abnormalities except for the fact that it required three services for first conception. This irregularity, however, may properly be blamed on the service bull because considerable difficulty was experienced while using this bull. When a different bull was put into service little more difficulty was experienced in getting the cows with calf.

Reproduction Record

		Oestrous Cycle
Age at first heat period	426 days	
" " second " "	446 "	20 days
" " third " "	467 "	21 "

Age at fourth heat period	490 days	Bred	23 days
" " fifth " "	519 "	"	29 "
" " sixth " "	581 "	"	62 " *

Services for conception - 3.

Gestation period - 268 days.

Ease of parturation - calved normally.

Health of calf - strong - weighed 64 pounds.

Recovery of cow - satisfactory - cleaned normally.

Days until first heat period after freshening	83	Bred

Services for second conception - 1.

* Two heat periods apparently unnoticed.

D-5

This heifer was born January 31,1928. In spite of the fact that it weighed but 70 pounds at birth it was considered best to put her in Lot II to balance the lots as to size. At ninety days of age it weighed 148 pounds.

Notes and Observations. As shown by the photograph this animal continued to be a rough, thin looking individual until first freshening. It exhibited a slightly depraved appetite by chewing wood and by chewing hair off the other animals occasionally. This animal like D-3 was a rather poor eater. After freshening, however, it consumed sufficient nutrients to meet the requirements as computed by the lower limits of the Morrison Feeding Standard. D-5 was the best milk producer of Lot II and this may have accounted for its better appetite.

Reproduction Record

			Oestrous Cycle	
Age at first heat period	324 days			
" " second " "	333 "		9 days	
" " third " "	358 "		25 "	
" " fourth " "	373 "		15 "	
" " fifth " "	533 "	Bred	160 "	*
" " sixth " "	680 "	"	147 "	*

Services for first conception - 2.

Gestation period - 262 days.

Ease of parturation - posterior presentation - Calf had to be pulled.

Health of calf - strong - weight 85 pounds.

Recovery of cow - satisfactory - cleaned normally.

Days until first heat period after freshening	73 days		
Days until second heat period after freshening	95 "	Bred	22 days
Days until third heat period after freshening	115 "	"	20 "
Days until fourth heat period after freshening	137 "	"	22 "

Services for second conception - 3.

* Several heat periods apparently unnoticed.

D-6

D-6 was born February 4,1928, weight 84 pounds. From an apparent inheritance for milk production standpoint it was considered best to put it in Lot I. When started on the experiment at ninety days of age it weighed 154 pounds.

Notes and Observations. This animal was observed chewing wood in its stall a few times. It was never off feed

and continued to grow at a rate close to normal. It developed a hump on the back which could not be associated in any way with nutrition. It must have been caused by some unnoticed injury.

Reproduction Record

			Oestrous Cycle
Age at first heat period	324 days		
" " second " "	553 "	Bred	229 days*
" " third " "	576 "	"	23 "
" " fourth " "	622 "	"	46 " *

Services for conception - 3.

Gestation period - 277 days.

Ease of parturation - calved normally.

Health of calf - strong-weight 73 pounds.

Recovery of cow - satisfactory - cleaned normally.

Days until first heat period after freshening	31 days		
Days until second heat period after freshening	52 "		21 days
Days until third heat period after freshening	118 "	Bred	66 " *

Services for second conception - 1.

*Intervening heat periods apparently unnoticed.

D-7

This heifer weighed 83 pounds when born February 10, 1928. It was placed in Lot II at ninety days of age. At that time it weighed 162 pounds.

<u>Notes and Observations.</u> This animal was the first one noticed chewing wood. It showed strong evidence of depraved appetite throughout the experiment by chewing wood,

eating dirt, and by chewing hair. It's appetite was fair up until just before freshening. At this time the animal went off feed and considerable difficulty was experienced during lactation in getting it to eat. This animal went dry at the end of 281 days lactation.

Reproduction Record

			Oestrous Cycle
Age at first heat period	423 days		
" " second " "	446 "		23 days
" " third " "	468 "	Bred	22 "
" " fourth " "	499 "	"	31 "
" " fifth " "	525 "	"	26 "

Services for conception - 3.

Gestation period - 274 days.

Ease of parturation - calved normally.

Health of calf - strong - weight 84 pounds.

Recovery of cow - satisfactory - cleaned normally.

Days until first heat period after freshening	10 days	
Days until second heat period after freshening	30 "	20 days
Days until third heat period after freshening	98 "	68 " *
Days until fourth heat period after freshening	129 "	31 "

Services required for second conception - 2.

* Apparently two heat periods were missed.

D-8

D-8 weighed 100 pounds at birth, February 11, 1928. At ninety days of age it weighed 196 pounds when started on the experiment. Placed in Lot I.

Notes and Observations. This heifer was not as good a feeder as some of the other heifers in Lot I. It chewed wood to a slight extent. Body weight kept as close to normal as any of the heifers. When eleven months of age this animal was observed to have a slight convulsion which never occurred again. It went off feed twice during the first lactation period, but came back on feed very soon in each case.

Reproduction Record

			Oestrous Cycle
Age at first heat period	374 days		
" " second " "	392 "		18 days
" " third " "	411 "		19 "
" " fourth " "	431 "		20 "
" " fifth " "	451 "		20 "
" " sixth " "	470 "	Bred	19 "
" " seventh " "	503 "	"	33 "

Services for first conception - 2.

Gestation period 278 days.

Ease of parturation - calved normally.

Health of calf - strong - weight 78 pounds.

Recovery of cow - satisfactory - cleaned normally.

Days until first heat period after freshening	22 days		
Days until second heat period after freshening	40 "		18 days
Days until third heat period after freshening	82 "	Bred	42 " *

Services for second conception - 1.

* One heat period apparently escaped notice.

D-9

D-9 was born February 18, 1928, weight 84 pounds at birth. It was placed on experiment in Lot II at ninety days of age, weighing 189 pounds.

Notes and Observations. Throughout the entire experiment this animal was a very poor feeder. Depraved appetite was shown about two months after being placed on experiment. This depraved appetite continued and the animal chewed bones, sticks and ate dirt and was observed chewing hair for long periods at a time. After freshening it was frequently off feed and would eat about half the food requirements during the first part of the lactation.

Reproduction Record

			Oestrous Cycle
Age at first heat period	433 days		
" " second " "	455 "	Bred	22 days
" " third " "	482 "	"	27 "
" " fourth " "	505 "	"	23 "

Services for conception - 3.

Gestation period - 275 days.

Days until first heat period after freshening	24 "		

Days until second heat period after freshening	44 days	20 days
Days until third heat period after freshening	104 "	Bred 60 " *

*Apparently two heat periods were missed.

D-10

D-10 was born May 17, 1928. Weight 82 pounds. Placed on experiment in Lot I at ninety days of age weighing 190 pounds.

Notes and Observations. At different times it was noticed chewing wood to a limited extent. This animal did not always consume sufficient nutrients to meet the requirements. It was very nearly normal in weight throughout the growing period. A little difficulty was experienced, however, in getting this animal to eat all of its required feed for a few weeks after freshening. It started eating well about six weeks after calving and has had a good appetite since.

Reproduction Record

			Oestrous Cycle	
Age at first heat period	383 days			
" " second " "	411 "		28 days	
" " third " "	449 "	Bred	38 "	*
" " fourth " "	469 "	"	20 "	
" " fifth " "	507 "	"	38 "	*
" " sixth " "	548 "	"	41 "	*

Services for conception - 4.

Gestation period - 268 days.

Ease of parturation - calved normally.

Health of calf - strong - 69 pounds.

Recovery of cow - satisfactory - cleaned normally.

Days until first heat period after freshening	25 days		
Days until second heat period after freshening	73 "		48 days*
Days until third heat period after freshening	138 "	Bred	65 " *

Services for second conception - 1.

* Intervening heat periods escaped notice.

D-11

This animal, born January 23, 1929, weight 92 pounds, was placed in Lot II. It weighed 192 pounds at ninety days of age when placed on the experiment.

Notes and observations. Always a very nervous and excitable individual this animal wasfrequently observed not eating the feed readily. It exhibited a depraved appetite by eating dirt, chewing hair, bones and wood. It remained undersized throughout the experiment.

Reproduction Record

			Oestrous Cycle
Age at first heat period	402 days		
" " second " "	426 "		24 days
" " third " "	451 "		25 "
" " fourth " "	479 "	Bred	28 "

Service for conception - 1

Gestation period 276 days.

Ease of parturation - required some help.

Health of calf - calf born dead - weight 85 pounds.

Recovery of cow - satisfactory - cleaned normally.

D-12

This heifer, born January 20, 1929 was placed in Lot I to offset it's full sister, D-5, in Lot II. It weighed 95 pounds at birth and 200 pounds when placed on the experiment at ninety days of age.

<u>Notes and Observations.</u> It was observed a few times chewing wood in it's stall. It continued to grow at a nearly normal rate, never exhibiting any depraved appetite after reaching the age of eleven months. Its appetite was good throughout the experiment.

Reproduction Record

				Oestrous Cycle
Age at first heat period	356 days			
" " second " "	380 "			24 days
" " third " "	406 "			26 "
" " fourth " "	431 "			25 "
" " fifth " "	458 "			27 "
" " sixth " "	484 "	Bred		26 "

Services for conception - 1.

Gestation period - 276 days.

Ease of parturation - posterior presentation.
Calf had to be pulled.

Health of calf - strong - weight 96 pounds.

Recovery of cow - satisfactory - cleaned normally.

D-13

D-13 was born January 26, 1929, weight 89 pounds. It weighed 185 pounds when placed on the experiment in Lot II at ninety days of age.

Notes and Observations. Like the other animals in Lot II this heifer exhibited symptoms of depraved appetite soon after being placed on the experimental ration. It ate dirt, chewed wood badly, and chewed hair. Its appetite was not of the best.

Reproduction Record

		Oestrous Cycle
Age at first heat period	481 days	Bred

Services for conception - 1.

Gestation period - 280 days.

Ease of parturation - calved normally.

Health of calf - strong - weight 85 pounds.

Recovery of cow - satisfactory - cleaned normally.

D-14

This heifer, a full sister to D-3, was placed in Lot I to offset D-3. It was born February 10,1929, weight 100 pounds, and weighed 205 pounds when placed on the experiment at ninety days of age.

Notes and Observations. It was observed chewing wood a few times. This was the only manifestation of a depraved appetite. It always was a good feeder and ate the ration readily.

Reproduction Record

		Oestrous Cycle
Age at first heat period	451 days	

Age at second heat period	520 days	Bred	69 days*
" " third " "	550 "	"	50 " *

Services for conception - 2.

Gestation period - had not freshened at time this data was compiled.

* Missed the intervening heat periods.

D-15

D-15. Weighing 112 pounds at birth on February 17, 1929, this heifer completed Lot II. It was an exceptionally large, growthy calf, and was considered a good test for the ration fed Lot II. It weighed 225 pounds at ninety days of age when placed on the experiment.

Notes and Observations. As shown by Graph No. 7, its body weight continued to increase at a normal rate longer than any of the other animals in Lot II. It later refused part of the feed and would not consume its requirements until nearly two years of age. It exhibited perhaps the most pronounced symptoms of depraved appetite of the group. It ate dirt, chewed wood and bones. It chewed hair from the other animals ravenously. As shown by the pictures it assumed the rough, undernourished appearace of the other heifers in the lot.

Reproduction Record

			Oestrous Cycle
Age at first heat period	418 days		
" " second " "	438 "		20 days
" " third " "	460 "	Bred	22 "

Services for conception - 1.

Gestation period - 279 days.

Ease of parturation - calved normally.

Health of calf - strong - weight 94 pounds.

Recovery of cow - satisfactory - cleaned normally.

DISCUSSION OF EXPERIMENTAL RESULTS

Period I. From 90 Days of Age to First Calving

In this investigation two lots of high grade Holstein heifers were placed on the experimental rations at ninety days of age. The basal ration fed the animals in Lot II, to first calving, consisted of alfalfa hay, corn and corn silage. The alfalfa hay used was low in phosphorus as shown by Table II. Lot I received the basal ration plus enough Steamed Bone Meal to bring the phosphorus content of the ration up to approximately 0.41 percent of the dry matter.

Growth of the Animals

The animals are compared to the Eckles Normal as to height at withers in Graphs I to VII, inclusive, which show that practically all of them were below the Eckles Normal during the first year, but reached this level shortly thereafter. As a group, the animals in Lot II gained at a very similar rate to the animals in Lot I. During the growing period there was little difference between the two groups in skeletal growth.

When comparing the two groups in respect to body weight a decided difference is shown by Graphs I to VII, inclusive, in favor of Lot I. This difference may be attributable to the greater feed consumption of the animals in Lot I. Less than two months after the animals were placed on the experimental rations all the animals in the group receiving the basal ration started refusing part of their feed. They continued to do this throughout the growing period. The animals which received the bone meal consumed their feed very readily, and as a result their total feed intake was considerably above that of the animals in Lot II. Tables III to XVI, inclusive, show the feed consumption during the growing period. These tables show that the crude digestible protein and net energy intake of the animals in Lot I conformed more closely to the Armsby Standard than did the crude digestible protein and net energy intake of the group on the basal ration.

Tables III to XVI, inclusive, show a greater water consumption by the animals receiving bone meal than by those on the basal ration. It was not determined whether or not this was due to the addition of the bone meal, but the indications are that this is the case because during the periods when the animals in each of the two groups were getting the same quantities of hay, silage, and corn, the water consumption was greater for the animals receiving bone meal. A seasonal variation in water consumption is shown by Tables III to XVI, inclusive. The amount of water consumed increased in general as the weather became warmer. No attempt was made to correlate water consumption to atmospheric temperature.

Phosphorus Intake. As shown by Tables III to XVI, inclusive, the phosphorus intake of the animals in Lot II was below ten grams per day during the first year while that of the animals in Lot I was approximately twice as great. The percentage of phosphorus in the dry matter of the ration was approximately 0.20 for the animals in Lot II as compared to approximately 0.38 for the animals in Lot I.

During the second year the intake of phosphorus gradually increased in both lots due to the greater feed consumption. The percentages of phosphorus in the dry matter continued to be very uniform up until about one month before calving when the phosphorus was increased. This was caused by the addition of more corn to the ration to get the animals into a higher condition of flesh at calving time.

Phosphorus Requirement for Growth. The optimum phosphorus content of the dry matter of a ration is given by McCollum as 0.4148. The rations of the animals in Lot I were adjusted to this figure by using 0.18 percent as the phosphorus content of alfalfa hay. This figure was given by Reed and Huffman as the average of 19 samples of Michigan grown alfalfa hay. The tables giving the feed consumption for the animals in Lot I show the phosphorus content of the dry matter in their rations to be slightly below this figure in most cases because the alfalfa hay used was consistently below the figure used for alfalfa hay in computing the phosphorus furnished by the rations.

The tables giving the feed consumption for the animals in Lot II show the percentage of phosphorus in the dry matter of their rations to be very close to the figure (0.20 percent phosphorus) which Palmer believes to be the danger line below which figure a ration may be said to be phosphorus deficient.

Table No. XXVIII, giving the results of metabolism tests made on eleven of the fourteen animals before calving shows an average phosphorus utilization by the animals in Lot I of 30 percent. This figure may be compared to 41.6 percent phosphorus utilization by the animals in Lot II which received the low phosphorus ration. These figures are in line with Kellner's recommendation that an animal should receive in its ration from two to three times the amount of phosphorus stored by the body, because of his belief that an animal could utilize but one-third to one-half the amount of the element furnished by its ration.

From analyses of the bones of animals Kellner computed the average daily retention of calcium and phosphorus. He found that on this basis an animal stored 8.3 grams of phosphorus per day. Applying the utilization percentages secured in this investigation to Kellner's figure it is found that an animal should receive from 20.24 grams to 27.67 grams of phosphorus per day. Lot I received almost this amount.

In as much as Lot I received very close to the percentage of phosphorus which McCollum believes to be optimum, and in as much as the phosphorus utilization by these animals is shown to be lower than was secured by Reed and Huffman, probably the animals received very nearly an optimum amount of phosphorus.

Calcium-Phosphorus Ratio. Table XXVIII shows that during the metabolism tests made on the animals before calving the calcium phosphorus ratio was quite wide. The literature on the calcium phosphorus ratio for cattle is not definite. The interdependence of the two elements was demonstrated by Sherman and Quinn. Analyses of bones have shown that the calcium and phosphorus are combined as tri-calcium-phosphate. Besides the calcium combined with phosphorus in this manner there is the calcium combined with carbon and oxygen as calcium carbonate. The ratio of calcium to phosphorus in tri-calcium-phosphate is 1.93. Knowing that the ration must provide the calcium for combination into tri-calcium-phosphate as well as calcium carbonate it is not unreasonable to assume that an optimum calcium phosphorus ratio would be considerable in excess of 1.93. In this investigation the animals in Lot I received a calcium-phosphorus ratio of 3.34 and those in Lot II received a ratio of 4.77. The narrower ratio in Lot I is because of the influence of the bone meal added to the ration. The difference in the utilization of phosphorus by the two groups may not be significant, but in this investigation the greater utilization was secured with the wider ratio. This, however, may be a coincidence,

and merely due to the limited absolute intake of phosphorus by the animals in Lot II. McCollum and Simmonds stated that for rats a ration should provide calcium considerably in excess of phosphorus. It is logical to assume that an optimal proportion of the two elements would be as near as possible to the proportion in which they are used in combination by the body. Therefore, the combining proportion of the two elements for tricalcium-phosphate in ossification should be about 1.93. Adding to this the amount of calcium needed for forming calcium carbonate the ratio of calcium to phosphorus in these two compounds is 2.14. Since these two compounds comprise 95 percent of the inorganic content of bone a combining proportion of the two elements calcium and phosphorus should be close to two parts of calcium and one part phosphorus. Obviously other factors enter into the metabolism of the two elements and affect them so that it is rather difficult to say how close the calcium-phosphorus ratios used in this investigation were to optimal. It is worthy of note that theratio of calcium to phosphorus in the alfalfa hay used in this investigation varied from 7:1 to more than 11:1.

Health of the Animals

The lack of appetite among all the animals in Lot II was one of the outstanding features of this investigation. As has been previously stated this condition was observed less than two months after the animals were placed on the experiment. It was a condition that persisted, as is shown by the reductions of food intake which appeared from time to time. A lack of appetite by animals on low phosphorus rations was not mentioned in the literature reviewed. Reports of the refusal of dairy cows on farms to eat alfalfa hay of apparent good quality have been quite frequent. There is a possibility that a lack of phosphorus may be a contributing factor in such instances.

In addition to the poor appetite for their feed, the animals in Lot II showed depraved appetite by chewing their stalls, eating dirt, and by chewing the hair from each other. Such symptoms are, according to Theiler, Marcq, Eckles and Becker, Reed and Huffman, Schmidt, Welch, and many others, evidence of insufficient phosphorus in the ration. Theiler, Palmer, and Welch specifically stated that bone chewing by cattle is proof of a phosphorus deficiency. The animals used in this experiment were given fresh bones to chew, but under the conditions of the experiment they did not chew these bones to any appreciable extent.

There was little difference in the general appearance of the animals of the two groups at fifteen months and at two years of age as shown by the photographs. There was a tendency, however, for the low phosphorus animals (Lot II) to grow longer, rougher coats of hair in the winter than were shown by those receiving optimal phosphorus in their ration.

At no time were there symptoms of stiffness, creaking of bones, and stilted gaits as reported by Eckles, Becker and Palmer in investigating phosphorus deficiency among dairy cattle in Northern Minnesota, or Hart and co-workers, investigating the same problem in Door County, Wisconsin. This fact suggests the possibility that under the conditions of this experiment the phosphorus deficiency did not become as severe as reported by the aforementioned workers.

The coats of hair on the animals in Lot II were duller than on the animals in Lot I. The eyes were somewhat sunken and rather dull in appearance.

Graphs IX to XV, inclusive, show the blood calcium and inorganic blood phosphorus of the animals from the time they were placed on the experiment until the data was assembled. The effects on blood of the low-phosphorus ration supplied to Lot II are in accord with the results of Henderson and Weakley, Eckles and Palmer, and Malan, Green and duToit, all of whom reported low inorganic blood phosphorus in animals on rations low in phosphorus.

Graphs IX to XV show that there was a drop in inorganic blood phosphorus of the low-phosphorus group soon after being placed on the basal ration. There was a tendency for the inorganic phosphorus graphs to come together at from fifteen to eighteen months of age. In both groups the inorganic blood phosphorus dropped prior to calving. These graphs show a tendency of the blood calcium to rise when the inorganic blood phosphorus drops.

Reproduction

The data secured in this investigation on age at first oestrum and on the oestrual cycles of the animals are not very complete. Probably in many cases the oestrual periods were not observed due to the fact that the animalswere stabled nearly all the time during the period that they would normally start to show oestrual periods. Table No. XXVII, giving the reproduction data for the two groups shows that the low phosphorus group, (Lot II) averaged 35 days older at first observed oestrual period than the animals in Lot I. This difference is probably insignificant in the light of the conditions of the experiment. This is in contrast to the reports of Eckles, Becker and Palmer, Welch, Hart and associates, and Theiler and co-workers, all of whom have stated that low phosphorus rations produce delayed oestrum in cattle. Perhaps the phosphorus content of the ration used with Lot II in this investigation was not low enough to produce the effects reported by theabove mentioned investigators.

