THE STUDY OF A SIMPLE HOME-GROWN RATION

FOR DAIRY CATTLE

THESIS FOR THE DEGREE OF M. S.

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Thesis

Respectfully submitted to the Faculty of Michigan State College in partial fulfillment of the requirements for the degree of Master of Science.

By

George Augustus Bowling

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THESIS

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INTRODUCTION

The protein in the ration of the dairy cow is the most important item in the feed cost of milk production. In the State of Michigan purchased protein-rich concentrates are generally high in price. Because of this fact a great many dairy farmers do not feed sufficient protein for maximum production. If it were possible to produce a crop, or a combination of crops, with a protein content which would be sufficient for growth, reproduction and lactation, a very considerable saving could be made in the feeding of growing and lactating dairy animals.

The cereal grains most commonly used in the feeding of dairy animals are corn, oats, and barley. The most commonly used roughages are corn stover, corn silage, alfalfa hay, clover hays, and timothy hay. Any home-grown ration will consist of various combinations of these feeds with the addition of common salt.

It has not been considered possible, by most investigators, to maintain high production in lactating dairy cattle by feeding a ration grown entirely on the farm. Deficiencies in both quantity and quality of the total protein are considered the limiting factors.

The State of Michigan produces more alfalfa hay than any state east of the Mississippi. The alfalfa plant is a very cheap and abundant source of protein. The leaves of the alfalfa plant are especially rich in protein. No attempts have been made to use the leaf of the alfalfa plant as a substitute in the grain ration for purchased protein-rich concentrates.

It is the purpose of this investigation to compare a simple grain ration composed of a home-grown cereal with alfalfa leaf meal as a protein supplement, to a complex grain ration containing cottonseed meal and linseed oil meal as protein supplements, in the feeding of high producing dairy cows. It is also the purpose of this investigation to compare, by nutritional experiments with rats, various simplified home-grown rations to an approved complex grain ration plus alfalfa hay, for growth, reproduction, and lactation.

REVIEW OF LITERATURE AND GENERAL DISCUSSION

Under present practices home-grown rations are usually too low in total protein to maintain very high milk production. It is possible, however, to produce a ration on the farm that will maintain a fairly satisfactory level of milk production in dairy cows. Such a ration is possible only when a high protein roughage, such as alfalfa hay, is fed in liberal amounts, and a grain ration of sufficient quality and quantity is supplied.

THE NECESSITY FOR QUALITY IN THE PROTEIN OF THE DAIRY COW'S RATION

Although a large quantity of protein is required to maintain high milk production with dairy cows, quantity alone is not the only essential protein requirement. In 1907 Hart, McCollum, Steenbock and Humphrey (1) in reporting on feeding trials, in which they used rations from restricted sources, made the following statement: "The rations ordinarily fed our farm animals are exceedingly complex in chemical composition. There are many different proteins, in addition to nitrogen-bearing bodies of non-protein character; fats of different composition and degree of saturation; carbohydrates of many types; and a host of undetermined and undefined bodies in the daily ration of a domestic animal. Whether this complex organic ensemble of the farm ration is always conducive to vigorous growth and sustained vitality, or whether dependent upon its source, it may contain either nutrients of inadequate chemical constitution or depressants, which counteract the favorable physiological effect of a part of the ration, is an unsolved problem."

Hart and Humphrey (2) state that "with the newer view-point of protein chemistry emphasizing the fact that the value of a protein mixture for growth or milk production will depend upon its qualitative and quantitative make-up and not merely on the quantity of the proteins injested it is impossible to state whether the home-grown ration would furnish a protein supply of proper quality for high milk production without drawing on the protein tissue reserves of the animal." These same investigators (3) after feeding lactating dairy cows on rations containing milk, corn grain or wheat grain as the principal source of protein came to this conclusion: "That the quality of the protein is an important factor in maintenance and production and that the synthetic powers of the mammary gland will not compensate for deficiencies in protein structure". They suggest that the sufficiency of the proteins will depend on their source and the quality of the amino-acids they can furnish.