Table XXVII, giving the gestation periods of the cows, size, health, and weight of the calves, show no difference between the two groups in these respects. One hundred percent reproduction was secured. In some cases several services were required for conception. It is felt that this difficulty was caused by the service bull, because, on changing bulls, little further difficulty was experienced in this respect.

Period II. First Lactation Period

Milk Production

The records of milk production given in Table XXVI show a significant difference in favor of Lot I for those animals which were in milk for a complete period. Two animals, D-2 and D-8 in Lot I and three animals, D-3, D-7 and D-9 completed an entire lactation period. The period for D-7 is for 281 days instead of 305 days. This is because lactation ceased at the end of this period. There was but one animal, D-5, in Lot II which gave indication of production comparable to the animals in Lot I. Animals D-11, D-12, D-13 and D-15 had just calved at the time of assembling this data and D-14 had not yet calved.

The difference in milk production between the two groups is probably attributable to the fact that with one exception the low phosphorus group would not eat the amounts of feed required by the standard used, whereas the group receiving the phosphorus supplement consumed their feed quite readily. This explanation is strengthened by the fact that D-5 the only animal in Lot II to consume her requirements of feed is the only animal in that group to produce at a rate comparable with the animals in Lot I.

The lack of appetite among three of the four animals which have been in lactation in Lot II continued as long as they were giving milk. As a result the animals appeared gaunt and emaciated. They assumed somewhat of the appearance of the animals described by Eckles, Becker, and Palmer in reporting on phosphorus deficiency conditions in Northern Minnesota, and by Hart and associates in describing cattle found in Door County, Wisconsin. The animals did not show the stiffness, creaking of joints and inability to rise as described by Eckles and co-workers, and Hart and associates, but their coats of hair were dull, their eyes were sunken, and they seemed listless and dull.

The animals in Lot I, on the other hand, appeared normal throughout the lactation period. Very little difficulty was experienced in getting these animals to eat their allotted rations.

A lack of appetite by animals on low phosphorus rations was not reported by any of the investigators whose work was reviewed. Theiler and co-workers, Eckles and associates, Hart and associates, Forbes, and Meigs and co-workers, all emphasized the fact that cows on phosphorus deficient rations did not produce as well as cows fed the same rations supplemented with phosphorus. None of these investigators, however, made any mention of a lack of appetite in lactating dairy cows fed phosphorus deficient rations.

Phosphorus Intake. The feeds used in this investigation during milk production were the same as were used previous to the time the animals calved, with the exception that, after calving, blood meal was added to the rations in order to provide the necessary protein. This feed was used because it is low in phosphorus in comparison to its protein content. By using it the protein of the ration was kept to the Lower Limits of the Morrison Feeding

Standard without appreciably increasing the phosphorus. Tables XVII to XXV, inclusive, show that the animals in Lot I received approximately 0.41 percent phosphorus in the dry matter of their ration as compared to from 0.23 to 0.26 percent for Lot II. The animals in Lot II would have received approximately 0.23 percent phosphorus had they eaten their rations as computed according to the standard used. This fact is illustrated by Table XX which shows the milk production and feed consumption for D-5, the only animal in the low phosphorus group which ate enough feed to meet its requirements.

The intake of phosphorus by the animals in Lot I averaged 42.34 grams daily compared to 20.09 grams for the low phosphorus group. Among the animals of the low phosphorus group D-5 stands out as having averaged 25.42 grams of phosphorus intake daily. The amounts of phosphorus received at times when D-3, D-5, and D-9 were practically in phosphorus equilibrium compared very favorably with the results secured by Rose. In his work a cow in phosphorus equilibrium received the amount of phosphorus in her milk plus 26 milligrams of phosphorus per kilogram of body weight.

<u>Phosphorus Requirement for Milk Production.</u> Kellner in computing the phosphorus requirement for milk production accepted Henneberg's estimate of 21.8 grams of phosphorus per 1000 kilograms of body weight and added to this figure three times the amount of phosphorus eliminated in the milk, on the assumption that from one-

third to one-half of the feed ash consumed was available. Thus a 1000 pound cow giving 20 pounds of milk would require 25 grams of phosphorus per day.

In this investigation the animals varied in weight from 650 pounds to 1100 pounds. The average daily milk production varied from 20.4 pounds produced by D-3 to 32.7 pounds produced by D-2 during complete 305-day lactation periods. It is evident that the ration of D-3 which contained an average of 16.46 grams of phosphorus per day, did not provide enough to meet its requirements. This cow was barely in phosphorus equilibrium when producing 17.6 pounds of milk. At that time it weighed 655 po unds. D-2, however, which produced an average of 32.7 pounds of milk a day during the entire lactation period received an average of 32.7 grams of phosphorus per day. This animal was in positive phosphorus balance while producing 35.3 pounds of milkper day during metabolism test. At this time its body weight was 948 pounds. As shown by Table XXIX the results obtained from D-2 on metabolism test are indicative of the animals in Lot I. The results obtained from D-3 are not as represantative of the performance of the animals in Lot II because the metabolism test was made on this animal later in lactation, at which time milk production had decreased materially. Neither D-7 nor D-9 are considered as nearly representative of the group as D-3.

The negative phosphorus balances secured on the low phosphorus group are in accord with the results of Forbes and associates, Hart and co-workers, and Meigs and Woodward who found negative phosphorus balances almost universal in cows receiving standard rations without mineral supplements.

The phosphorus utilization shown by Table XXIX is considerably higher in Lot II than in Lot I. Apparently Lot I received considerable excess phosphorus. The utilization secured in both groups was higher than Kellner's estimate. The higher utilization of phosphorus by the animals in Lot II is in contrast to the work of Eckles and Gullickson who found that animals on low phosphorus rations did not make as good use of their feed as animals on adequate rations.

The results secured indicate that the basal ration was inadequate in phosphorus content for satisfactory milk production. The lower utilization of phosphorus by the animals in Lot I combined with the positive phosphorus balances indicate that these animals received enough, if not a slight excess, of phosphorus.

Calcium-Phosphorus Ratio. There was no evidence in the literature reviewed to indicate that the optimal calcium-phosphorus ratio for milk production should be materially different from the ratio for growth. In this investigation the average calcium-phosphorus ratio was 2.912 for the animals in Lot I and 3.060 for the animals in Lot II during lactation. This difference is insignifi-

cant. The results received with D-5, D-11, D-13, and D-15 in Lot II, however, show that the average calcium-phosphorus ratio would have been much higher (3.51) had all the animals in the group consumed their feed, as these four animals were doing at the time of metabolism test. The addition of the bone meal to the rations of Lot I narrowed the calcium-phosphorus ratio for this group. The results from these metabolism tests do not agree with the results obtained by Turner, Harding and Hartman who secured better assimilation from rations showing a calcium-phosphorus ratio of 1.25 than they did from rations with a ratio of 2.50.

Health of Animals

The differences in general appearance observed in the two groups of animals previous to calving were accentuated by milk production. The animals in Lot I continued in normal condition. The animals in Lot II, to the contrary, were frequantly off feed. Allof them except D-5 refused to eat more than one-half as much hay, and one-half to two-thirds as much silage as the animals in Lot I. Their coats were rough, eyes sunken, and they were somewhat dull and listless.

The depraved appetites observed previous to calving became much worse after calving. The animals would search the exercise lot for material on which to chew. They chewed the fences, chewed hair off each other, and were frequently observed eating dirt, On one occassion D-5 got out of the stanchion during the night and chewed a rubber hose into two pieces. Another time this same animal chewed an extension cord almost beyond recognition. These results agree with those of Eckles, Becker. and Palmer, and Theiler and associates.

As shown by Graph VIII the animals in Lot I maintained their body weights to a much better advantage than did the animals in Lot II. The low phosphorus group continued to lose weight much longer than the animals in Lot I. Graph VIII also shows that at any given time after calving the animals in Lot I were heavier than those in Lot II. D-7 is an exception in the low phosphorus group, but she was fed far in excess of her requirements during the latter part of her lactation period, in an effort to induce greater milk production as indicated by Table XXII.

The blood pictures of animals D-2 and D-10 inclusive, which are shown by Grapsh XIX to XV, inclusive, show a decided drop in inorganic blood phosphorus in the group receiving the low phosphorus ration immediately after calving. The blood phosphorus of these animals remained at a lower level than that of the animals in Lot I. There was one exception to this, the case of D-7 which received nutrients far in excess of her requirements for the last three months of her lactation periodl These low phosphorus percentages are in accord with the results of Henderson and Weakley. In fact, they are more pronounced than the results secured by these investigators. These also agree with those secured by Palmer and Eckles and Malan, Green, and duToit who worked with cattle fed on phosphorus deficient rations.

Reproduction. At the time of assembling this data none of the animals had calved the second time. After reviewing the findings of Eckles, Becker and Palmer, and Hart and associates, Theiler and co-workers, and Welch, it was anticipated that delayed oestrum and difficulty in conception would occur. The data on these subjects as given below shows no significant differences between the two groups as to time between calving and the first oestrual period thereafter, regularity of oestrual periods and number of services for second conception.

Reproduction Data for Second Conception

Animal	Lot	Days from Calving to First Oestrual Period	Regularity of Oestrual Periods	Services for each Conception
D-2	I	77	Irregular	1
D-3	II	29	"	3
D-4	I	83	"	1
D-5	II	73	"	3
D-6	I	31	"	1
D-7	II	10	"	1
D-8	I	22	"	1
D-9	II	24	"	1
D-10	I	25	"	1
Average for Lot I		48	Irregular	1
" " " II		34	"	2

Apparently the phosphorus content of the ration fed Lot II was not low enough to produce the delayed oestrum and poor breeding ability of the cattle studied by Eckles, Becker and Palmer, Hart and associates, Theiler and co-workers, and Welch.

SUMMARY

Period I. From 90 Days of Age to First Calving.

1. The basal ration fed Lot II, consisting of alfalfa hay low in phosphorus, corn silage and corn, supplemented with common salt, was adequate for normal skeletal growth in dairy heifers. This ration contained about 0.20 percent phosphorus on the dry basis.
2. The basal ration, low in phosphorus, did not support normal growth in body weight. The heifers receiving the basal ration supplemented with enough bone meal to bring the phosphorus content of the dry matter up to 0.41 percent made greater gains in body weight than those receiving the basal ration.
3. The basal ration was responsible for the development of poor appetites in the animals receiving it. This resulted in a feed intake below that of the group receiving the phosphorus supplement.
4. The low phosphorus content of the basal ration produced rough, staring coats, dull eyes and a general unthrifty appearance in the animals in Lot II.
5. Approximately 0.20 percent of phosphorus in the dry matter, as provided by the basal ration, was not sufficient to prevent the development of depraved appetite.

6. The phosphorus intake of the animals on the basal ration was not sufficient to maintain their inorganic blood phosphorus at a normal level.
7. There was no significant difference between the two groups of animals in the age at first oestrum, number of services for conception, gestation period, size and health of calves produced, or the recovery of the cows after calving.

Period II. First Lactation Period

1. The basal ration plus enough blood meal to meet the requirements of the lower limits of the Morrison Feeding Standard did not support liberal milk production.
2. The thin, emaciated condition of the animals in Lot II and their failure to maintain their body weights were a result of the low phosphorus content of the basal ration.
3. The poor appetites shown before calving by the animals receiving the basal ration were more pronounced after lactation began and persisted during the lactation period.
4. The depraved appetites which developed before lactation began, became more acute during lactation.
5. After calving, the inorganic blood phosphorus of the group receiving the basal ration dropped very markedly and remained at a low level as long as

lactation continued, indicating inadequate phosphorus in this ration.

6. The low phosphorus content of the basal ration had no significant effect upon the fecundity of the animals receiving it. These results indicate that the basal ration was adequate in phosphorus for normal reproduction.

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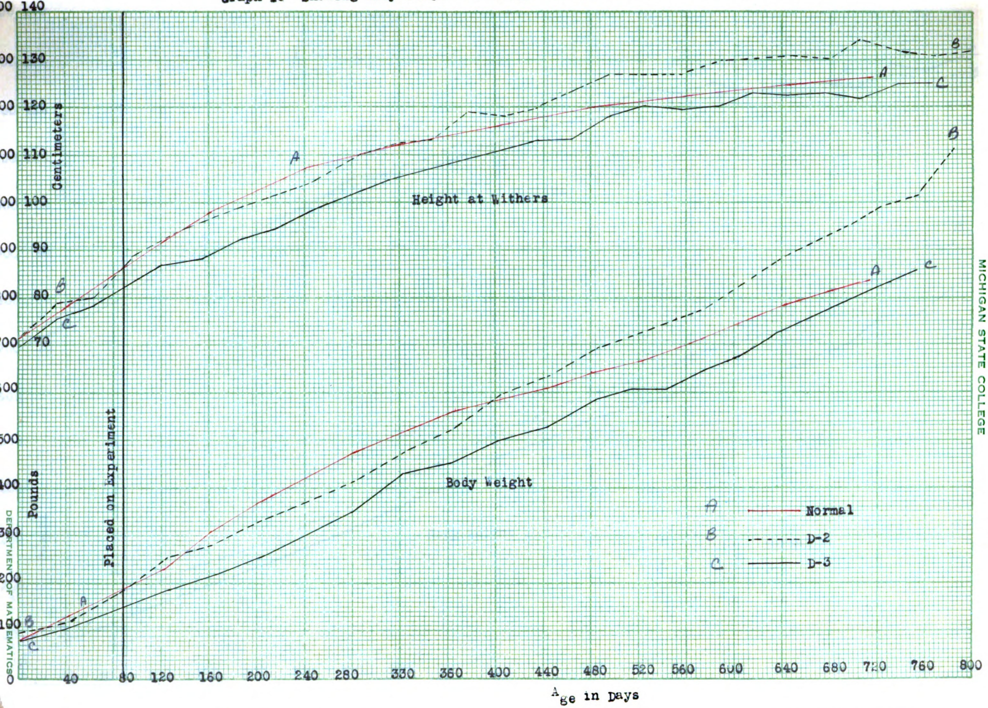
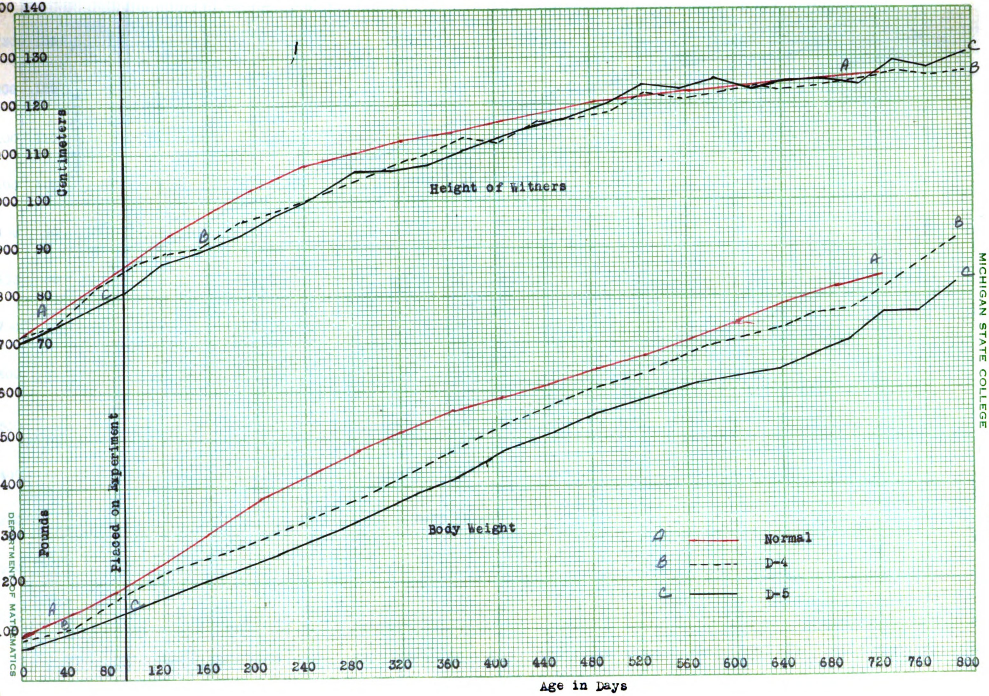
APPENDIX

Graph I. Showing Body Weight and Height at Withers, Birth to Two Years of Age.

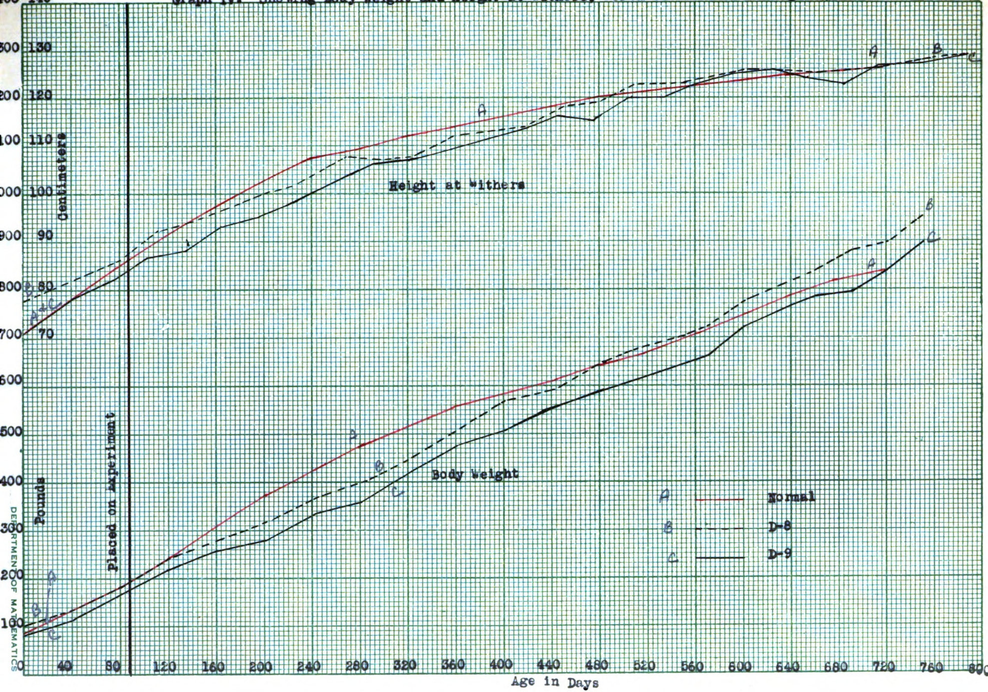


Graph II. Showing Height of Withers and Body Weight, Birth to Two Years of Age

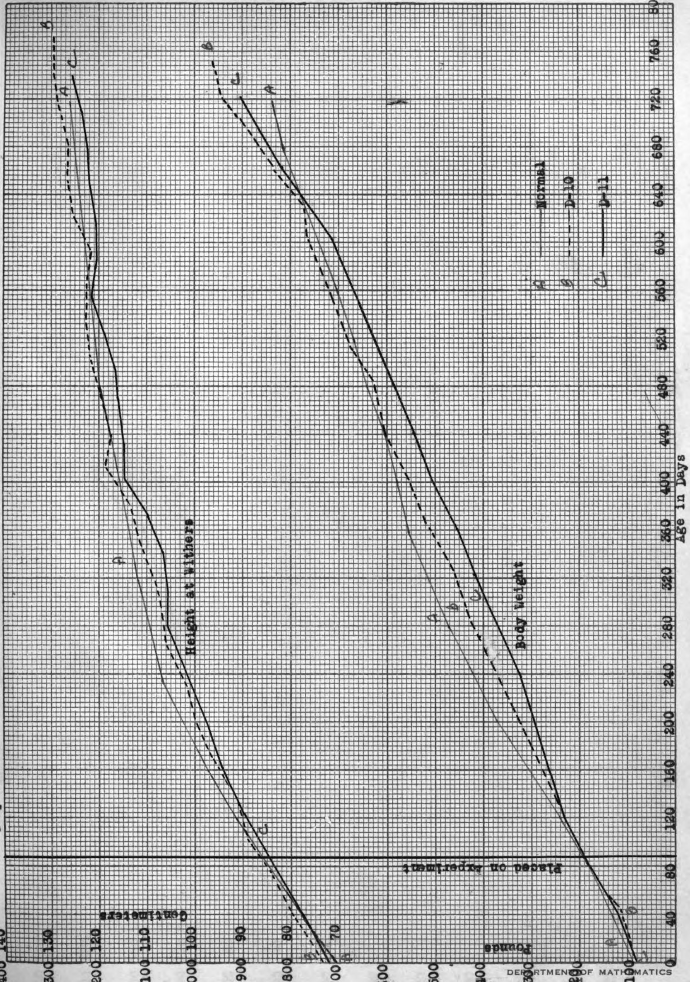


Graph III. Showing Body Weight and Height of Withers, Birth to Two Years of Age.

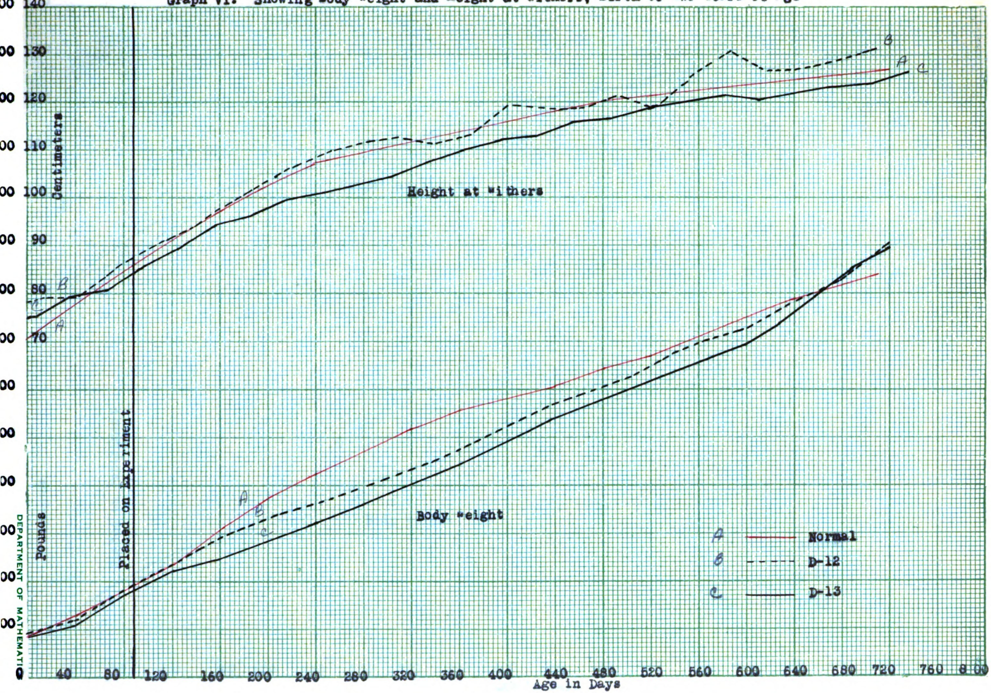
Graph IV. Showing Body Weight and Height at Withers, Birth to Two Years of Age



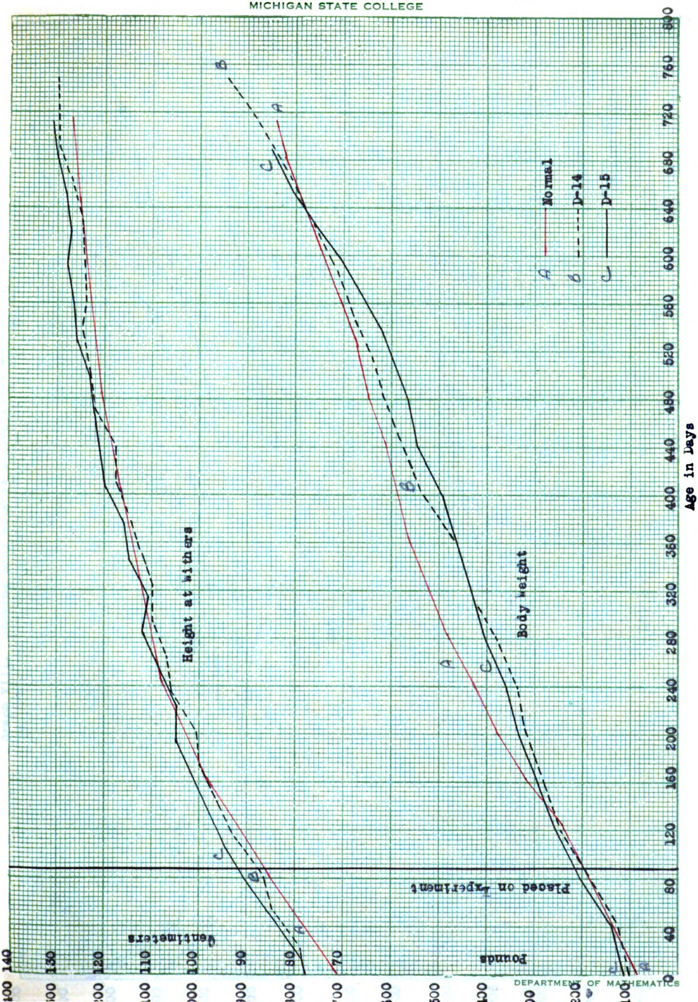
Graph V. Showing Body Weight and Height at Withers, Birth to Two Years of Age



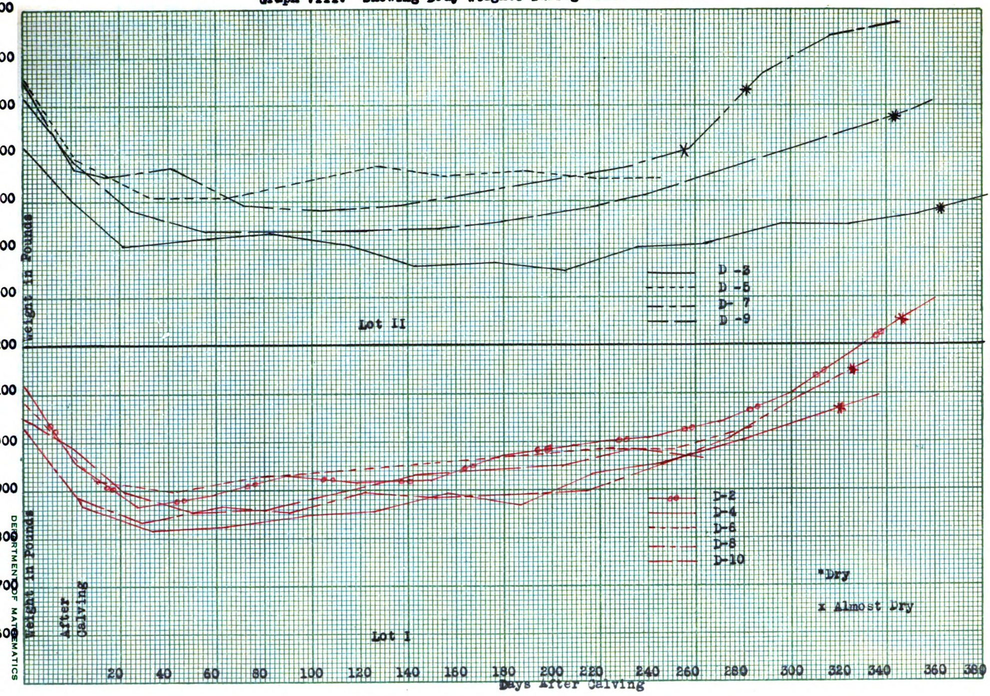
Graph VI. Showing Body weight and Height at Withers, Birth to Two Years of Age



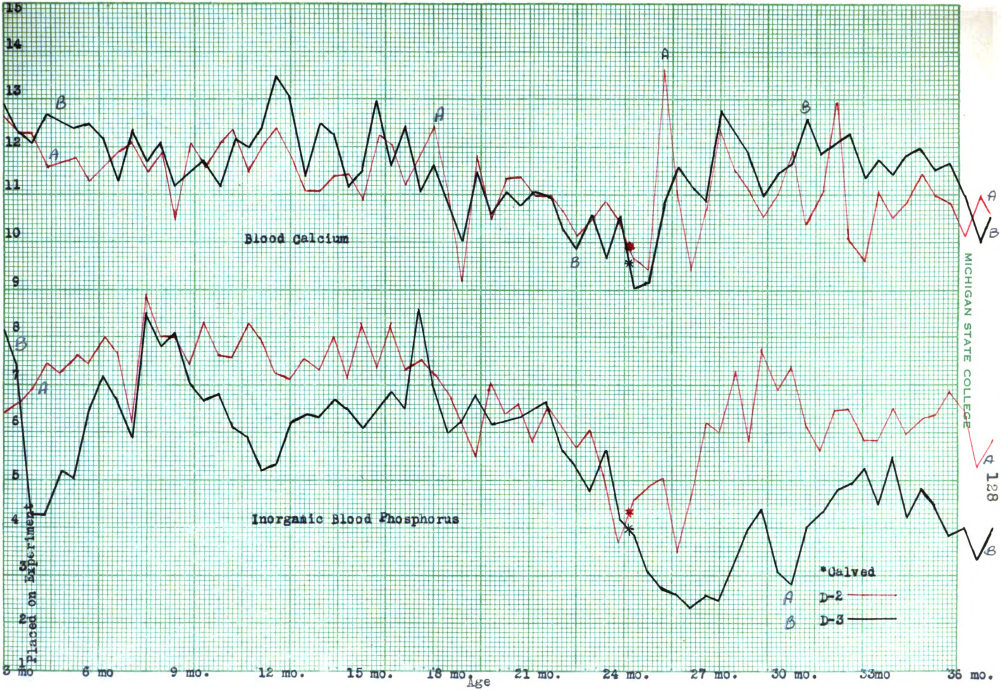
Graph VII. Showing Body Weight and Height at Withers. Birth to Two Years of Age



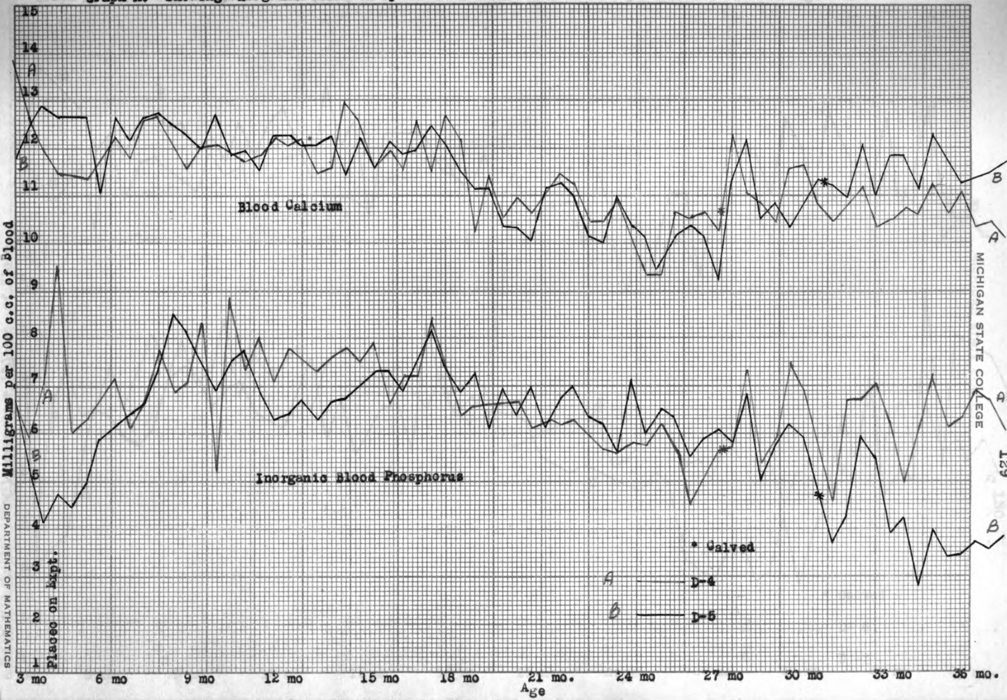
Graph VIII. Showing Body Weights During First Lactation.



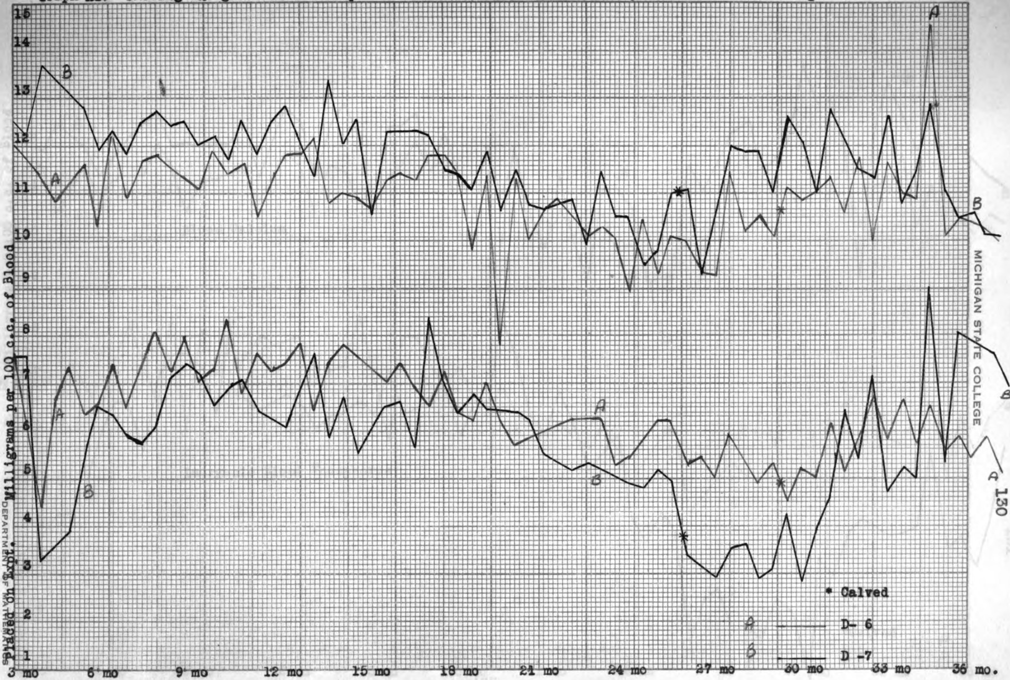
Graph IX. Showing Inorganic Blood Phosphorus and Blood Calcium From 90 Days to Three Years of Age



Graph X. Showing Inorganic Blood Phosphorus and Blood Calcium from 90 Days to Three Years of Age



Graph XI. Showing Inorganic Blood Phosphorus and Blood Calcium from 90 Days to Three Years of Age



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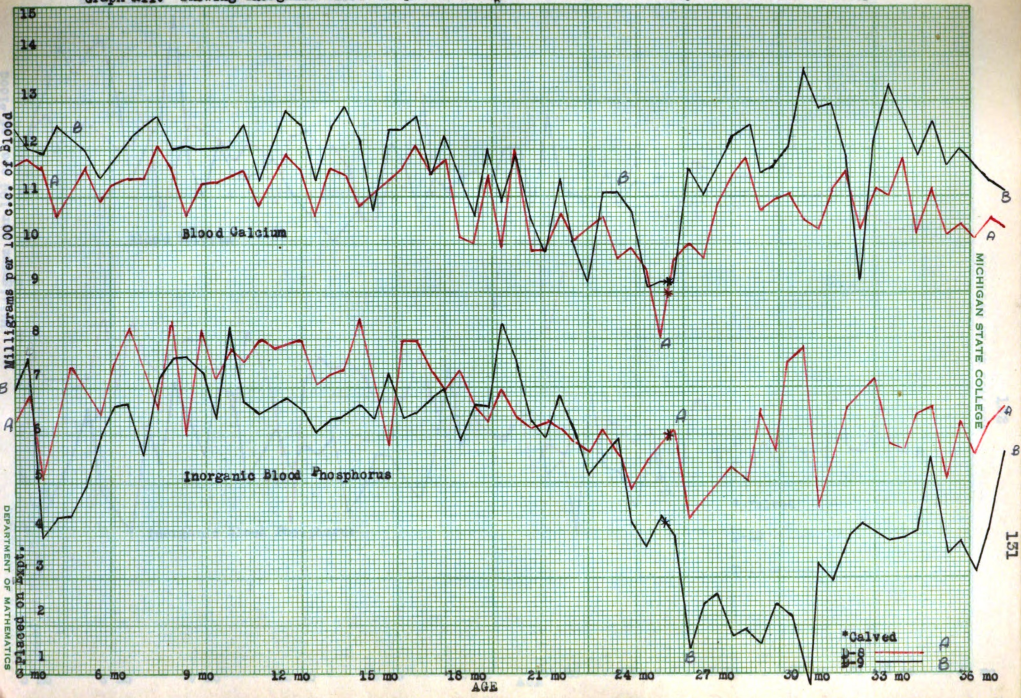
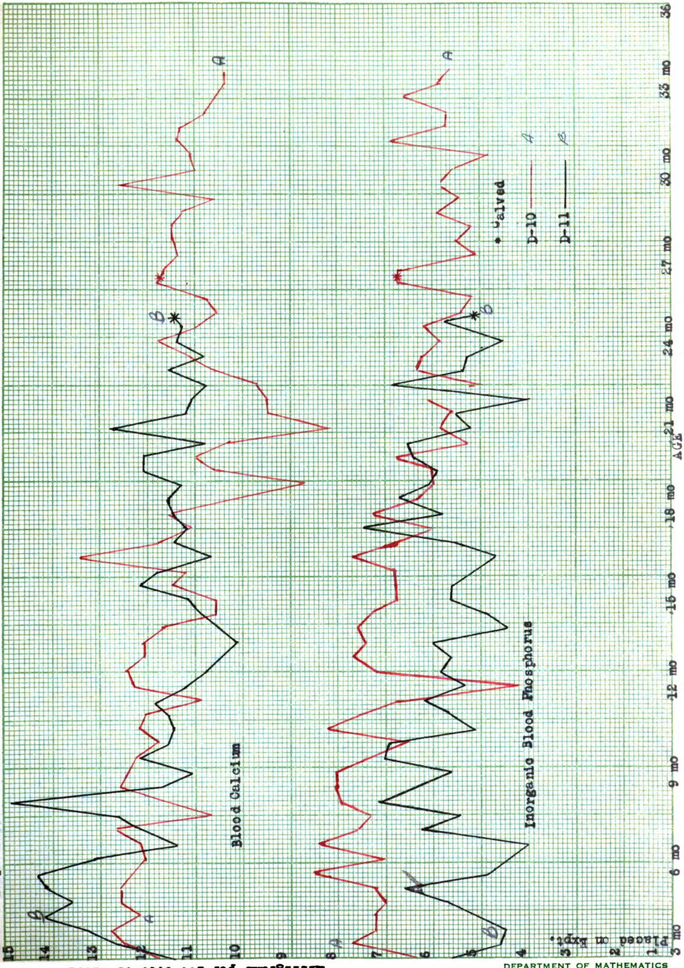
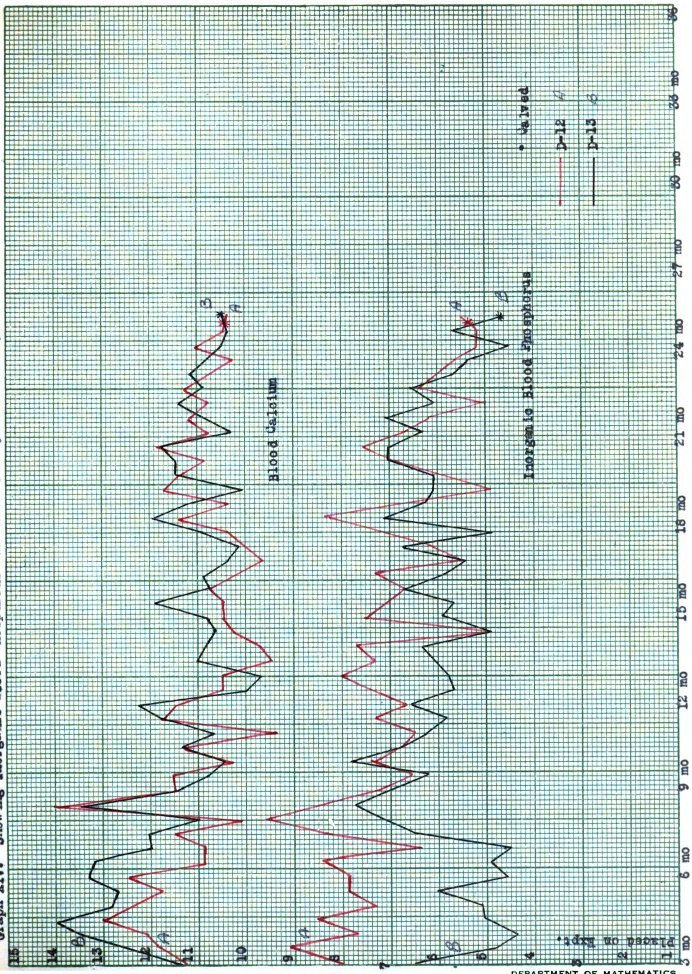
Graph XII. Showing Inorganic Blood Phosphorus and Blood Calcium from 90 Days to Three Years of Age





Graph XIII. Showing Inorganic Blood Phosphorus and Blood Calcium from 90 Days to Three Years of Age



Graph XIV. Showing Inorganic Blood Phosphorus and Blood Calcium from 90 Days to Two Yearsof Age.