Essential Amino Acids

The quality of proteins, in regard to their ability to maintain animals or to produce growth in animals, depends on the completeness of their amino acid content.

Osborne and Mendel (4) stated that "Abderhalden has maintained that so long as there is no evidence that amino-acids can readily experience a transformation into one another in the organism, the extent of protein construction in the body must be limited by the amino-acid which is present in the smallest relative amount in our intake".

Osborne and Mendel (5) suggest that all those amino-acids that can not be synthesized by the animal must be supplied in the ration.

Mathews (6) states that animals "cannot make sufficient tryptophane, tyrosine, lysine and cystine to supply their needs, but these amino acids must be present in the diet".

Hawk and Bergeim (7) list as essential for normal development, lysine, tryptophane, cystine, and tyrosine; and they suggest that histidine and proline may be essential.

Lysine

Osborne and Mendel (5) found that a ration containing gliadin as the sole source of protein, and which was only able to maintain the animals, was sufficient to promote normal growth when supplemented with lysine. Gliadin is deficient in lysine. These investigators suggest that lysine is probably not essential for maintenance.

Hart, Nelson and Pitz (8) found that it was practically impossible to get rats to grow and reproduce on a ration deficient in lysine. They found that if grown rats placed on a lysine-free ration were bred, reproduction would occur but the young would die. The addition of lysine corrected this condition. These investigators concluded that lysine was not necessary for maintenance. They also concluded that the mammary gland is not capable of synthesizing lysine.

Hogan (9) in using corn as a source of protein for rats found that these animals would not grow without an adequate supply of lysine to supplement the corn when the ration was otherwise complete.

Osborne and Mendel (10), (11), (12) reporting on a number of different trials in which lysine was used to supplement lysine-deficient rations have shown that lysine is necessary for growth, but is not necessary for

for maintenance. These authorities (13) also found that lysine was necessary for growth in chickens.

Tryptophane

Osborne and Mendel (5) have shown that tryptophane cannot be synthesized by the animal organism. They also demonstrated by feeding a ration deficient in tryptophane that this amino-acid is necessary for both maintenance and growth.

Hogan (9) found that rats would not grow without tryptophane and concluded that tryptophane is the first limiting amino-acid of the corn kernel.

Osborne and Mendel (10) found that lysine could not replace tryptophane in making maintenance possible and (10), (12) that tryptophane was essential for maintenance. They concluded (11) that the supplementary powers of certain proteins, when fed with corn lies in their ability to supply lysine and tryptophane, the amino acids which are deficient in the corn grain.

Totani (14) working with rats confirmed the opinion that tryptophane is essential for both maintenance and growth. Osborne and Mendel (13) found that chickens failed to grow on a ration deficient in tryptophane.

Cystine

Osborne and Mendel (12) state that cystine is essential for growth. They found (15) that the addition of cystine to a ration deficient in this amino acid produced growth that would indicate a necessity for cystine in the ration.

Sherman and Merrill (16) found that the addition of 0.2 per cent of cystine to a ration containing milk as the essential source of protein, but ever diluted with corn starch, caused young rats to greatly outgrow similar animals on a basal ration containing no cystine. These investigators point out that cystine is the first limiting amino acid in milk.

Sherman and Wood (17) demonstrated that cystine is essential and determined the amount of this amino acid in casein by measuring growth on casein fed animals and checking with the growth of animals getting pure cystine in the ration.

Geiling (18) showed that cystine added to a ration, the protein of which consisted of casein, produced growth. When the cystine was removed there was a decline in body weight. It was concluded that cystine was essential for maintenance and growth.

Woods (19) found that rats kept on a cystine free diet and then changed to a normal diet were able to resume growth at a remarkable rate, and were able to reproduce and rear young.