Graph XV. Showing Inorganic Blood Phosphorus and Blood Calcium from 90 Days to Two Years of Age

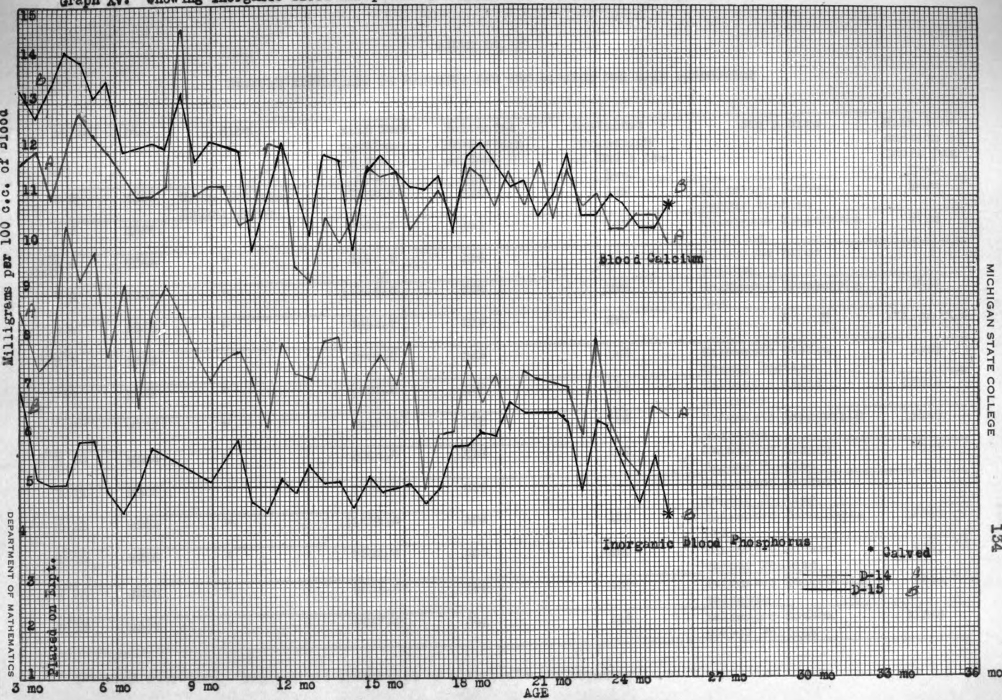


TABLE NO. I

SHOWING SIMILARITY OF BREEDING AND INHERITANCE FOR MILK PRODUCTION

Animal	Dam	Sire	Milk Production of Dam Lbs.	Butterfat Production of Dam Lbs.	Butterfat Production of Dam's Dam Lbs.	Dam's Sire	Milk Production of Dam's Dam Lbs.
D 2	M253	Mich. College Mutual Johan	7542.7	225	146	Kalamazoo Goshen Caesar Pontiac	8000
D 3	M256	"	5325.0 *	160	149	Kalamazoo Hengerveld Colantha	5764
D 4	M244	"	3166.5*	114		Kalamazoo Fayne Pontiac	
D 5	M335	"	11318.0	328	182	Kalamazoo Cornucopia Lad	12889
D 6	M335	"	8463.0	295	270	" " "	Killed T.B.
D 7	M332	"	6579.0	235	143	Kalamazoo Goshen Caesar Pontiac	9539
D8	M259	"	7455.0	256	191	Kalamazoo Segis Larkspur	10621
D 9	M252	"	5946.4*	178	188	Kalamazoo Hengerveld Colantha	11769
D 10	M334	"	5964.0	216	158	Kalamazoo Goshen Caesar Pontiac	7026
D 11	M222	"	8196.0	269		Kalamazoo Goshen Caesar Pontiac	
D 12	M335	"	11318.0	328	182	Kalamazoo Cornucopia Lad	12889
D 13	M266	"	7386.6	260	180	Kalamazoo Goshen Caesar Pontiac	8761
D 14	M256	"	5325.0*	160	149	Kalamazoo Hengerveld Colantha	5764
D 15	M329	"	9387.0*	341	145	Kalamazoo Goshen Caesar Pontiac	11246

* Abnormal Nutrition. Figures not indicative of milk producing capacity.

TABLE NO. II

SHOWING CALCIUM, PHOSPHORUS AND NITROGEN ANALYSES OF FEEDS USED

Date	Skim Milk			Alfalfa Hay			Corn Silage			Corn			Blood Meal			Bone Meal		
	Ca %	P %	N %	Ca %	P %	N %	Ca %	P %	N %	Ca %	P %	N %	Ca %	P %	N %	Ca %	P %	N %
5/3/28	.122	.098	.512	2.05	.147	2.31	.118	.037	.351	.035	2.41	1.46						
9/25/28				1.28	.120	2.02										29.37	12.62	
11/10/28				2.01	.198	3.24												
11/27/28				1.31	.135	2.16												
5/20/29				1.45	.181		.111	.061	.374									
6/27/29				1.90	.160													
10/11/29				1.63	.113													
11/13/29				1.58	.157	2.18												
12/12/29							.093	.059	.366	.056	.265	1.38						
1/6/30							.110	.046	.342	.139	.242	1.28				27.9	13.6	1.53
1/10/30							.096	.063	.428	.069	.397	1.49				28.10	14.14	1.46
7/10/30				1.69	.146	2.35	.159	.057	.363	.036	.254	1.41	.503	.300	13.05	29.25	12.78	2.69
7/24/30				1.66	.158	2.31	.322	.049	.348	.035	.270	1.38	.796	.450	13.05			
8/13/30				1.16	.190	2.33	.272	.040	.355	.030	.245	1.40	.505	.328	12.97	29.33	13.26	2.69
11/10/30				1.29	.148	1.89	.114	.041	.334	.045	.239	1.38	.499	.355	12.78	28.21	12.62	1.97
11/27/30				1.19	.149	1.83	.131	.036	.330	.209	.332	1.43	.512	.328	12.78	28.50	12.64	1.97
3/27/31				1.47	.144	2.10	.099	.022	.266	.037	.227	1.47	.238	.214	12.86	27.38	12.76	1.52
Average	.122	.098	.512	1.55	.153	2.25	.148	.047	.351	.069	.271	1.41	.501	.329	12.92	28.51	13.05	1.98

ANIMAL D-2

TABLE NO. III. SHOWING FEED, WATER AND PHOSPHORUS CONSUMPTION

FROM 90 DAYS OF AGE TO FIRST CALVING

Age for period days	Ave. Body Weight Lbs.	Feed Consumed Alf. Hay Lbs.	Corn Sil. Lbs.	Corn Lbs.	Bone Meal Grams	Nutrients Required* Prot. Lbs.	Net E. Therms	Nutrients Received Prot. Lbs.	Net E. Therms	Daily Water Consumed Gallons	% Phos. in Dry Matter	Ave. Daily Phos. Intake Grams
90	227	89	20	75	882.4	0.65	3.88	0.62	3.88	**	0.47	9.64
120	266	115	96	75	1245.0	0.69	4.06	0.60	3.97		0.39	11.74
150	296	145	120	75	1427.0	0.72	4.25	0.71	4.45		0.38	13.35
180	327	150	120	75	1388.2	0.75	4.42	0.73	4.49		0.37	13.30
210	354	150	150	75	1457.0	0.77	4.67	0.74	4.64		0.38	13.82
240	388	150	250	75	1556.1	0.79	4.99	0.71	5.07		0.35	14.19
270	420	150	250	75	1604.0	0.81	5.28	0.99	5.17		0.40	16.32
300	460	150	336	72	1739.7	0.82	5.62	0.77	5.54		0.36	15.97
330	512	150	428	69	1951.0	0.84	6.07	0.80	5.95		0.37	17.42
360	562	150	450	69	2037.0	0.85	6.50	0.81	6.06		0.37	17.96
390	597	150	461	77	2086.1	0.85	6.78	0.85	6.35		0.38	18.58
420	635	150	480	90	2160.0	0.85	7.06	0.87	6.82		0.38	19.57
450	675	150	480	90	2160.0	0.85	7.38	0.87	6.82		0.38	19.57
480	705	150	480	90	2160.0	0.85	7.63	0.89	6.82		0.38	20.07
520	734	150	480	90	2160.0	0.85	7.80	0.89	6.82		0.38	20.07
540	767	150	480	90	2160.0	0.85	8.00	0.89	6.82		0.38	20.07
570	804	150	480	90	2160.0	0.85	8.22	0.89	6.82		0.38	20.07
600	840	150	480	90	2160.0	0.85	8.48	0.89	6.82		0.38	20.07
630	895	150	480	90	2160.0	0.85	8.76	0.89	6.82	3.76	0.38	20.07
660	929	164	506	90	2433.0	0.85	8.97	0.95	7.12	3.29	0.40	21.76
690	970	210	600	90	3330.0	0.85	9.22	1.15	8.16	2.87	0.45	28.10
720	1004	210	600	90	3330.0	0.85	9.42	1.15	8.16	3.00	0.45	28.10
750***	1063	192	420	95	2586.0	0.85	9.78	1.46	10.10	3.30	0.58	32.27

* Nutrients Required by the Armsby Feeding Standard

** Water Consumption not Measured Prior to October, 1929

*** Last period 21 days

Nutrients Received in First Period Include Protein and Net Energy Received From 150 Pounds Skim Milk.

ANIMAL D-3

TABLE NO. IV. SHOWING FEED, WATER AND PHOSPHORUS CONSUMPTION
FROM 90 DAYS OF AGE TO FIRST CALVING

Age for Period	Ave. Body Weight	Feed Consumed Alf. Hay	Corn Sil.	Corn	Nutrients Required* Prot.	Net E.	Nutrients Received Prot.	Net. E.	Daily Water Consumed	% Phos. in Dry Matter	Ave. Daily Phos. Intake
Days	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Therms	Lbs.	Therms	Gallons		Grams
90	177	58.0	14	62.0	0.57	3.65	0.43	2.96	**	0.40	5.60
120	194	79.0	52	75.0	0.59	3.73	0.45	3.29		0.25	5.20
150	224	90.0	72	75.0	0.63	3.87	0.50	3.52		0.22	5.60
180	260	130.0	85	75	0.68	4.03	0.63	4.04		0.21	6.58
210	289	135.0	120	75	0.71	4.19	0.67	4.28		0.21	6.95
240	327	150.0	109	75	0.75	4.42	0.69	4.22		0.19	6.57
270	360	150.0	204	75	0.77	4.73	0.96	4.72		0.19	7.26
300	407	150.0	243.	75	0.80	5.16	0.74	4.93		0.20	7.90
330	446	150.0	290	75	0.81	5.50	0.76	5.18		0.19	8.24
360	476	150.0	330	75	0.82	5.77	0.78	5.39		0.19	8.53
390	505	150.0	369	72	0.83	6.01	0.78	5.51		0.19	8.69
420	527	150.0	432	69	0.84	6.20	0.80	5.76		0.19	9.03
450	563	150.0	450	69	0.85	6.50	0.81	5.86		0.19	9.16
480	600	150.0	415	69	0.85	6.80	0.81	5.67		0.19	8.90
510	610	150.0	450	69	0.85	6.88	0.82	5.86		0.19	9.16
540	630	150.0	450	69	0.85	7.04	0.82	5.86		0.19	9.16
570	662	150.0	450	69	0.85	7.30	0.82	5.86		0.19	9.16
600	705	150.0	451	70	0.85	7.62	0.82	5.89		0.19	9.20
630	744	150.0	480	90	0.85	7.86	0.87	6.61	3.16	0.20	10.24
660	779	150.0	480	90	0.85	8.07	0.87	6.61	2.93	0.20	10.24
690	809	150.0	480	90	0.85	8.25	0.87	6.61	2.56	0.20	10.24
720	842	150.0	480	90	0.85	8.45	0.87	6.61	3.05	0.20	10.24
750***	888	107.0	444	72	0.85	8.73	0.98	10.40	3.80	0.28	15.89

* Nutrients Required by the Armsby Feeding Standard
** Water Consumption Not Measured Prior to October, 1929.
*** Last Period 22 Days
Nutrients Received Include Protein and Net Energy from 147 Lbs. Skim Milk in First Period.

ANIMAL D-4

TABLE NO. V. SHOWING FEED, WATER AND PHOSPHORUS CONSUMPTION
FROM 90 DAYS OF AGE TO FIRST CALVING.

Age for Period	Ave. Body Weight	Feed Consumed Alf. Hay	Corn Sil.	Corn	Bone Meal	Nutrients Required* Prot.	Net E.	Nutrients Received Prot.	Net E.	Daily Water Consumed	% Phos. in Dry Matter	Ave. Daily Phos. Intake
Days	Lbs.	Lbs.	Lbs.	Lbs.	Grams	Lbs.	Therms	Lbs.	Therms	Gallons		Grams
90	208	90	16	72	636.0	0.61	3.80	0.58	3.61	**	0.41	9.50
120	258	150	60	75	1147.9	0.65	3.95	0.64	3.90		0.37	11.38
150	269	135	76	75	1301.2	0.69	4.07	0.66	4.05		0.39	12.28
180	300	145	102	75	1292.8	0.73	4.25	0.69	4.29		0.37	12.66
210	325	150	96	75	1322.0	0.75	4.39	0.72	4.32		0.37	12.85
240	350	150	148	75	1445.0	0.77	4.64	0.68	4.59		0.36	15.15
270	385	150	216	75	1566.0	0.79	4.94	0.98	4.96		0.40	15.94
300	419	150	265	75	1673.0	0.81	5.27	0.75	5.21		0.37	15.34
330	454	150	289	75	1721.0	0.82	5.57	0.76	5.54		0.37	15.72
360	498	150	330	75	1806.0	0.83	5.95	0.78	5.56		0.37	16.39
390	529	150	427	71	1868.6	0.84	6.21	0.81	5.96		0.36	17.20
420	559	150	480	69	2037.0	0.85	6.47	0.81	6.02		0.38	18.02
450	595	150	480	69	2037.0	0.85	6.47	0.81	6.02		0.38	18.02
480	615	150	486	80	2106.7	0.85	6.92	0.87	6.42		0.39	19.37
510	640	150	480	90	2160.0	0.85	7.12	0.90	6.78		0.38	20.11
540	673	150	480	90	2160.0	0.85	7.38	0.90	6.78		0.39	20.11
570	698	150	480	90	2160.0	0.85	7.58	0.90	6.78		0.39	20.11
600	716	150	480	90	2160.0	0.85	7.70	0.90	6.78	3.6	0.39	20.11
630	744	150	480	90	2160.0	0.85	7.86	0.90	6.78	3.6	0.39	20.11
660	765	150	480	90	2160.0	0.85	7.98	0.90	6.78	3.0	0.39	20.11
690	789	150	480	90	2160.0	0.85	8.15	0.90	6.78	2.3	0.39	20.11
720	835	150	480	90	2160.0	0.85	8.41	0.90	6.78	4.12	0.39	20.11
750	887	237	506	90	3378.0	0.85	8.72	1.24	8.36	4.30	0.41	28.30
780	929	240	600	90	3365.0	0.85	8.97	1.25	8.42	4.50	0.41	28.35
810	960	229	600	116	3330.0	0.85	9.16	1.25	9.04	5.70	0.41	29.00
840***	1041	65	180	45	999.0	0.85	9.64	1.28	9.80	5.70	0.41	29.95

* Nutrients Required by the Armsby Feeding Standard
** Water Consumption not Measured Prior to October, 1929
*** Last Period 9 days
Nutrients Received in First Period Include Protein and Net Energy Received from 99 Pounds Skim Milk

ANIMAL D-5

TABLE NO. VI. SHOWING FEED, WATER AND PHOSPHORUS CONSUMPTION
FROM 90 DAYS OF AGE TO FIRST CALVING.

Age For Period	Ave Body Weight	Feed Consumed Alfa. Hay	Corn Silage	Corn	Nutrients Required* Protein	Net Energy	Nutrients Received Protein	Net Energy	Daily Water Consumed	% Phos. in Dry Matter	Ave. Daily Phos. Intake
Days	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Therms	Lbs.	Therms	Gallons		Grams
90	164	55	16	72	0.55	3.59	0.45	3.18	**	0.31	5.62
120	187	54	56	75	0.58	3.70	0.37	3.04		0.24	4.69
150	215	103	60	75	0.62	3.83	0.54	3.60		0.22	5.81
180	245	121	106	75	0.66	3.96	0.56	4.05		0.21	6.54
210	272	135	105	75	0.70	4.09	0.66	4.20		0.21	6.84
240	305	131	129	75	0.73	4.28	0.60	4.28		0.19	6.38
270	336	150	126	75	0.76	4.51	0.93	4.48		0.24	8.48
300	372	150	195	75	0.78	4.84	0.71	4.84		0.20	7.56
330	407	149	255	75	0.80	5.16	0.69	5.15		0.20	7.97
360	438	150	270	75	0.81	5.43	0.74	5.24		0.19	8.08
390	466	150	324	75	0.82	5.67	0.76	5.53		0.19	8.47
420	494	150	375	72	0.83	5.92	0.77	5.71		0.19	8.71
450	532	150	434	69	0.84	6.24	0.79	5.94		0.19	9.02
480	562	150	450	69	0.85	6.50	0.82	6.02		0.20	9.64
510	581	150	450	69	0.85	6.45	0.82	6.02		0.20	9.64
540	603	150	450	69	0.85	6.82	0.82	6.02		0.20	9.64
570	623	150	450	69	0.85	6.98	0.82	6.02		0.20	9.64
600	634	150	454	72	0.85	7.07	0.83	6.13	2.80	0.20	9.79
630	657	150	480	90	0.85	7.26	0.88	6.78	2.43	0.21	10.71
660	686	150	480	90	0.85	7.49	0.88	6.78	1.38	0.21	10.71
690	729	150	480	90	0.85	7.77	0.88	6.78	1.97	0.21	10.71
720	762	150	480	90	0.85	7.97	0.88	6.78	2.75	0.21	10.71
750	794	208	596	90	0.85	8.16	1.12	8.04	3.20	0.20	12.93
780	826	210	600	90	0.85	8.36	1.12	8.08	3.83	0.20	12.96
810	875	210	600	90	0.85	8.65	1.12	8.08	4.00	0.20	12.96
840	914	210	600	90	0.85	8.88	1.12	8.08	4.98	0.20	12.96
870	952	210	600	98	0.85	9.11	1.14	8.31	5.44	0.20	13.34
900	989	210	384	87	0.85	9.33	1.04	6.85	5.89	0.20	11.32
930***	1039	75	173	33	0.85	9.63	1.06	7.35	5.89	0.20	11.95

* Nutrients Required by the Armsby Feeding Standard
** Water Consumption Not Measured Prior to October, 1929

*** Last Period 11 days
Nutrients Received in First Period Include Protein and Net Energy Received from 90 Pounds Skim Milk

ANIMAL D-6

TABLE NO. VII. SHOWING FEED, WATER AND PHOSPHORUS CONSUMPTION FROM 90 DAYS OF AGE TO FIRST CALVING.

Age for Period	Ave. Body Weight	Feed Consumed: Alfa. Hay	Corn Sil.	Corn	Bone Meal	Nutrients Required*: Prot.	Net E	Nutrients Received: Prot.	Net E.	Daily Water Consumed	% Phos. in Dry Matter	Ave. Daily Phos. Intake
Days	Lbs.	Lbs.	Lbs.	Lbs.	Grams	Lbs.	Therms	Lbs.	Therms	Gallons		Grams
90	174	83	11	69	512	0.56	3.64	0.53	3.18	**	0.41	8.13
120	206	120	65	75	928	0.61	3.79	0.59	3.82		0.35	10.25
150	241	135	75	75	1168	0.65	3.95	0.66	4.04		0.37	11.70
180	273	135	90	75	1217	0.70	4.09	0.66	4.12		0.37	12.02
210	299	140	122	75	1303	0.72	4.24	0.70	4.35		0.37	12.76
240	330	150	110	75	1355	0.75	4.45	0.66	4.39		0.35	12.47
270	371	150	180	75	1496	0.78	4.83	0.96	4.76		0.40	15.39
300	405	150	250	75	1530	0.80	5.15	0.74	5.14		0.36	14.62
330	441	150	285	75	1714	0.81	5.46	0.76	5.32		0.37	15.67
360	480	150	330	75	1812	0.83	5.80	0.77	5.56		0.37	16.42
390	516	150	430	69	1968	0.84	6.10	0.80	5.87		0.37	17.50
420	556	150	435	69	2012	0.85	6.45	0.80	5.89		0.38	17.75
450	592	148	405	69	2037	0.85	6.74	0.79	5.77		0.38	17.65
480	618	150	470	85	2119	0.85	6.94	0.87	6.55		0.39	19.57
510	646	150	480	90	2160	0.85	7.17	0.88	6.78		0.39	20.11
540	672	150	480	90	2160	0.85	7.38	0.88	6.78		0.39	20.11
570	697	150	480	90	2160	0.85	7.58	0.88	6.78		0.39	20.11
600	717	150	480	90	2160	0.85	7.70	0.88	6.78		0.39	20.11
630	746	150	480	90	2160	0.85	7.88	0.88	6.78		0.39	20.11
660	769	150	480	90	2160	0.85	8.01	0.88	6.78	4.15	0.39	20.11
690	789	150	480	90	2160	0.85	8.15	0.88	6.78	3.50	0.39	20.11
720	810	159	492	90	2286	0.85	8.26	0.95	6.95	3.24	0.39	20.95
750	852	240	600	90	3420	0.85	8.51	1.26	8.42	3.00	0.40	27.80
780	902	240	600	90	3420	0.85	8.81	1.26	8.42	4.37	0.40	27.80
810	960	240	600	90	3420	0.85	9.16	1226	8.42	4.08	0.40	27.80
840	990	264	600	90	3602	0.85	9.54	1.34	8.69	5.92	0.41	29.95
870***	1052	290	580	107	3612	0.85	9.71	1.44	9.55	6.50	0.40	31.15

* Nutrients Required by the Armsby Feeding Standard

** Water Consumption Not measured Prior to December, 1929

*** Last Period 20 days

Nutrients Received in First Period Include Protein and Net Energy Received from 105 Pounds Skim Milk

ANIMAL D-7

TABLE NO. VIII. SHOWING FEED, WATER AND PHOSPHORUS CONSUMPTION FROM 90 DAYS OF AGE TO FIRST CALVING

Age for Period	Ave. Body Weight	Feed Consumed: Alf. Hay	Feed Consumed: Corn Sil.	Feed Consumed: Corn	Nutrients Required*: Prot.	Nutrients Required*: Net E.	Nutrients Received: Prot.	Nutrients Received: Net E.	Daily Water Consumed	% Phos. in Dry Matter	Ave. Daily Phos. Intake
Days	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Therms	Lbs.	Therms	Gallons		Grams
90	180	72	11	75	0.57	3.67	0.49	3.38	**	0.29	5.95
120	201	81	35	75	0.60	3.76	0.45	3.23		0.23	5.13
150	227	119	58	75	0.63	3.88	0.59	3.78		0.21	6.14
180	262	138	70	75	0.68	4.04	0.65	4.01		0.21	6.59
210	294	145	96	75	0.72	4.22	0.69	4.10		0.21	6.95
240	331	150	128	75	0.75	4.46	0.66	4.23		0.19	6.71
270	370	150	196	75	0.78	4.82	0.96	4.49		0.23	8.99
300	406	150	245	75	0.80	5.16	0.73	5.11		0.19	7.92
330	439	150	268	75	0.81	5.45	0.74	5.23		0.19	8.09
360	476	150	284	75	0.82	5.77	0.75	5.32		0.19	8.29
390	504	150	330	75	0.83	6.00	0.76	5.56		0.19	8.54
420	535	150	405	70	0.85	6.27	0.78	5.82		0.19	8.87
450	572	150	444	69	0.85	6.58	0.79	5.99		0.19	9.11
480	601	150	450	69	0.85	6.81	0.82	6.05		0.20	9.64
510	624	150	450	69	0.85	6.99	0.82	6.05		0.20	9.64
540	652	150	450	69	0.85	7.22	0.82	6.05		0.20	9.64
570	678	150	450	69	0.85	7.42	0.82	6.05		0.20	9.64
600	710	150	464	59	0.85	7.66	0.84	6.38	4.92	0.20	10.15
630	752	150	480	90	0.85	7.91	0;88	6.78	3.70	0.21	10.71
660	786	150	480	90	0.85	8.11	0.88	6.78	2.88	0.21	10.71
690	818	150	480	90	0.85	8.31	0.88	6.78	3.15	0.21	10.71
720	866	177	516	90	0.85	8.59	0.98	7.27	3.59	0.20	11.62
750	935	240	600	150	0.85	9.01	1.31	9.56	4.29	0.21	15.35
780***	1006	149	390	89	0.85	9.45	13.1	9.31	6.50	0.20	15.25

* Nutrients Required by the Armsby Feeding Standard

** Water Consumption Not Measured Prior to October, 1929

*** Last Period 19 days

Nutrients Received in First Period Include Protein and Net Energy Received from 79 Pounds Skim Milk.

ANIMAL D-8

TABLE NO. IX. SHOWING FEED, WATER AND PHOSPHORUS CONSUMPTION FROM 90 DAYS OF AGE TO FIRST CALVING.

Age for Period	Ave. Body Weight	Feed Consumed: Alf. Hay	Corn Sil.	Corn	Bone Meal	Nutrients Required*: Prot.	Net E	Nutrients Received: Prot.	Net E	Daily Water Consumed	% Phos. in Dry Matter	Ave. Daily Phos. Intake
Days	Lbs.	Lbs.	Lbs.	Lbs.	Grams	Lbs.	Therms	Lbs.	Therms	Gallons		Grams
90	222	74	20	77	605.0	0.65	3.86	0.55	3.60	**	0.42	9.06
120	257	153	69	75	1187.0	0.68	4.02	0.65	3.99		0.37	11.69
150	285	140	82	75	1227.0	0.71	4.16	0.68	4.13		0.37	12.14
180	319	150	95	75	1411.0	0.74	4.37	0.72	4.31		0.38	13.24
210	352	150	155	75	1558.5	0.77	4.66	0.73	4.55		0.36	12.92
240	385	150	218	75	1565.0	0.79	4.95	0.70	4.97		0.36	14.17
270	410	150	245	75	1607.0	0.80	5.19	0.98	5.11		0.40	16.35
300	442	150	270	75	1683.0	0.81	5.47	0.75	5.24		0.37	15.42
330	485	150	387	75	1906.0	0.83	5.84	0.80	5.80		0.37	17.16
360	526	150	428	69	1986.4	0.84	6.19	0.81	5.91		0.37	17.64
390	555	150	450	69	2037.0	0.85	6.44	0.82	6.05		0.38	18.02
420	595	150	450	69	2037.0	0.85	6.74	0.82	6.05		0.38	18.02
450	632	150	475	87	2139.5	0.85	7.06	0.87	6.67		0.38	19.39
480	659	150	480	90	2160.0	0.85	7.27	0.90	6.78		0.38	19.96
510	686	150	480	90	2160.0	0.85	7.49	0.90	6.78		0.38	19.96
540	710	150	480	90	2160.0	0.85	7.66	0.90	6.78		0.38	19.96
570	747	150	480	90	2160.0	0.85	7.88	0.90	6.78		0.38	19.96
600	788	150	480	90	2160.0	0.85	8.12	0.90	6.78	3.93	0.93	19.96
630	820	152	480	90	2160.0	0.85	8.32	0.91	6.80	3.20	0.38	20.01
660	857	210	570	90	3054.0	0.85	8.54	1.15	7.93	3.03	0.40	25.86
690	886	210	600	90	3330.0	0.85	8.71	1.16	8.66	2.82	0.42	27.29
720	922	250	600	1 10	3440.0	0.85	8.93	1.33	9.11	4.05	0.40	29.48
750	965	270	600	150	3660.0	0.85	9.21	1449	10.47	3.29	0.40	32.53

* Nutrients Required by the Armsby Feeding Standard

** Water Consumption Not Measured Prior to October, 1929.

Nutrients Received in First Period Include Protein and Net Energy Received from 100 pounds Skim Milk.

ANIMAL D-9

TABLE NO. X. SHOWING FEED, WATER AND PHOSPHORUS CONSUMPTION
FROM 90 DAYS OF AGE TO FIRST CALVING.

Age for Period	Ave. Body Weight	Feed Consumed			Nutrients Required*		Nutrients Received		Daily Water Consumed	% Phos. in Dry Matter	Ave. Daily Phos. Intake
		Alf. Hay	Corn Sil.	Corn	Pro.	Net E.	Prot.	Net E.			
Days	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Therms	Lbs.	Therms	Gallons		Grams
90	204	75	19	75	0.60	3.78	0.52	3.40	**	0.30	6.24
120	218	71	41	75	0.62	3.84	0.42	3.15		0.25	4.96
150	240	125	70	75	0.65	3.94	0.62	3.90		0.21	6.37
180	279	155	97	75	0.70	4.15	0.66	4.15		0.21	6.78
210	314	146	113	75	0.74	4.34	0.69	4.37		0.19	6.52
240	345	150	145	75	0.76	4.50	0.93	4.58		0.33	8.62
270	384	150	195	75	0.79	4.95	0.71	4.84		0.20	7.56
300	418	150	255	75	0.80	5.26	0.73	5.18		0.19	7.99
330	451	150	300	75	0.82	5.45	0.75	5.35		0.19	8.25
360	488	150	372	72	0.85	5.87	0.78	5.69		0.19	8.71
390	520	150	422	69	0.84	6.14	0.79	5.88		0.19	8.95
420	563	150	450	69	0.85	6.50	0.80	6.05		0.20	9.42
450	587	127	380	67	0.85	6.70	0.72	5.53		0.20	8.51
480	598	150	450	69	0.85	6.78	0.81	6.05		0.20	9.65
510	625	150	450	69	0.85	7.00	0.81	6.05		0.20	9.65
540	650	150	450	69	0.85	7.20	0.81	6.05		0.20	9.65
570	691	150	450	69	0.85	7.53	0.81	6.05		0.20	9.65
600	756	150	471	84	0.85	7.82	0.85	6.56	2.90	0.20	10.40
630	767	150	490	90	0.85	8.00	0.90	6.60	2.83	0.20	10.65
660	786	150	480	90	0.85	8.11	0.90	6.60	2.50	0.20	10.65
690	811	150	490	90	0.85	8.23	0.90	6.60	2.86	0.20	10.65
720	865	198	544	90	0.85	8.59	1.07	7.48	4.26	0.20	12.31
750***	950	252	580	150	0.85	9.13	1.29	9.61	7.10	0.21	15.39

* Nutrients Required by the Armsby Feeding Standard

** Water Consumption not Measured prior to October, 1929.

*** Last Period 29 days

Nutrients Received in First Period Include Protein and Net Energy Received from 96 Pounds Skim Milk

ANIMAL D-10

TABLE NO. XI. SHOWING FEED, WATER AND PHOSPHORUS CONSUMPTION
FROM 90 DAYS OF AGE TO FIRST CALVING

Age for Period	Ave. Body Weight	Feed Consumed: Alf. Hay	Feed Consumed: Corn Sil.	Feed Consumed: Corn	Feed Consumed: Bone Meal	Nutrients Required*: Prot.	Nutrients Required*: Net E.	Nutrients Received: Prot.	Nutrients Received: Net E.	Daily Water Consumed	% Phos. in Dry Matter	Ave. Daily Phos. Intake
Days	Lbs.	Lbs.	Lbs.	Lbs.	Grams	Lbs.	Therms	Lbs.	Therms	Gallons		Grams
90	211	89	22	75	300.0	0.61	3.81	0.58	3.74	**	0.30	8.92
120	246	135	60	75	1167.0	0.66	3.97	0.59	3.96		0.35	11.03
150	278	135	92	75	1226.5	0.70	4.12	0.85	4.13		0.40	13.13
180	323	145	116	75	1331.0	0.75	4.39	0.64	4.37		0.36	12.67
210	361	145	155	73	1421.0	0.77	4.74	0.69	4.52		0.37	13.27
240	388	150	230	75	1575.0	0.79	4.99	0.74	5.03		0.37	14.66
270	420	150	257	75	1640.0	0.81	5.28	0.75	5.17		0.37	15.14
300	451	150	290	75	1712.5	0.82	5.55	0.76	5.35		0.37	15.70
330	488	150	346	74	1837.0	0.83	5.87	0.79	5.61		0.37	16.59
360	529	145	450	69	2037.0	0.84	6.22	0.80	5.98		0.38	17.92
390	561	150	450	69	2037.0	0.85	6.49	0.84	6.03		0.39	18.87
420	589	150	450	69	2037.0	0.85	6.71	0.84	6.03		0.39	18.94
450	615	150	450	69	2037.0	0.85	6.90	0.84	6.03		0.39	18.94
480	649	150	450	70	2037.0	0.85	7.19	0.84	6.06		0.39	18.98
510	690	150	475	85	2121.0	0.85	7.52	0.88	6.60	3.84	0.39	19.86
540	719	150	480	90	2160.0	0.85	7.71	0.90	6.78	3.60	0.39	20.11
570	749	150	480	90	2160.0	0.85	7.89	0.90	6.78	2.45	0.39	20.11
600	769	150	480	90	2160.0	0.85	8.01	0.90	6.78	2.44	0.39	20.11
630	804	186	556	90	2862.0	0.85	8.22	1.05	7.59	2.67	0.41	24.57
660	859	210	600	90	3330.0	0.85	8.55	1.16	8.09	2.90	0.42	27.50
690	915	210	600	90	3330.0	0.85	8.88	1.16	8.09	3.20	0.42	27.50
720	956	210	600	90	3330.0	0.85	9.15	1.16	8.09	3.92	0.42	27.50
750	970	210	600	90	3330.0	0.85	9.32	1.16	8.09	4.72	0.42	27.50
780	1011	252	480	122	3772.0	0.85	9.46	1.30	8.83	4.93	0.44	30.84
810***	1029	21	30	15	384.0	0.85	9.57	1.26	8.21	5.87	0.49	30.00

* Nutrients Required by the Armsby Feeding Standard

** Water Consumption Not Measured Prior to October, 1929

*** Last Period 3 days.

Nutrients Received Include Protein and Net Energy Received From 103 Pounds Skim Milk.

ANIMAL D-11

TABLE NO. XII. SHOWING FEED, WATER AND PHOSPHORUS CONSUMPTION FROM 90 DAYS OF AGE TO FIRST CALVING

Age for Period	Ave. Body Weight	Feed Consumed			Nutrients Required*		Nutrients Received		Daily Water Consumed	% Phos. in Dry Matter	Ave. Daily Phos. Intake
		Alf. Hay	Corn Sil.	Corn	Pro.	Net E.	Prot.	Net. E.			
Days	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Therms	Lbs.	Therms	Gallons		Grams
90	212	72.0	28	75	0.61	3.81	0.55	3.68	**	0.32	6.67
120	245	103	78	75	0.66	3.96	0.54	3.70		0.22	6.08
150	264	107	104	75	0.68	4.05	0.56	3.88		0.22	6.37
180	286	128	107	75	0.71	4.17	0.65	4.14		0.21	6.88
210	315	146	96	75	0.74	4.34	0.69	4.28		0.21	7.51
240	344	150	155	75	0.76	4.58	0.72	4.57		0.21	7.62
270	380	150	240	75	0.79	4.92	0.75	5.08		0.21	8.36
300	420	150	240	75	0.81	5.28	0.81	5.08		0.21	8.36
330	447	150	240	75	0.82	5.51	0.82	5.08		0.21	8.36
360	475	150	240	82	0.82	5.75	0.85	5.28	2.07	0.24	9.86
390	514	150	408	69	0.84	6.09	0.82	5.80	2.25	0.20	9.35
420	547	150	428	69	0.85	6.37	0.82	5.91	2.00	0.20	9.48
450	575	150	450	69	0.85	6.60	0.82	6.03	2.35	0.20	9.64
480	602	150	450	69	0.85	6.82	0.82	6.03	2.72	0.20	9.64
510	635	150	456	75	0.85	7.06	0.85	6.17	3.50	0.20	9.84
540	670	150	480	90	0.85	7.36	0.88	6.78	4.64	0.21	10.71
570	701	159	495	89	0.85	7.61	0.89	6.95	3.32	0.20	10.99
600	738	150	480	90	0.85	7.83	0.88	6.78	3.47	0.21	10.71
630	795	150	480	90	0.85	8.15	0.88	6.78	3.88	0.21	10.71
660	844	150	480	90	0.85	8.46	0.88	6.78	3.24	0.21	10.71
690	885	150	480	90	0.85	8.71	0.88	6.78	2.10	0.21	10.71
720	928	150	480	120	0.85	8.97	0.94	7.63	3.46	0.21	11.94
750***	955	25	80	25	0.85	9.12	1.01	11.06	3.46	0.22	13.17

* Nutrients Required by the Armsby Feeding Standard

** Water Consumption not Measured prior to January, 1930

*** Last Period 5 days

Nutrients Received in First Period Include Protein and Net Energy Received from 136 pounds Skim Milk

ANIMAL D-12

TABLE NO. XIII. SHOWING FEED, WATER AND PHOSPHORUS CONSUMPTION FROM 90 DAYS OF AGE TO FIRST CALVING

Age for Period	Ave. Body Weight	Feed Consumed Alf. Hay	Corn Sil.	Corn	Bone Meal	Nutrients Required* Prot.	Net E.	Nutrients Received Prot.	Net E.	Daily Water Consumed	% Phos. in Dry Matter	Ave. Daily Phos. Intake
Days	Lbs.	Lbs.	Lbs.	Lbs.	Grams	Lbs.	Therms	Lbs.	Therms	Gallons		Grams
90	219	65	22	75	595.0	0.62	3.85	0.52	3.61	**	0.43	8.46
120	258	130	88	75	1188.4	0.68	4.02	0.64	4.06		0.38	11.96
150	290	140	120	75	1310.0	0.72	4.19	0.68	4.34		0.38	12.95
180	320	150	120	75	1350.0	0.75	4.37	0.71	4.45		0.37	13.36
210	355	150	137	75	1358.0	0.77	4.67	0.72	4.54		0.37	13.52
240	375	150	165	75	1474.0	0.78	4.87	0.73	4.68		0.38	14.23
270	405	150	206	75	1596.0	0.80	5.15	0.75	4.90		0.39	15.06
300	435	150	254	75	1680.0	0.81	5.39	0.76	5.26		0.39	15.77
330	459	150	240	75	1680.0	0.82	5.61	0.76	5.18	2.90	0.39	15.67
360	493	150	240	75	1680.0	0.83	5.91	0.76	5.18	2.64	0.39	15.67
390	530	150	390	70	1920.0	0.84	6.23	0.81	5.74	2.75	0.38	17.59
420	566	150	425	69	1974.0	0.85	6.53	0.85	5.92	3.00	0.38	18.05
450	598	150	450	69	2037.0	0.85	6.78	0.84	6.06	3.60	0.39	18.50
480	625	150	454	71	2051.0	0.85	7.00	0.89	6.10	3.71	0.39	18.67
510	658	150	480	90	2160.0	0.85	7.26	0.90	6.78	4.13	0.39	20.11
540	687	150	480	90	2160.0	0.85	7.50	0.90	6.78	5.75	0.39	20.11
570	716	150	496	90	2160.0	0.85	7.70	0.92	6.97	4.38	0.38	20.44
600	753	150	478	90	2160.0	0.85	7.91	0.90	6.77	4.31	0.39	20.10
630	795	150	480	90	2160.0	0.85	8.16	0.90	6.78	5.73	0.39	20.11
660	852	150	480	90	2160.0	0.85	8.51	0.90	6.78	4.57	0.39	20.11
690	904	150	480	90	2160.0	0.85	8.82	0.90	6.78	3.10	0.39	20.11
720	949	150	480	116	2160.0	0.85	9.09	0.95	7.52	6.84	0.38	21.18
750***	980	50	160	50	720.0	0.85	9.28	1.05	8.49	3.41	0.38	22.57

* Nutrients Required by the Armsby Feeding Standard

** Water Consumption Not Measured Prior to December, 1929

*** Last Period 10 Days

Nutrients Received Include Protein and Net Energy Received from 136 Pounds Skim Milk.

ANIMAL D-13

TABLE XIV. SHOWING FEED, WATER AND PHOSPHORUS CONSUMPTION
FROM 90 DAYS OF AGE TO FIRST CALVING

Age for Period	Ave. Body Weight	Feed Consumed			Nutrients Required*		Nutrients Received		Daily Water Consumed	% Phos. in Dry Matter	Ave. Daily Phos. Intake
		Alf. Hay	Corn Sil.	Corn	Prot.	Net E.	Prot.	Net. E.			
Days	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Therms	Lbs.	Therms	Gallons		Grams
90	204	83	32	75	0.60	3.78	0.56	3.79	**	0.29	6.73
120	235	84	72	75	0.64	3.91	0.47	3.46		0.23	5.58
150	249	75	58	75	0.66	3.98	0.45	3.29		0.23	5.27
180	271	130	87	75	0.69	4.08	0.62	4.05		0.21	6.78
210	305	135	136	75	0.73	4.28	0.66	4.36		0.21	7.25
240	341	137	139	75	0.76	4.55	0.66	4.41		0.21	7.32
270	372	145	215	75	0.78	4.84	0.72	4.90		0.21	8.06
300	402	150	240	73	0.80	5.12	0.75	5.02	2.25	0.21	8.27
330	431	150	240	75	0.81	5.37	0.75	5.08	1.76	0.21	8.36
360	462	150	240	75	0.82	5.64	0.75	5.08	2.17	0.21	8.36
390	502	150	327	75	0.83	5.98	0.78	5.54	2.30	0.20	8.99
420	538	150	366	73	0.85	6.30	0.80	5.69	2.82	0.20	9.19
450	566	150	450	69	0.85	6.53	0.82	6.03	2.76	0.20	9.64
480	593	150	393	69	0.85	6.74	0.80	5.72	3.58	0.20	9.22
510	623	150	456	76	0.85	6.98	0.85	6.26	4.20	0.20	9.97
540	653	148	430	88	0.85	7.22	0.84	6.44	4.53	0.21	10.22
570	678	158	497	90	0.85	7.42	0.90	6.96	4.20	0.20	11.03
600	721	150	480	90	0.85	7.73	0.88	6.78	3.11	0.21	10.71
630	772	150	480	90	0.85	8.03	0.88	6.78	3.38	0.21	10.71
660	829	150	480	90	0.85	8.37	0.88	6.78	3.11	0.21	10.71
690	880	150	480	90	0.85	8.68	0.88	6.78	4.92	0.21	10.71
720	920	150	480	128	0.85	8.92	0.96	7.86	3.43	0.21	12.27
750***	944	55	176	55	0.85	9.06	1.01	8.49	3.43	0.22	13.17

* Nutrients Required by the Armsby Feeding Standard

** Water Consumption not Measured prior to December, 1929

*** Last Period 11 days

Nutrients Received in First Period Include Protein and Net Energy Received from 117 pounds Skim Milk

ANIMAL D-14

TABLE NO. XV. SHOWING FEED, WATER AND PHOSPHORUS CONSUMPTION FROM 90 DAYS OF AGE TO FIRST CALVING.