Lewis (20) fed dogs on a low protein diet and found that the additions of small amounts of cystine favorably influenced the nitrogen balance. He concluded that there is a specific demand for cystine for metabolic processes.

Lewis and Lewis (21), Rose and Huddlestun (22) and Westerman and Rose (23) demonstrated that it was not possible at that time to substitute successfully closely related chemical substances for cystine.

<u>Histidine</u>

Geiling (18) found that in feeding histidine and arginine with an otherwise complete ration that "full grown mice are able to hold their weight when either of them (histidine or arginine) is present" in the otherwise complete ration. In the absence of both, a loss of weight occurred.

Hart, Nelson and Pitz (8) showed that the addition of histidine and arginine did not bring about an increase in growth.

Ackroyd and Hopkins (24) stated that "when arginine and histidine are together removed from the diet of rats which have previously been growing on a complete amino acid mixture there is a rapid loss in weight." They also found that nutritional equilibrium was possible in the absence of one of these protein constituents, but not in the absence of both. They suggested that this is because each of these amino acids can, in metabolism, be converted into the other.

Harrow and Sherwin (25) stated that histidine is an essential amino acid and that arginine and histidine are not interchangeable.

Rose and Cox (26) demonstrated that arginine cannot replace histidine in the diet. They concluded that histidine is absolutely essential for growth and maintenance.

Cox and Rose (27) in feeding trials with growing rats found that neither adenine, guanine, creatinine, creatine nor a combination of these compounds is capable of replacing histidine in the ration.

Harrow and Sherwin (25) found that imidazol lactic acid, a compound closely related to histidine serves as a very good substitute for histidine in the diet.

Cox and Rose (28) stated that "the addition of dl-Beta-4 imidazole lactic acid to the histidine-deficient diet caused an immediate resumption of growth, at a rate slightly lower than that induced by the equivalent quantity of histidine". They suggest that such a substitution is possible probably through being transformed by the cells into the amino acid.

Rose and Cook (29) demonstrated that arginine could not replace histidine in the diet. They concluded that these two amino acids were not interchangeable in purine metabolism.

Arginine

Early investigators associated arginine and histidine very closely in protein metabolism.

Ackroyd and Hopkins (24) suggested that in metabolism arginine and histidine could be converted one into the other, and that if one was present in the diet the other one was not absolutely necessary.

Geiling (18) stated that "arginine and histidine seem to be interchangeable in nutrition".

More recent investigations, however, have shown that arginine and histidine are not so closely associated in metabolism as was at first suggested.

Rose and Cook (29) concluded that "arginine and histidine are not interchangeable in purine metabolism", and that arginine could not replace histidine.

Sure (30) found that 0.4 per cent of arginine added to a ration deficient in arginine produced increased growth.

It has been demonstrated (18), (24) that the addition of arginine to a ration deficient in this amino acid produced growth.

Tyrosine

Abderhalden (31) found that dogs readily lost weight when fed on a ration containing casein, as the source of protein, from which the tyrosine had been removed by crystallization. When tyrosine was supplied in the ration there was a gain in weight.

Jackson, Sommer and Rose (32) fed a ration containing gelatin as a basal protein plus cystine and tryptophane. The addition of tyrosine to the diet produced satisfactory growth in only 2 of 26 animals.

Mathews (6) points out that gelatin cannot meet the protein requirements of the human body, and that gelatin lacks both tyrosine and tryptophane.

Totani (14) found that the absence of tyrosine from the ration did not provide a deficiency in the ration.

Sure (33) in attempting to determine the nutritive value of lactalbumin fed a basal ration of dextrinized corn starch, agar-agar, Wisconsin salt mixture number 32, filtered butterfat and an alcoholic extract of wheat embryo. When lactalbumin was fed at a 9 per cent level plus cystine with the basal ration, it was found to be deficient in nutritive value. When tyrosine was added as 5 per cent of the total protein of the diet the ration showed excellent nutritive value.