Age for Period	Ave. Body Weight	Feed Consumed: Alf. Hay	Feed Consumed: Corn Sil.	Feed Consumed: Corn	Feed Consumed: Bone Meal	Nutrients Required*: Prot.	Nutrients Required*: Net E.	Nutrients Received: Prot.	Nutrients Received: Net E.	Daily Water Consumed	% Phos. in Dry Matter	Ave. Daily Phos. Intake
Days	Lbs.	Lbs.	Lbs.	Lbs.	Grams	Lbs.	Therms	Lbs.	Therms	Gallons		Grams
90	225	74	28	72	337.4	0.65	3.87	0.58	3.62	**	0.39	8.21
120	258	125	74	71	1209.5	0.68	4.02	0.61	3.80		0.39	11.66
150	285	135	120	75	1350.0	0.71	4.16	0.66	4.28		0.39	12.99
180	314	139	108	70	1347.0	0.74	4.34	0.67	4.12		0.39	12.79
210	334	150	110	75	1360.0	0.76	4.49	0.71	4.39		0.38	13.34
240	355	150	145	75	1430.0	0.77	4.68	0.72	4.57		0.38	13.88
270	388	150	183	75	1564.0	0.79	4.99	0.74	4.78		0.39	14.75
300	420	145	240	75	1527.0	0.81	5.28	0.75	5.03	2.51	0.37	14.88
330	450	150	240	75	1590.0	0.82	5.54	0.76	5.08	2.26	0.38	15.28
360	495	150	336	74	1792.0	0.83	5.93	0.79	5.56	2.46	0.38	16.81
390	537	150	420	69	1968.0	0.85	6.29	0.83	5.87	2.55	0.38	17.98
420	566	150	446	69	2018.0	0.85	6.53	0.84	6.00	3.12	0.38	18.39
450	597	150	447	69	2037.0	0.85	6.78	0.84	6.01	3.47	0.39	18.48
480	625	150	462	87	2139.5	0.85	7.00	0.88	6.60	4.11	0.39	19.76
510	656	150	446	90	2160.0	0.85	7.25	0.89	6.60	4.35	0.39	19.87
540	685	155	481	90	2160.0	0.85	7.46	0.91	6.85	4.38	0.38	20.24
570	711	150	488	90	2160.0	0.85	7.67	0.90	6.83	4.35	0.39	20.17
600	747	150	480	90	2160.0	0.85	7.88	0.90	6.78	4.11	0.39	20.11
630	783	150	480	90	2160.0	0.85	8.09	0.90	6.78	3.87	0.39	20.11
660	826	150	480	90	2160.0	0.85	8.36	0.90	6.78	2.88	0.39	20.11
690	869	150	480	90	2160.0	0.85	8.61	0.90	6.78	2.36	0.39	20.11
720***	920	145	464	87	2088.0	0.85	8.92	0.90	6.78	2.61	0.39	20.11

* Nutrients Required by the Armsby Feeding Standard

** Water Consumption Not Measured Prior to December, 1929

*** Last Period 29 Days

Nutrients Received Include Protein and Net Energy Received from 125 Pounds Skim Milk

ANIMAL D-15

TABLE XVI. SHOWING FEED, WATER AND PHOSPHORUS CONSUMPTION
FROM 90 DAYS OF AGE TO FIRST CALVING

Age for Period	Ave. Body Weight	Feed Consumed			Nutrients Required*		Nutrients Received		Daily Water Consumed	% Phos. in Dry Matter	Ave. Daily Phos. Intake
		Alf. Hay	Corn Sil.	Corn	Prot.	Net E.	Prot.	Net E.			
Days	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Therms	Lbs.	Therms	Gallons		Grams
90	259	68	45	75	0.65	3.94	0.54	3.73	**	0.32	6.84
120	265	111	87	75	0.69	4.05	0.56	3.84		0.22	6.35
150	291	114	90	75	0.72	4.20	0.57	3.89		0.22	6.42
180	325	142	90	75	0.75	4.39	0.67	4.20		0.21	7.08
210	348	150	90	75	0.77	4.62	0.69	4.29		0.21	7.27
240	374	147	152	75	0.78	4.86	0.71	4.59		0.21	7.65
270	401	141	167	75	0.80	5.11	0.69	4.60		0.21	7.62
300	426	150	120	75	0.81	5.35	0.70	4.45	2.36	0.21	7.49
330	452	142	150	75	0.82	5.55	0.70	4.52	2.16	0.21	7.52
360	475	107	282	75	0.82	5.74	0.62	4.82	2.33	0.21	7.66
390	497	114	356	75	0.83	5.94	0.66	5.19	2.33	0.21	8.21
420	529	118	420	69	0.84	6.22	0.71	5.51	2.63	0.20	8.66
450	555	109	420	69	0.85	6.44	0.68	5.41	2.89	0.21	8.45
480	578	90	442	69	0.85	6.62	0.61	5.31	3.81	0.21	8.16
510	607	124	455	71	0.85	6.86	0.75	5.80	5.19	0.20	9.15
540	644	159	497	90	0.85	7.15	0.90	6.97	5.19	0.20	11.05
570	687	149	474	90	0.85	7.50	0.87	6.74	4.38	0.21	10.65
600	738	150	480	90	0.85	7.85	0.88	6.78	3.73	0.21	10.71
630	791	150	480	90	0.85	8.14	0.88	6.78	2.96	0.21	10.71
660	838	150	480	90	0.85	8.45	0.88	6.78	2.74	0.21	10.71
690	882	150	480	112	0.85	8.69	0.94	7.40	2.72	0.21	11.61
720***	921	95	304	95	0.85	8.92	1.01	8.49	4.62	0.22	13.17

* Nutrients Required by the Armsby Feeding Standard

** Water Consumption not Measured prior to December, 1929

*** Last Period 19 days

Nutrients Received in First Period Include Protein and Net Energy Received from 125 pounds Skim Milk

ANIMAL D-2

TABLE NO. XVII. SHOWING MONTHLY MILK AND BUTTERFAT PRODUCTION; AND FEED, WATER AND PHOSPHORUS CONSUMPTION DURING FIRST LACTATION PERIOD.

	Days in Period	Ave. Body Wt.	Milk Produced	Butterfat Produced	Feed Consumed					Nutrients Required*		Nutrients Received		Daily Water Consumed	% Phos. in Dry Matter	Ave. Daily Phos. Intake
					Alf.Hay	Corn Sil.	Corn	Blood Meal	Bone Meal	Prot.	T.D.N.	Prot.	T.D.N.			
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Grams	Lbs.	Lbs.	Lbs.	Lbs.	Gal.		Grams
r	25	911	879	27.2	208	376	167	**	2944	2.44	17.04	1.59	11.82	***	0.41	35.59
r	30	878	1205	36.1	348	514	219		3840	2.58	17.27	1.87	12.44	9.7	0.39	37.62
y	31	910	1268	36.8	380	600	331	24.5	4618	2.56	17.72	2.64	16.53	10.1	0.41	46.05
ne	30	921	1188	34.4	300	600	326	30.0	4630	2.51	17.48	2.67	16.64	11.2	0.41	46.43
ly	31	917	1058	29.6	310	620	328	13.5	4745	2.26	16.03	2.26	15.87	12.1	0.41	45.19
g	31	946	1027	31.9	310	620	344	25.0	4712	2.22	16.01	2.49	16.52	11.4	0.41	46.22
pt	30	983	889	26.7	298	600	316	17.8	4538	2.08	15.40	2.35	16.00	10.8	0.41	44.97
t	31	1000	886	26.6	306	620	342	15.5	4681	2.04	15.28	2.29	16.26	10.7	0.41	45.47
v	30	1020	775	24.8	300	600	317	15.0	4476	1.95	14.71	2.30	15.89	7.6	0.41	44.65
c	31	1070	670	25.5	310	620	326	15.5	4619	1.77	14.05	2.29	15.86	7.6	0.41	44.67
n	7	1101	135	4.7	70	140	74	3.5	1045	1.68	13.69	2.21	15.89	6.8	0.40	44.58
tal	305		9978	302.5												

* Nutrients Required by the Lower Limits of the Morrison Feeding Standard
** Blood Meal Not Fed Prior to May, 1930
*** Water Consumption Not Measured During First Month

ANIMAL D-5

TABLE NO. XVIII. SHOWING MONTHLY MILK AND BUTTERFAT PRODUCTION; AND FEED, WATER AND PHOSPHORUS PRODUCTION DURING FIRST LACTATION PERIOD

Days in Period		Ave. Body Wt.	Milk Produced	Butterfat Produced	Feed Consumed				Nutrients Required*		Nutrients Received		Daily Water Consumed	% Phos. in Dry Matter	Ave. Daily Phos. Intake
					Alf. Hay	Corn Sil.	Corn	Blood Meal	Prot.	T.D.N.	Prot.	T.D.N.			
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Gal.		Grams
Mar	19	755	585	15.8	158	512	119	**	1.98	13.90	1.45	10.76	***	0.22	17.18
Apr	30	718	957	25.8	568	516	225		2.00	13.89	1.85	12.10	10.3	0.22	20.20
May	31	732	995	29.9	247	544	336	12.0	2.01	14.05	1.89	13.98	9.7	0.24	22.05
June	30	725	796	27.1	131	229	324	14.5	1.76	12.56	1.55	12.23	8.8	0.26	18.75
July	31	691	594	17.8	117	210	303	6.0	1.38	10.41	1.23	10.84	7.3	0.26	16.58
Aug	31	674	500	15.0	135	173	224	11.0	1.23	9.48	1.21	8.78	6.9	0.25	13.79
Sept	30	669	370	12.2	118	263	199	13.7	1.05	8.46	1.24	8.68	6.7	0.24	13.53
Oct	31	682	436	12.2	123	295	229	15.5	1.14	9.02	1.33	9.52	6.5	0.25	14.77
Nov	30	712	423	11.8	118	295	221	14.7	1.16	9.26	1.34	9.50	5.7	0.25	14.71
Dec	31	738	419	12.6	119	299	223	15.0	1.15	9.32	1.30	9.31	4.9	0.25	14.45
Jan	11	757	157	4.7	44	110	83	5.5	1.20	9.65	1.34	9.77	5.6	0.25	15.05
Total	305		6232	184.9											

* Nutrients Required by the Lower Limits of the Morrison Feeding Standard
** Blood Meal Not Fed Prior to May, 1930
*** Water Consumption Not Measured During First Month.

ANIMAL D-4

TABLE NO. XIX. SHOWING MONTHLY MILK AND BUTTERFAT PRODUCTION; AND FEED, WATER AND PHOSPHORUS CONSUMPTION DURING FIRST LACTATION PERIOD

Days in period	Ave. Body Wt.	Milk Produced	Butterfat Produced	Feeds Consumed: Alf. Hay	Feeds Consumed: Corn Sil.	Feeds Consumed: Corn	Feeds Consumed: Blood Meal	Feeds Consumed: Bone Meal	Nutrients Required*: Prot.	Nutrients Required*: T.D.N.	Nutrients Received: Prot.	Nutrients Received: T.D.N.	Daily Water Consumed	% Phos. in Dry Matter	Ave. Daily Phos Intake
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Grams	Lbs.	Lbs.	Lbs.	Lbs.	Gal.		Grams
Jun 30	879	1031	34.0	235	600	277	10.0	3959	2.24	15.81	1.87	13.92	11.3	0.41	38.94
Jul 31	842	1081	34.6	292	620	364	5.5	4600	2.23	15.64	2.09	16.50	12.0	0.41	45.21
Aug 31	820	1014	36.5	296	620	370	10.8	4681	2.11	14.90	2.24	16.82	13.5	0.41	46.14
Sept 30	834	895	31.3	300	600	320	15.0	4286	1.98	14.27	2.32	16.15	10.8	0.41	45.68
Oct 31	849	854	28.2	310	620	315	14.9	4619	1.88	13.80	2.26	15.54	10.4	0.41	44.20
Nov 30	876	661	21.8	300	600	224	14.4	4173	1.64	12.59	2.09	13.23	8.4	0.40	39.48
Dec 31	884	686	22.6	310	620	233	15.5	4154	1.66	12.69	2.09	13.29	6.5	0.40	38.99
Jan 31	901	617	22.9	310	620	233	15.5	4278	1.57	12.25	2.09	13.29	10.1	0.40	39.51
Feb 28	942	490	18.6	280	560	210	14.0	3864	1.48	11.97	2.09	13.27	6.0	0.40	39.43
Total 273		7329	250.5												

* Nutrients Required by the Lower Limits of the Morrison Feeding Standard.

ANIMAL D-5

TABLE NO. XX. SHOWING MONTHLY MILK AND BUTTERFAT PRODUCTION; AND FEED, WATER AND PHOSPHORUS CONSUMPTION DURING FIRST LACTATION PERIOD.

Days in Period		Ave. Body Wt.	Milk Produced	Butterfat Produced	Feeds Consumed				Nutrients Required*		Nutrients Received		Daily Water Consumed	% Phos. in Dry Matter	Ave. Daily Phos. Intake
					Alf. Hay	Corn Sil.	Corn	Blood Meal	Prot.	T.D.N.	Prot.	T.D.N.			
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Gal.		Grams
Sept	30	850	1258	37.7	249	476	285	13.9	2.57	17.51	1.95	13.73	7.5	0.24	21.47
Oct	31	821	1290	33.5	310	617	344	15.5	2.55	17.20	2.29	16.34	11.6	0.23	25.30
Nov	30	834	1245	33.6	300	600	335	28.5	2.55	17.28	2.59	16.66	11.1	0.23	26.50
Dec	31	861	1296	36.3	308	619	344	31.0	2.56	17.56	2.62	16.67	10.5	0.23	25.99
Jan	31	862	1274	37.0	310	620	344	31.0	2.53	17.39	2.62	16.69	12.0	0.23	26.68
Feb	28	865	1026	27.7	280	560	311	28.0	2.54	16.27	2.62	16.69	9.5	0.23	26.60
Total	181 da.		7389	205.8											

* Nutrients Required by the Lower Limits of the Morrison Feeding Standard.

ANIMAL D-6

TABLE NO. XXI. SHOWING MONTHLY MILK AND BUTTERFAT PRODUCTION; AND FEED, WATER AND PHOSPHORUS CONSUMPTION DURING FIRST LACTATION PERIOD

Days in Per-iods		Ave. Body Wt.	Milk Pro-duced	Butter-fat Pro-duced	Feeds Consumed					Nutrients Required*		Nutrients Received		Daily Water Con-sumed	% Phos. in Dry Matter	Ave. Daily Phos. Intake
					Alf. Hay	Corn Sil.	Corn	Blood Meal	Bone Meal	Prot.	T.D.N.	Prot.	T.D.N.			
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Gal.		Grams
July	7	942	218	6.5	70	139	35	1.5	896	2.12	15.46	1.72	10.67	10.1	0.41	34.19
Aug.	31	910	1040	32.3	273	570	299	11.0	3968	2.21	15.82	2.00	14.35	8.6	0.40	39.43
Sept	30	910	1054	31.6	293	600	333	25.5	4365	2.29	16.23	2.54	16.51	8.7	0.40	45.17
Oct	31	929	1060	31.8	310	620	344	31.0	4743	2.26	16.15	2.67	16.69	12.5	0.41	46.65
Nov	30	943	890	34.7	299	599	317	16.5	4486	2.06	15.10	2.32	15.90	14.1	0.41	44.74
Dec	31	956	881	26.4	308	620	326	15.5	4619	2.00	14.88	2.28	15.84	9.3	0.41	44.62
Jan	31	969	797	26.3	287	619	296	15.3	4619	1.89	14.28	2.15	14.78	6.5	0.42	42.93
Feb	28	980	744	23.8	280	560	294	14.0	4172	1.94	14.61	2.30	15.83	10.3	0.41	44.57
Tot.	219		6684	213.4												

* Nutrients Required by the Lower Limits of the Morrison Feeding Standard.

ANIMAL D-7

TABLE NO. XXII. SHOWING MONTHLY MILK AND BUTTERFAT PRODUCTION; AND FEED, WATER AND PHOSPHORUS CONSUMPTION DURING FIRST LACTATION PERIOD

Days in Period	Ave. Body Wt.	Milk Produced	Butterfat Produced	Feeds Consumed: Alf. Hay	Feeds Consumed: Corn Sil.	Feeds Consumed: Corn	Feeds Consumed: Blood Meal	Nutrients Required*: Prot.	Nutrients Required*: T.D.N.	Nutrients Received: Prot.	Nutrients Received: T.D.N.	Ave. Daily Water Consumed	% Phos. in Dry Matter	Ave. Daily Phos. Intake
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Gal.		Grams
Apr 9	865	243	8.5	99	126	44	**	1.88	13.80	1.85	10.08	10.0	0.30	16.85
May 31	868	1065	34.1	268	366	350	13.0	2.22	15.70	2.02	14.71	10.0	0.27	25.90
Jun 30	835	869	26.1	250	240	308	15.0	1.94	14.07	1.94	13.18	9.8	0.24	21.01
Jul 31	791	802	26.5	186	248	302	13.5	1.77	12.93	1.62	11.91	10.9	0.26	19.68
Aug 31	792	781	26.6	186	248	326	11.0	1.73	12.76	1.61	12.49	11.2	0.25	19.56
Sept 30	808	654	22.2	180	240	315	15.0	1.59	12.00	1.71	12.49	10.3	0.25	19.77
Oct 31	831	617	22.2	186	248	326	15.5	1.52	11.73	1.71	12.49	12.1	0.25	19.77
Nov 30	854	543	19.5	180	240	315	15.0	1.45	11.42	1.71	12.49	10.2	0.25	19.77
Dec 31	898	786	10.6	186	248	326	15.5	1.06	9.48	1.71	12.49	7.5	0.25	19.77
Jan 27	986	44	1.6	162	216	274	12.5	0.77	8.22	1.68	12.28	5.4	0.25	19.28
Total 281		5903	197.9											

* Nutrients Required by the Lower Limits of the Morrison Feeding Standard
** Blood Meal Not Fed Prior to May, 1930.

ANIMAL D-8

TABLE XXIII. SHOWING MONTHLY MILK AND BUTTERFAT PRODUCTION, FEED, WATER AND PHOSPHORUS CONSUMPTION DURING FIRST LACTATION PERIOD

	Days in Period	Ave. Body Wt. Lbs.	Milk Produced Lbs.	Butterfat Produced Lbs.	Feed Consumed: Alf. Hay Lbs.	Corn Sil. Lbs.	Corn Lbs.	Blood Meal Lbs.	Bone Meal Grams	Nutrients Required*: Protein Lbs.	T. D. N. Lbs.	Nutrients Received: Protein Lbs.	T. D. N. Lbs.	Daily Water Consumed Gal.	% Phos. in dry Matter	Ave. Daily Phos. Intake Grams
Apr.	26	860	826	24.8	255	596	144	**	3294	2.09	14.99	1.47	10.19	9.7	0.42	35.07
Mar.	31	852	1221	36.6	304	398	357	15.0	4302	2.45	16.88	2.12	15.24	10.1	0.42	42.50
June	30	861	1152	31.7	287	380	360	14.5	4060	2.37	16.51	2.24	15.80	11.2	0.40	42.67
July	31	874	1022	31.7	306	425	360	9.5	4290	2.16	15.41	2.14	15.62	8.5	0.41	42.87
Aug.	31	889	816	21.2	195	387	361	11.0	4098	1.86	13.81	1.80	14.27	11.1	0.44	39.35
Sept.	30	884	696	22.3	240	420	311	15.0	3852	1.72	13.02	2.00	14.10	7.5	0.41	38.88
Oct.	31	891	755	21.5	248	434	326	15.5	3815	1.75	13.15	2.01	14.22	10.2	0.41	38.54
Nov.	30	922	644	20.6	240	420	315	15.0	3690	1.66	12.84	2.01	14.22	8.8	0.41	38.54
Dec.	31	974	506	20.5	248	434	326	15.5	3815	1.57	12.58	2.01	14.22	6.9	0.41	38.54
Jan.	31	1047	452	17.5	248	434	326	15.5	3815	1.38	11.87	2.01	14.22	7.5	0.41	38.54
Feb.	3	1055	51	1.2	24	42	32	1.5	369	1.22	10.98	2.01	14.36	6.1	0.40	38.54
Total	305		8141	249.2												

* Nutrients Required by the Lower Limits of the Morrison Feeding Standard

** Blood Meal not Fed prior to May, 1930

ANIMAL D-9

TABLE XXIV. SHOWING MONTHLY MILK AND BUTTERFAT PRODUCTION, FEED, WATER AND PHOSPHORUS CONSUMPTION DURING FIRST LACTATION PERIOD

	Days in Period	Ave. Body Wt. Lbs.	Milk Produced Lbs.	Butterfat Produced Lbs.	Feed Consumed: Alf. Hay Lbs.	Feed Consumed: Corn Sil. Lbs.	Feed Consumed: Corn Lbs.	Feed Consumed: Blood Meal Lbs.	Nutrients Required*: Protein Lbs.	Nutrients Required*: T.D.N. Lbs.	Nutrients Received: Protein Lbs.	Nutrients Received: T.D.N. Lbs.	Daily Water Consumed Gal.	% Phos. in Dry Matter	Ave. Daily Phos. Intake Grams
Apr.	22	858	760	21.5	211	340	157	**	2.22	15.55	1.75	10.99	7.1	0.22	17.82
May	31	767	956	30.6	129	398	282	12.5	1.99	14.00	1.42	11.49	7.6	0.25	17.65
June	30	743	801	24.8	95	300	302	13.5	1.77	12.75	1.40	11.57	8.5	0.26	17.47
July	31	742	785	22.8	122	305	321	9.5	1.71	12.51	1.39	11.95	7.6	0.26	18.22
Aug.	31	745	625	19.6	104	252	304	9.2	1.51	11.51	1.26	10.90	6.3	0.26	16.61
Sept.	30	751	509	16.8	109	285	300	14.1	1.33	10.52	1.45	11.59	5.7	0.26	17.64
Oct.	31	771	564	18.6	124	310	326	15.5	1.40	10.79	1.55	12.27	7.4	0.26	18.79
Nov.	30	801	543	17.4	120	408	315	15.0	1.41	11.00	1.57	12.82	5.1	0.25	19.57
Dec.	31	841	549	18.7	122	428	322	15.1	1.42	11.21	1.56	12.74	5.7	0.25	19.41
Jan.	31	889	491	17.7	119	429	316	14.7	1.36	11.11	1.52	12.52	5.0	0.25	19.08
Feb.	7	920	104	3.7	28	98	74	3.5	1.34	11.09	1.59	12.87	4.0	0.25	19.62
Total	305		6715	211.9											