Lightbody and Kenyon (34) found that the absence of tyrosine from a ration that was otherwise complete did not prevent growth over a period of 12 weeks.

<u>Proline</u>

Using edestine (the globulin from hempseed) as a basal protein, Sure (30) added cystine, arginine and lysine. At a 9 per cent protein level there were no significant indications of a nutritive deficiency when fed to rats. When the protein level was reduced to 6 per cent, however, growth was retarded. The addition of 0.4 per cent of proline at this level produced no additional growth.

The addition of 0.4 per cent of arginine in addition to the proline produced a noticeable increase in growth. Sure concluded that as arginine alone, or proline alone did not produce the growth that a resumption of growth when arginine was added should be credited to proline. He also found that two male rats receiving proline in addition to a proline-free diet made much better growth than two females on the proline-free diet. These results would not seem to indicate a need for proline in the diet of the growing rat.

From the review of literature presented it appears that tryptophane, cystine and histidine are essential for maintenance and growth and that lysine is essential for growth. It also appears that tyrosine and arginine may be essential for growth.

THE DISTRIBUTION OF THE NITROGEN OF ALFALFA HAY AND SOME OF THE CEREALS

The data concerning the amino acid content of the alfalfa plant and the common cereals are very incomplete, and in many cases disagree to a marked degree.

Alfalfa

Hamilton, Nevens and Grindly (35) and Miller (36) found the following nitrogen distribution expressed in percentage of the total nitrogen of the alfalfa plant as determined by the Van Slyke method.

Amino acid	Hamilton, Nevens & Grindley Av. of 4 samples containing 2.628 per cent N	Miller Av. of 2 samples
Arginine	7.996	14.05
Histidine	3.931	3.18
Lysine	4.434	11.30
Cystine	0.991	.93

Mitchell and Hamilton (37) have compiled the following data concerning the amino acid content of the green alfalfa leaf as determined by the Van Slyke method and classified as to protein character. Expressed as percentages of total nitrogen.

Character of Protein	Nitrogen Content	Arginine	Histidine	Lysine	Cystine
Cytoplasmic proteins	15.76	15.3	3.1	10.0	0.8
Soluble in dilute alkali	13.60	11.0	6.3	5.3	0.8
Water-soluble; Sample A	13.94	18.8	6.8	5.5	1.3
Water-soluble; Sample B	12.72	17.6	7.5	5.3	1.3

Chibnall and Nolan (38) found the following nitrogen distribution in the cytoplasmic protein which constitutes about 8.61 per cent of the protein of the alfalfa leaf. The distribution is expressed in percentage of total nitrogen of the protein. These two investigators used the upper 6-8 inches of plants which had grown to a height of two feet.

Arginine	15.32 per cent
Histidine	3.09
Lysine	9.97
Cystine	0.84

Vickery (39) isolated tyrosine in very small amounts from the juice of the alfalfa plant.

Vickery and Vinson (40) isolated appreciable amounts of arginine, lysine and tyrosine from the juice of the alfalfa plant.

Jones, Gersdorff and Moeller (45) reported the presence of tryptophane in the crude protein of the alfalfa plant.

<u>Corn grain</u>

Hamilton, Nevens and Grindley (35), Brewster and Alsberg (41) and Nollau (42) found the following nitrogen distribution in corn, expressed as percentage of total nitrogen as determined by the Van Slyke method.

Amino acid	Hamilton, Nevens & Grindley Av. of 6 samples containing 1.4074 gms. N.	Brewster and Alsberg	Nollau
Arginine	6.725	7.75	16.19
Histidine	4.832	2.46	4.45
Lysine	2.200	2.06	6.53
Cystine	1.072	1.60	4.06

The tryptophane, tyrosine and proline content of the total protein of corn was not given in the literature reviewed. The amino acid content of some of the proteins of corn has been determined.