* Nutrients Required by the Lower Limits of the Morrison Feeding Standard

** Blood Meal not Fed Prior to May, 1930

ANIMAL B-10

TABLE XXV. SHOWING MONTHLY MILK AND BUTTERFAT PRODUCTION, FEED, WATER AND PHOSPHORUS CONSUMPTION DURING FIRST LACTATION PERIOD

	Days in Period	Ave. Body Wt. Lbs.	Milk Produced Lbs.	Butterfat Produced Lbs.	Feed Consumed: Alf. Hay Lbs.	Corn Sil. Lbs.	Corn Lbs.	Blood Meal Lbs.	Bone Meal Grams	Nutrients Required*: Protein Lbs.	T.D.N. Lbs.	Nutrients Received: Protein Lbs.	T.D.N. Lbs.	Daily Water Consumed Gal.	% Phos. in Dry Matter	Ave. Daily Phos. Intake Grams
Aug.	19	938	707	30.5	165	351	145	2.5	2162	2.41	16.99	1.70	12.29	9.8	0.39	34.37
Sept.	30	872	1234	34.6	266	475	338	14.9	4162	2.54	17.47	2.17	15.45	11.5	0.41	42.45
Oct.	31	856	1245	36.1	279	496	570	15.5	4464	2.49	17.21	2.25	16.10	11.1	0.41	44.18
Nov.	30	879	1190	33.3	270	480	560	28.5	4520	2.40	17.17	2.55	16.46	10.0	0.41	44.81
Dec.	31	915	1250	34.5	279	496	572	31.0	4469	2.55	17.61	2.59	16.49	10.0	0.41	44.90
Jan.	31	955	1177	36.5	279	496	572	31.0	4469	2.44	17.18	2.59	16.49	9.2	0.41	44.90
Feb.	28	944	1052	31.0	252	448	536	28.0	4032	2.39	16.94	2.59	16.49	6.5	0.41	44.88
Total	200		7855	229.4												

* Nutrients Required by the Lower Limits of the Morrison Feeding Standard

TABLE NO. XXVI

SHOWING MILK AND BUTTERFAT PRODUCTION. FIRST LACTATION PERIOD

Lot I Basal Ration Plus Steamed Bone Meal

Animal	Days	Pounds Milk	Percent Butterfat	Pounds Butterfat
D 2	305	9978	3.03	302.3
D 4	273*	7529	3.33	250.5
D 6	219*	6684	3.19	213.4
D 8	305	8141	3.06	249.2
D 10	200*	7835	2.93	229.4

Lot II Basal Ration

Animal	Days	Pounds Milk	Percent Butterfat	Pounds Butterfat
D 3	305	6232	2.97	184.9
D 5	181*	7389	2.79	205.8
D 7	281	5903	3.35	197.9
D 9	305	6715	3.16	211.9

* Indicates Incomplete Lactation Periods.

TABLE NO. XXVII

SHOWING REPRODUCTION DATA ON ANIMALS IN THIS EXPERIMENT.

Animal	Age at First Heat Period	Times Bred	Gestation Period	Age at Freshening	Weight of Calf	Sex of Calf	Health of Calf	Recovery of Cow	Remarks
D 2	318 days	1	282 days	769 da.	93 lbs.	Male	Strong	Normal	Normal Calving
D 4	426 "	3	268 "	849 "	64 "	Female	"	"	" "
D 6	324 "	3	277 "	898 "	73 "	"	"	"	" "
D 8	374 "	2	278 "	780 "	78 "	"	"	"	" "
D 10	383 "	4	268 "	814 "	69 "	"	"	"	" "
D 12	356 "	1	276 "	760 "	96 "	Male	"	"	Posterior Presentation. Calf Pulled
D 14*	431 "	2							
Ave.	373 "	2.28	275 "	812 "	79 "				

* Had not freshened at time of compiling this data.

D 3	376 days	2	270 days	771 days	69 lbs.	Female	Strong	Normal	Normal Calving
D 5	324 "	2	262 "	940 "	85 "	Male	"	"	Posterior Presentation. Calf Pulled
D 7	423 "	3	274 "	798 "	84 "	Female	"	"	Normal Calving
D 9	433 "	3	275 "	779 "	74 "	"	"	"	" "
D 11	402 "	1	276 "	756 "	85 "	Male	Born Dead	"	Calf Apparently Normal - Born Dead
D 13	481 "	1	280 "	762 "	85 "	"	Strong	"	Normal Calving
D 15	418 "	1	279 "	739 "	94 "	"	"	"	" "
Ave.	408 "	1.85	274 "	792	82 "				

TABLE NO. XXVIII

SHOWING CALCIUM, PHOSPHORUS AND NITROGEN METABOLISM BEFORE CALVING

Animal	Calcium Metabolism*			Phosphorus Metabolism*			Nitrogen Metabolism			Cal/Phos. Ratio
	Cal. Bal	Cal. Assim-ilated	Percent Assimi-lated	Phos. Bal.	Phos. Assim-ilated	Percent Assimi-lated	Nitrogen Balance	Nitrogen Assimi-lated	Percent Assimi-lated	
D 2	24.14	24.14	25.71	8.77	8.77	31.83	27.66	74.60	62.48	3.407
D 4	20.99	20.99	31.55	6.91	6.91	34.60	23.80	60.44	65.14	3.328
D 6	8.84	8.84	13.51	7.13	7.13	31.90	20.88	68.42	67.19	2.927
D 8	21.73	21.73	23.16	8.88	8.88	32.23	30.50	81.00	67.84	3.405
D 10	6.37	6.37	9.87	6.51	6.51	29.13	18.14	64.66	63.50	2.887
D 12	15.53	15.53	18.30	4.25	4.25	20.53	2.64	58.20	59.17	4.097
Ave.	16.27	16.27	20.35	7.08	7.08	30.04	20.60	67.89	64.25	3.342
D 3	15.37	15.37	34.82	5.81	5.81	50.74	29.93	62.97	66.40	3.854
D 5	19.71	19.71	24.88	4.00	4.00	32.65	8.23	73.73	62.72	6.466
D 7	13.39	13.39	30.30	4.33	4.33	37.80	24.49	60.99	64.30	3.859
D 9	14.59	14.59	33.24	4.93	4.93	43.06	26.33	58.43	61.60	3.833
D 11	15.88	15.88	25.15	4.73	4.73	43.76	8.48	58.60	60.77	5.840
Ave.	15.79	15.79	19.73	4.76	4.76	41.60	19.49	62.92	63.16	4.770

*** Assimilated Refers to Feed Calcium and Phosphorous Utilized for Storage.**

TABLE NO. XXIX

SHOWING CALCIUM, PHOSPHORUS AND NITROGEN METABOLISM DURING

HIGH PRODUCTION.

Animal	Daily Milk Production	Calcium Metabolism* Ca. Bal.	Ca. Assimilated	Percent Assimilated	Phosphorus Metabolism* Phos. Bal.	Phos. Assimilated	Percent Assimilated	Nitrogen Metabolism Nitrogen Balance	Phos. Assimilated	Percent Assimilated	Days From Freshening	Ca/Phos. Ratio
D 2	16022.4 g.	10.56	25.78	19.94	4.96	17.94	38.89				159	2.803
D 4	16324.9 g.	3.69	19.20	13.54	4.36	18.40	40.36	17.34	132.58	53.05	42	3.109
D 6	12482.5 g.	7.73	21.33	18.05	3.08	13.94	33.66	65.31	121.30	56.77	111	2.853
D 8	16045.0 g.	9.45	24.85	18.44	3.47	16.95	40.62	16.78	139.93	59.79	99	3.230
D 10	18465.0 g.	2.50	22.25	20.35	0.14	14.91	35.46	33.15	148.21	62.40	92	2.600
D 12	13743.0 g.	-7.31	6.71	6.50	1.81	14.59	40.69	19.69	117.38	59.70	36	2.878
Ave.	15513.8	4.44	20.02	16.14	2.96	16.12	38.28	30.45	131.88	58.34	89.8	2.912
D 3	8020.0 g.	- 2.53	5.73	17.21	0.38	7.20	52.86				155	2.444
D 5	19467.0 g	-10.52	8.56	11.09	- 3.09	12.48	51.83	25.04	147.32	60.45	73	3.204
D 7	11430.3 g	- 5.35	5.62	11.57	1.04	10.41	54.62				116	2.548
D 9	12462.4 g	1.13	13.59	31.56	- 0.37	10.72	59.49	5.02	94.66	60.73	95	2.390
D 11	16280.0 g	-1 5.14	1.95	2.98	-11.85	2.64	14.58	12.34	120.90	62.16	38	3.610
D 13	18724.0 g	-20.11	- 1.76	-2.69	- 7.56	8.54	47.13	4.13	121.92	62.68	29	3.614
D 15	14167.5 g	-13.58	1.86	2.84	- 5.22	7.96	43.93	13.02	124.27	63.89	29	3.613
Ave.	14364.5 g	-9.06	5.46	11.23	-3.81	8.56	46.35	10.91	121.81	61.98	76.4	3.060

* Assimilated Refers to the Feed Calcium and Phosphorous Utilized for Storage and Milk Production

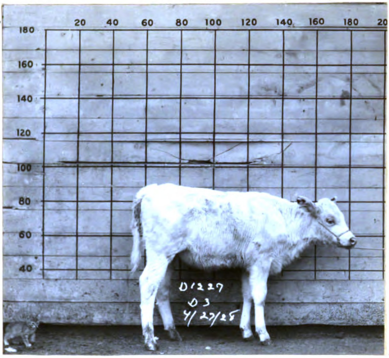
TABLE NO. XXX

SHOWING CALCIUM, PHOSPHORUS AND NITROGEN METABOLISM DURING MEDIUM PRODUCTION

Animal	Days From Freshening	Daily Milk Production	Calcium Metabolism*			Phosphorus Metabolism*			Nitrogen Metabolism			Ca/Phos Ratio
			Ca. Bal.	Ca. Assimilated	Percent Assimilated	Phos. Bal.	Phos. Assimilated	Percent Assimilated	Nitrogen Balance	Nitrogen Assimilated	Percent Assimilated	
D 2	266	10943 g	15.62	26.23	21.53	10.83	21.01	46.26	26.38	134.00	62.92	2.682
D 8	262	8081 g	10.97	19.96	19.99	8.92	18.45	46.37	27.24	119.16	63.77	2.510
Ave.	264	10012 g	13.30	23.10	20.76	9.88	19.73	46.34	26.61	126.08	63.35	2.596
D 9	235	8513 g	4.40	13.34	31.31	4.55	13.66	63.38	23.24	91.22	60.31	1.977

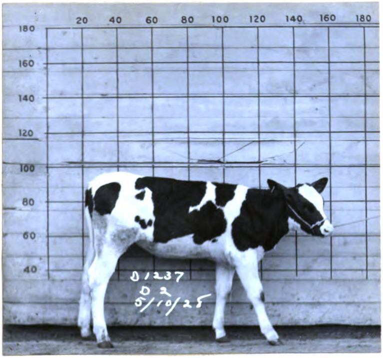
* Assimilated Refers to Feed Calcium and Phosphorus Utilized for Storage and Milk Production

PLATE I



D-3. 90 Days of Age.
Basal Ration-Alfalfa Hay, Corn Silage, Corn

PLATE II

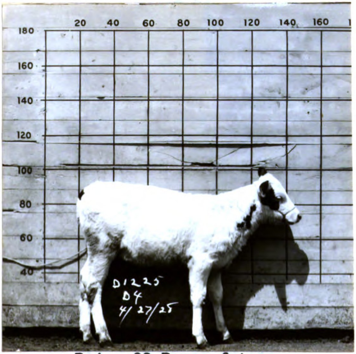


D-2. 90 Days of Age.
Basal Ration Plus Steamed Bone Meal.

PLATE III

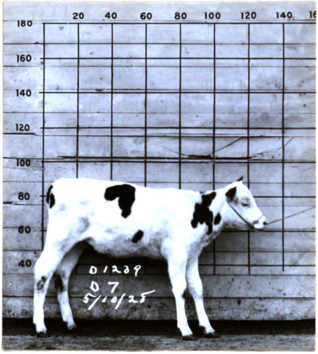
D-5. 90 Days of Age.
Basal Ration-Alfalfa Hay, Corn Silage, Corn.

PLATE IV



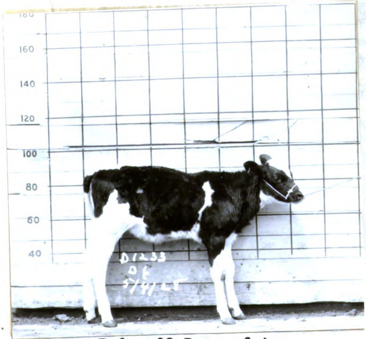
D-4. 90 Days of Age.
Basal Ration Plus Steamed Bone Meal

PLATE V



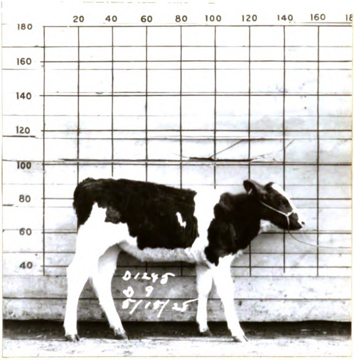
D-7. 90 Days of Age
Basal Ration-Alfalfa Hay, Corn Silage, Corn.

PLATE VI



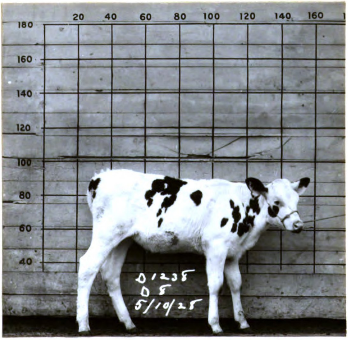
D-6. 90 Days of Age
Basal Ration Plus Steamed Bone Meal.

PLATE VII



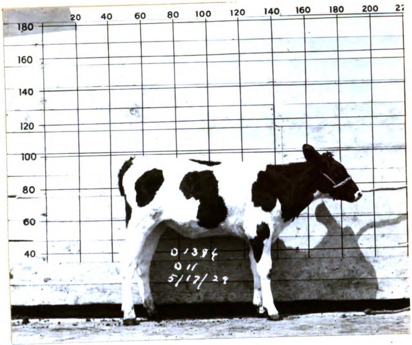
D-9. 90 Days of Age
Basal Ration-Alfalfa Hay, Corn Silage, Corn.

PLATE VIII



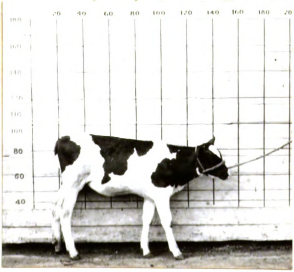
D-8. 90 Days of Age
Basal Ration Plus Steamed Bone Meal

PLATE IX



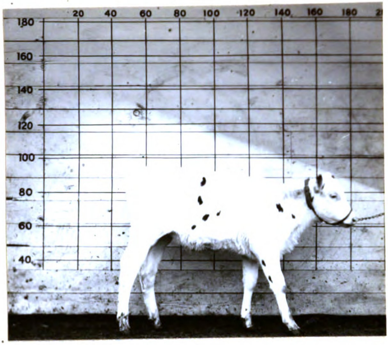
D-11. 90 Days of Age
Basal Ration-Alfalfa Hay, Corn Silage, Corn.

PLATE X



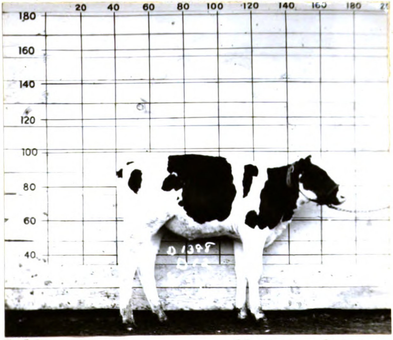
D-10. 90 Days of Age
Basal Ration Plus Steamed Bone Meal

PLATE XI



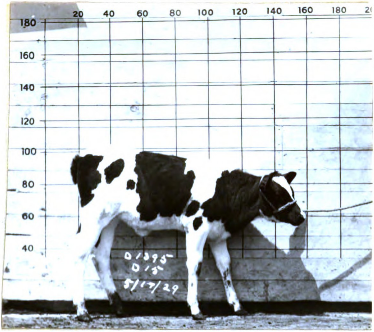
D-13. 90 Days of Age
Basal Ration-Alfalfa Hay,Corn Silage,Corn.

PLATE XII



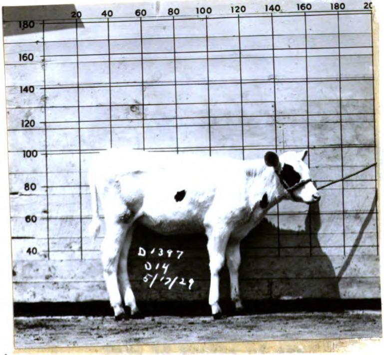
D-12 90 Days of Age.
Basal Ration Plus Steamed Bone Meal

PLATE XIII



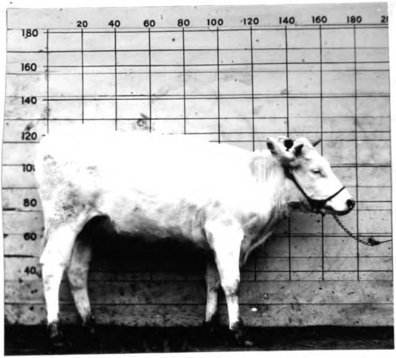
D-15. 90 Days of Age
Basal Ration-Alfalfa Hay, Corn Silage, Corn.

PLATE XIV



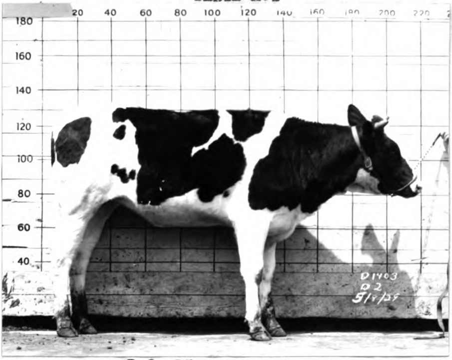
D-14. 90 Days of Age
Basal Ration Plus Steamed Bone Meal.

PLATE XV



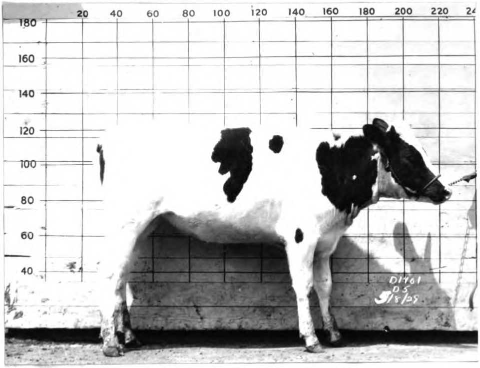
D-3. 15 Months of Age
Basal Ration-AlfalfaHay,Corn Silage, Corn

PLATE XVI



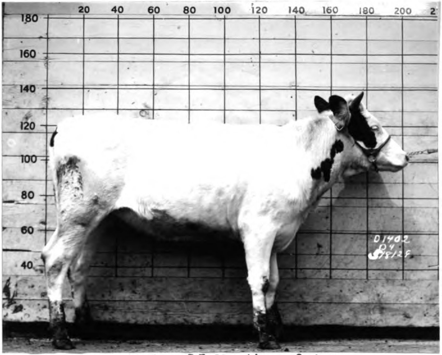
D-2. 15 Months of Age
Basal Ration Plus Steamed Bone Meal

PLATE XVII



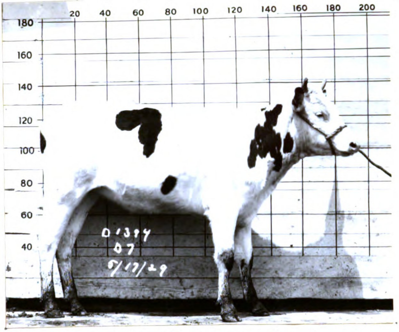
D-5. 15 Months of Age
Basal Ration-Alfalfa Hay, Corn Silage, Corn

PLATE XVIII



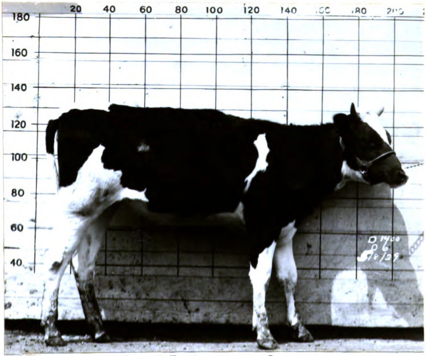
D-4. 15 Months of Age
Basal Ration Plus Steamed Bone Meal.