Jones and Csonka (45) give the distribution of nitrogen in the alpha Glutelin of corn as follows - average of two determinations expressed as percentage of the total nitrogen.

Arginine	15.11 per cent
Histidine	2.81
Lysine	7.99
Cystine	2.04

Rabin and Denis (44) give the tyrosine content of corn glutelin as 6.5 per cent.

The following table shows the percentage amino acid content of zein, a protein of corn as determined by a number of investigators. Only those amino acids considered as essential for growth or maintenance are given.

(According to Berg (53) zein makes up about 50 per cent of the corn protein and glutelin about 30 per cent of the corn protein.)

Amino acid	Osborne and Mendel (5)	Jones, Gersdorff and Moeller (45)	Folin and Marenzi (46)	Hanke (47)	Folin and Denis (44)	Cohn (48)
Proline	9.04					
Tyrosine	3.55		5.88	3.66	5.5	
Cystine		3.48				1.03
Histidine	0.82			1.25		
Arginine	1.55					
Lysine	0.00					
Tryptophane	0.00	0.00	0.20			

Brewster and Alsberg (41) give the following distribution of the nitrogen of the pressed corn germ, expressed as percentage of total nitrogen - arginine, 11.04 per cent, histidine, 5.84 per cent, cystine none, and lysine, 5.62 per cent.

Corn leaf

Chibnall and Nolan (49) made a determination of the distribution of nitrogen in the cytoplasmic protein of the corn leaf. Cytoplasmic protein included 12 per cent of the leaf nitrogen of the sample studied. The leaves were obtained about one week before tassels were observed. Following is the nitrogen distribution found, expressed in per cent of nitrogen.

Amide N	7.44 per cent
Cystine	.77
Arginine	14.69
Histidine	4.70
Lysine	8.78
Amino N	55.81
Non-Amino N	2.04

Oat grain

Hamilton, Nevens and Grindley (35) and Nollau (42) gave the following distribution of the nitrogen of the oat grain, expressed as percentage of total nitrogen as determined by the Van Slyke method.

Amino Acid	Hamilton, Nevens and Grindley. Av. of 6 samples containing 1.680% N	Mellan		
	Oat grain	Oat grain	Rolled oats	Sprouted oats
Arginine	11.647	11.42	12.12	11.26
Histidine	5.796	9.58	10.40	9.61
Lysine	2.841	0.00	0.00	0.70
Cystine	.944	4.48	5.22	5.32

Hanke (47) found that the sativin of oats contained 0.74 per cent histidine and 1.56 per cent tyrosine expressed as percentage of total nitrogen. Eagins (50) by using the indirect vanillin - HCl reaction found 0.15 per cent of tryptophane as expressed in percentage of total nitrogen.

Csonka (51) found that the yield of glutelin was approximately 1.9 per cent of the oat flour. Using the Van Slyke analysis he showed the following nitrogen distribution in glutelin, expressed as the percentage of total nitrogen -

Arginine	15.30 per cent
Histidine	3.49
Lysine	5.45
Cystine	1.99

Jones, Gersdorff and Moeller (48) found that the gliadin of oats contained no tryptophane and 3.48 per cent of cystine nitrogen.

Mitchell and Hamilton (37) have assembled data on the avenin of oats into the following table, expressed as the percentage of total nitrogen in the various amino acids. Three different samples are given.

Proteins	Nitrogen content	Arginine	Histidine	Lysine	Tryptophane	Cystine
Oat avenin	15.84	14.4	7.2	4.4		1.5
Oat avenin	15.77	15.5	3.2	4.6		1.1
Oat avenin	17.53	15.3	3.5	5.4	1.0	2.0

Wheat grain

Brewster and Alsberg (41) and Grindley (52) give the following distribution of nitrogen in wheat as determined by the Van Slyke method and expressed as the percentage of total nitrogen.

Amino Acid	Brewster and Alsberg	Grindley
Arginine	8.96	8.0
Histidine	1.73	1.7
Lysine	2.65	2.5
Cystine	0.87	1.3

Jones, Gersdorff and Moeller (45), Hagins (50) and Osborne and Mendel (5) reported the presence of tryptophane in the gliadin of wheat.

Osborne and Mendel (5) and Hanke (47) reported tyrosine in the gliadin of the wheat grain.

Barley

Mollan (42) and Grindley (52) gave the following distribution of nitrogen in the barley grain as determined by the Van Slyke method and expressed as the percentage of total nitrogen.

Amino Acid	Nollau	Grindley
Arginine	8.65	9.5
Histidine	6.70	3.6
Lysine	0.00	2.2
Cystine	4.38	1.3

Hagins (50) by using the indirect vanillin-HCl reaction found 0.60 per cent of tryptophane nitrogen in the hordein of barley.

Hanke (47) reported 2.45 per cent of tyrosine in the hordein of barley.

It appears from the data presented in the literature reviewed regarding the amino acid content of the alfalfa plant, and corn, oats, wheat and barley, that practically all of the essential amino acids are present in these common feeds. It is probable that some of the amino acids are present in some of these feeds in quantities so small as to render them individually inadequate for normal growth, reproduction and lactation in mammals. However, the true value of a feed can be measured only by animal experimentation.

THE EFFICIENCY OF THE PROTEINS OF ALFALFA, CORN, AND OATS

While it is not considered the best practice to feed animals nutrients from only one source, nevertheless it is the practice in some sections of the country to feed animals largely on one hay and one grain. For this reason it is important to know the biological value of the various feeds when fed alone, or when fed as the principal source of a certain class of nutrient.

Feeding Trials in which Alfalfa Hay Has Been Used as the Principal Source of Protein

Dairy Cows

Larsen, Putney and Henderson (54) state that "alfalfa hay is one of the very best of roughages for dairy cattle. It is very palatable and has a very good effect upon the digestive system, as it is slightly laxative in character. It is high in protein, and is highest of all common feeds in calcium."

A Wisconsin Annual Report (55) summarizes the results of comparing alfalfa hay and red clover hay as a roughage for dairy cows.

It was found that the feeding of red clover in a home-grown ration containing in addition, corn silage, and the cereal grains, would not maintain a positive nitrogen balance in high producing dairy cows. When alfalfa hay was substituted for red clover hay, however, it was found possible to maintain a nitrogen balance for at least 16 weeks.

McCandlish and Weaver (56) compared alfalfa hay and corn silage with timothy hay and corn fodder at the Iowa Experiment Station. The double reversal system was used. A grain mixture of 4 parts cracked corn, 4 parts ground oats, and one part linseed oil meal was fed. During the first and third periods alfalfa and silage were fed, and timothy hay and corn fodder were fed during the second period. While on timothy hay and corn fodder the animals lost 2 per cent in body weight, and 18 per cent and 14 per cent in milk and butterfat production, respectively. They concluded that "with alfalfa hay at $15.00 per ton timothy hay is worth 86 cents per ton for feeding producing cows".

The New Mexico Station (57) has reported on trials in which a ration of alfalfa and wheat bran was compared to a ration of alfalfa hay over a period of six weeks. While the addition of wheat bran caused an increase in milk production the increase was not enough to pay the cost of the wheat bran fed.

True, Wall, and Voorhies (58) found that by supplementing alfalfa hay with barley they secured greater milk production, but the extra production was not enough to pay for the grain fed during the short feeding period used. Appreciating, however, the residual effects of grain feeding they made this statement - "On account of the increased production obtained and the residual effect of the grain feeding, as well as its favorable influence on the condition of the cows and their offspring, it may be concluded, however, that the practice of feeding grain to cows on alfalfa is economically sound and may be recommended."

Snyder (59) fed chopped alfalfa against wheat bran for 15 day periods. It was concluded that the chopped alfalfa was equal to the wheat bran as a feed for dairy cows.