PLATE XIX



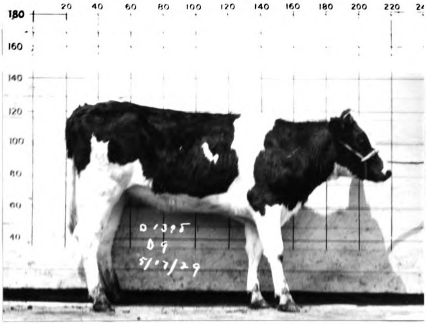
D-7. 15 Months of Age
Basal Ration-Alfalfa Hay, Corn Silage, Corn

PLATE XX



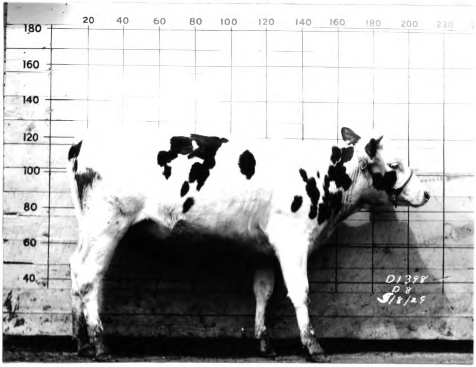
D-6. 15 Months of Age
Basal Ration Plus Steamed Bone Meal.

PLATE XXI



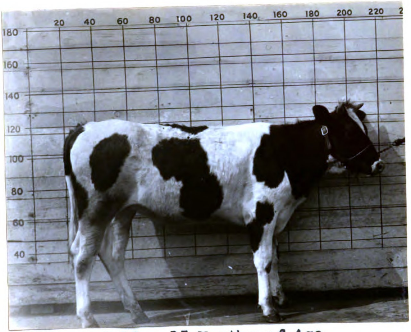
D-9. 15 Months of Age
Basal Ration-Alfalfa Hay, Corn Silage, Corn

PLATE XXII



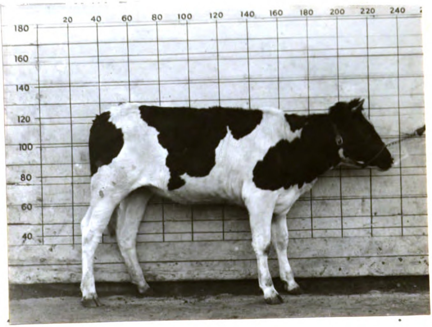
D-8. 15 Months of Age
Basal Ration Plus Steamed Bone Meal

PLATE XXIII



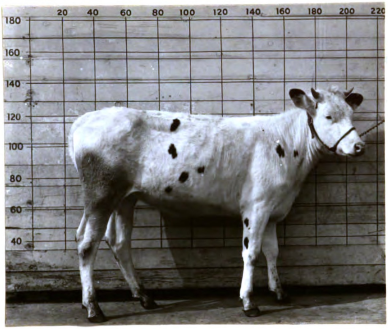
D-11. 15 Months of Age
Basal Ration-Alfalfa Hay, Corn Silage, Corn

PLATE XXIV



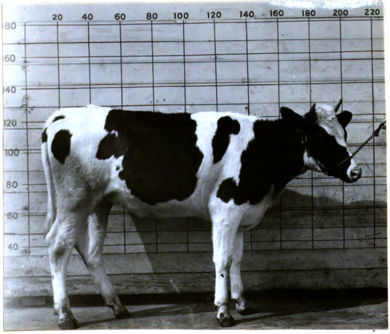
D-10. 15 Months of Age
Basal Ration Plus Steamed Bone Meal

PLATE XXV



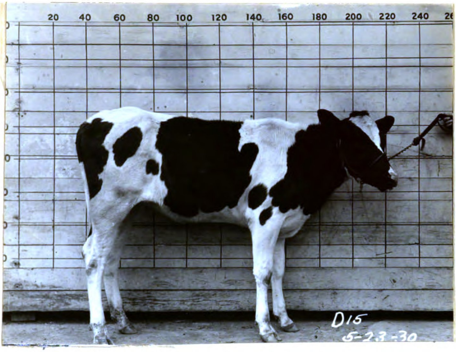
D-13. 15 Months of Age
Basal Ration-Alfalfa Hay, Corn Silage, Corn

PLATE XXVI



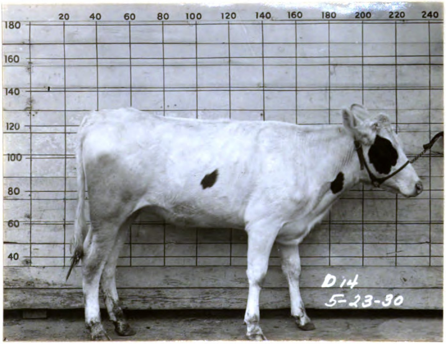
D-12. 15 Months of Age
Basal Ration Plus Steamed Bone Meal.

PLATE XXVII



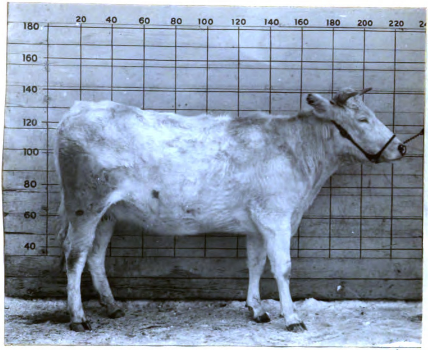
D-15. 15 Months of Age
Basal Ration-Alfalfa Hay, Corn Silage, Corn

XXVIII



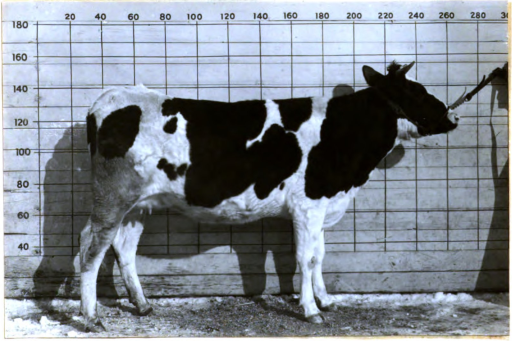
D-14. 15 Months of Age
Basal Ration Plus Steamed Bone Meal

PLATE XXIX



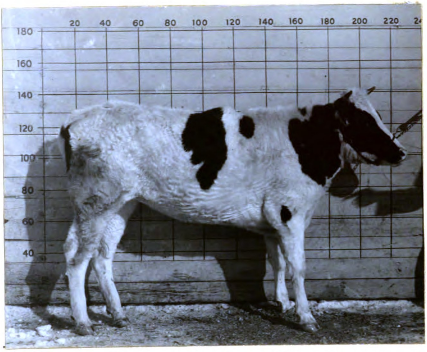
D-3. Two Years of Age
Basal Ration-Alfalfa Hay, Corn Silage, Corn

PLATE XXX



D-2. Two Years of Age
Basal Ration Plus Steamed Bone Meal

PLATE XXXI



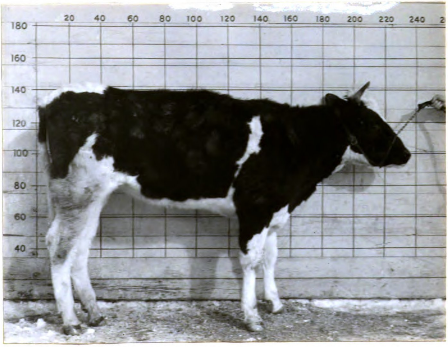
D-5. Two Years of Age
Basal Ration-Alfalfa Hay, Corn Silage, Corn

PLATE XXXII

D-4. Two Years of Age
Basal Ration Plus Steamed Bone Meal

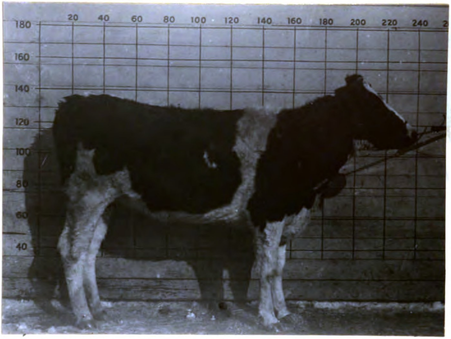
D-7. Two Years of Age
Basal Ration-Alfalfa Hay, Corn Silage, Corn

PLATE XXXIV



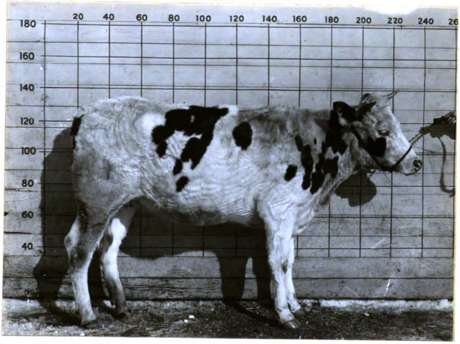
D-6. Two Years of Age
Basal Ration Plus Steamed Bone Meal

PLATE XXXV



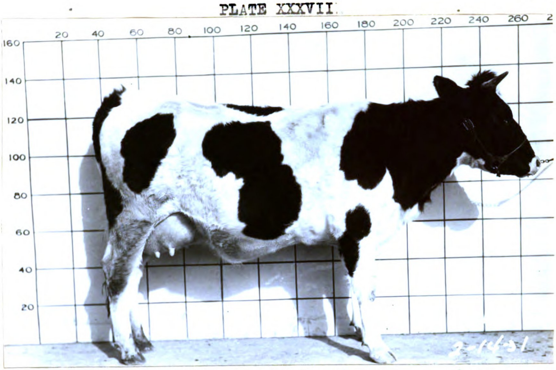
D-9. Two Years of Age
Basal Ration-Alfalfa Hay, Corn Silage, Corn

PLATE XXXVI



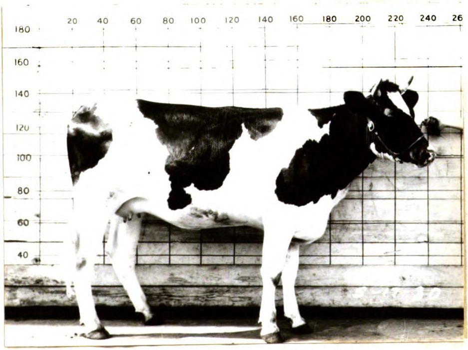
D-8. Two Years of Age
Basal Ration Plus Steamed Bone Meal

PLATE XXXVII



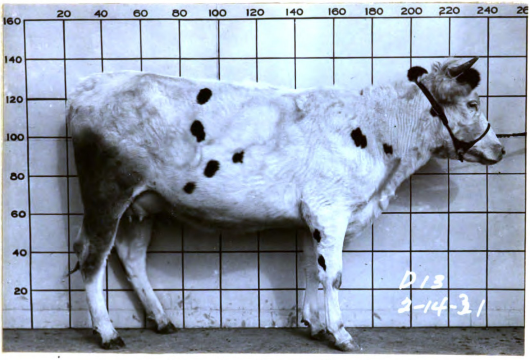
D-11. Two Years of Age
Basal Ration-Alfalfa Hay, Corn Silage, Corn

PLATE XXXVIII



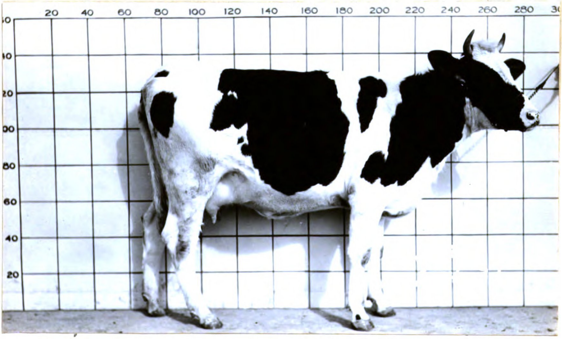
D-10. Two Years of Age
Basal Ration Plus Steamed Bone Meal

PLATE XXXIX



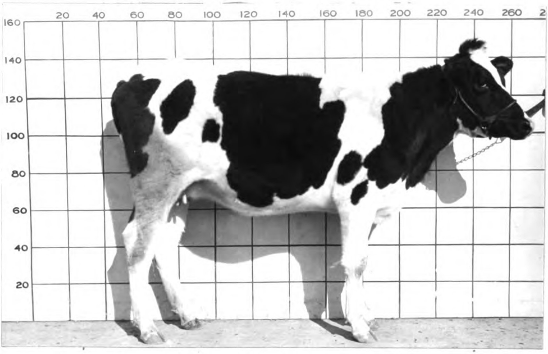
D-13. Two Years of Age
Basal Ration-Alfalfa Hay, Corn Silage, Corn

PLATE XL



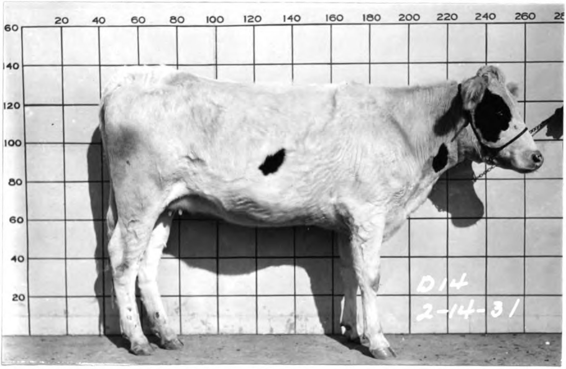
D-12. Two Years of Age
Basal Ration Plus Steamed Bone Meal.

PLATE XLI



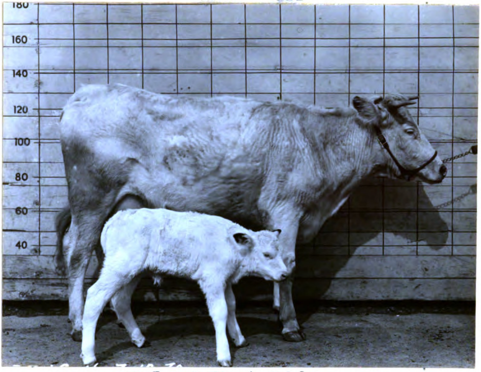
D-15. Two Years of Age
Basal Ration-Alfalfa Hay, Corn Silage, Corn

PLATE XLII



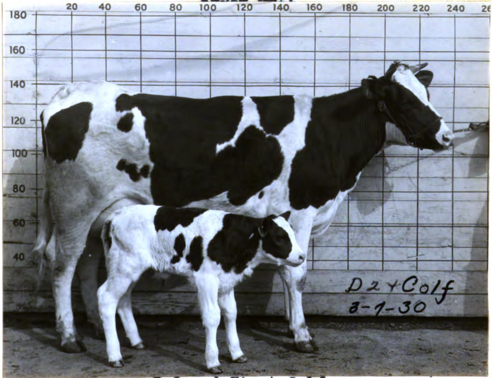
D-14. Two Years of Age
Basal Ration Plus Steamed Bone Meal

PLATE XLIII



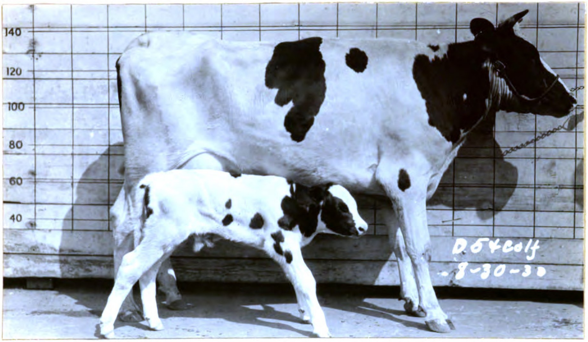
D-3 and First Calf
Basal Ration-Alfalfa Hay, Corn Silage, Corn

PLATE XLIV



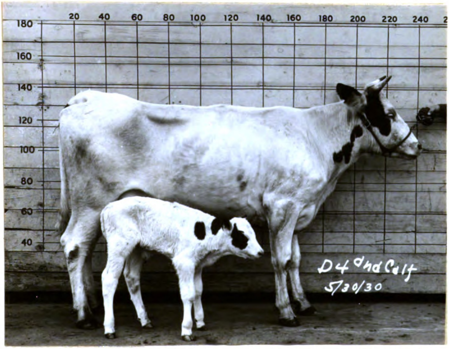
D-2 and First Calf
Basal Ration Plus Steamed Bone Meal.

PLATE XLV



D-5.and First Calf
Basal Ration-Alfalfa Hay, Corn Silage,Corn

PLATE XLVI



D-4 and First Calf
Basal Ration Plus Steamed Bone Meal

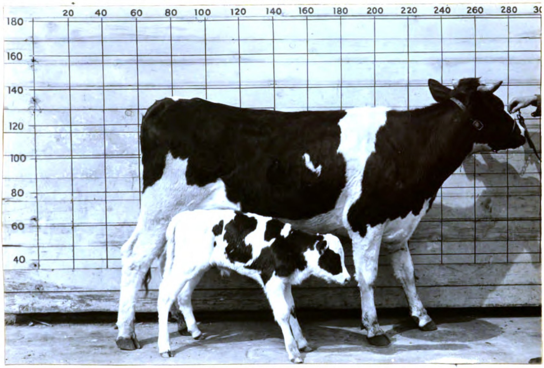
PLATE XLVII

D-7 and First Calf
Basal Ration-Alfalfa Hay,Corn Silage, Corn

PLATE XLVIII

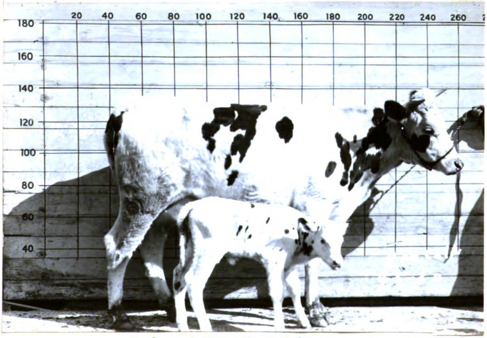
D-6 and First Calf
Basal Ration Plus Steamed Bone Meal

PLATE XLIX



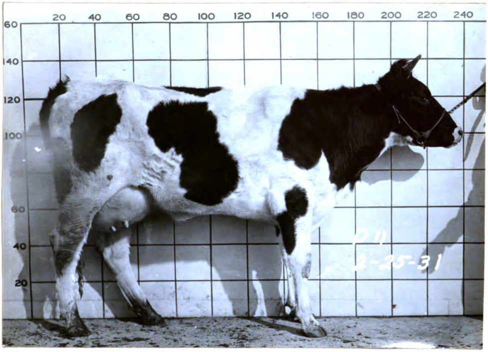
D-9 and First Calf
Basal Ration-Alfalfa Hay, Corn Silage, Corn

PLATE L



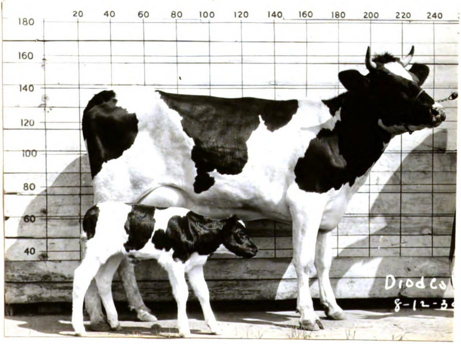
D-8 and First Calf
Basal Ration Plus Steamed Bone Meal

PLATE LI



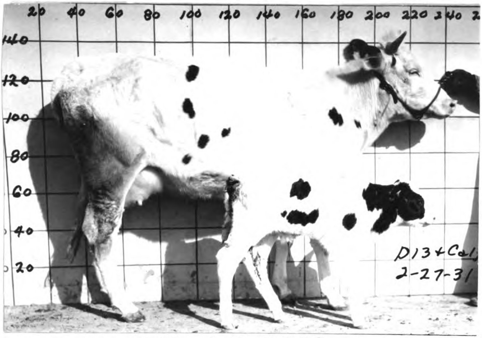
D-11 at First Calving. Calf Born Dead.
Basal Ration-Alfalfa Hay, Corn Silage, Corn.

PLATE LII



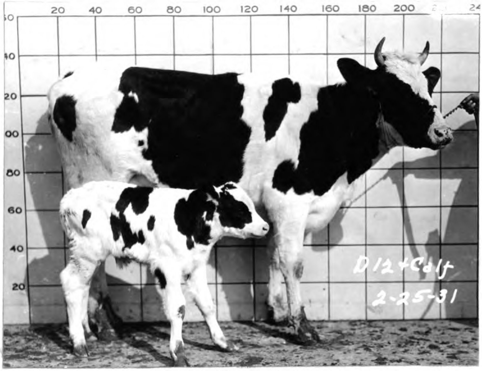
D-10 and first calf
Basal Ration Plus Steamed Bone Meal.

PLATE LIII



D-13 and First Calf
Basal Ration-Alfalfa Hay, Corn Silage, Corn

PLATE LIV



D-12 and First Calf
Basal Ration Plus Steamed Bone Meal

PLATE LV

D-15 and First Calf
Basal Ration Plus Steamed Bone Meal.