Henry and Morrison (60) state that "even though alfalfa hay excels as a roughage for dairy cows, it is nevertheless a roughage and not a concentrate. Hence, when it is substituted for all the concentrates in a ration, the production of good dairy cows will be decreased markedly".

Hart, Humphrey and Morrison (61) fed two lots of growing heifers, one receiving alfalfa and the other the corn grain as the principal sources of protein. The lots were alternated. These investigators came to the following conclusions:

"(a) On the basis of total nitrogen ingested the utilization of nitrogen for growth was as efficient when the source was from alfalfa hay as when it came from the corn kernel.

(b) With the high intake of total digestible protein, which in the case of the alfalfa includes the 'amide nitrogen', the storage of nitrogen was essentially alike in the two rations."

Hart and Humphrey (62) found that the protein of the alfalfa plant was just as efficient for milk production as the protein of the corn plant.

Reed, Fitch and Cave (63) using 6 Holstein heifers per lot fed one lot on alfalfa hay and compared their growth, reproduction and milk production to similar lots fed on alfalfa and silage, and alfalfa, silage and grain. The heifers were placed on these rations when very young, and carried on through two lactation periods. These investigators concluded that the exclusive feeding of alfalfa hay failed to produce a satisfactory development of Holstein heifers, nor did it prove to be an economical feed for the production of milk.

At the Nevada Station (64) it was found that the feeding of grain in addition to alfalfa increased production over that secured on an alfalfa ration alone. The alfalfa ration proved to be more economical. Fifty pounds of grain saved only 34 pounds of hay.

Rats

Although alfalfa hay and alfalfa leaf meal have been fed in many feeding trials with rats, in practically all of them alfalfa has been fed with other proteins, thus obscuring its true biological value.

At the Oregon Station (65) some difficulty was experienced in maintaining animals on a high level of the alfalfa leaf. "Growth curves show that the addition of small amounts of cystine to the alfalfa leaf protein clearly indicated an incompleteness of the protein of the alfalfa leaf".

Nevens (66) found that rats could be maintained on a diet of alfalfa hay plus a protein free basal ration. On a biological basis the proteins of cottonseed meal, alfalfa hay and corn showed nutritive values of 66, 62 and 49 per cent respectively. Nevens stated that "alfalfa hay proved very palatable, as all rations of which it formed a part were readily eaten".

Feeding Trials in which Corn Has Been Used as the Principal Source of Protein

Dairy Cows

Hart, McCollum, Steenbock and Humphrey (1) studied the effect on growth and reproduction of rations from restricted sources. They fed heifers, 5-6 months old, on rations restricted to the corn, oat or wheat plant, or a mixture of these cereal plants. Four lots of 4 heifers each were used.

Group one was fed entirely on the grain and roughage of the corn plant.

Group two was fed entirely on the grain and roughage of the oat plant.

Group three was fed entirely on the grain and roughage of the wheat plant.

Group four was fed entirely on a mixture of equal parts of the corn, oat, and wheat plant.

The various groups were balanced to the protein level of the ration consisting of the oat plant.

The animals in the various lots were confined to their respective rations until they had calved twice.

The investigators came to the following conclusions.

"Animals receiving their nutrients from the wheat plant were unable to perform normally and with vigor all the normal physiological processes.

"Those receiving their nutrients from the corn plant were strong and vigorous, remained in splendid condition and reproduced young of great weight and vigor.

"Animals receiving their nutrients from the oat plant were able to perform all the physiological processes of growth, reproduction and milk secretion with a certain degree of vigor, but not in the same degree as manifested by the corn fed animals.

"When a mixture of all the above plant materials was used, the animals responded to the ration with less vigor than to the corn or oats ration, but with more vigor than to the wheat ration."

The following table summarizes some of the more important observations on the animals of the various lots. The observations were of a comparative nature so that they are ranked, 1, 2, 3, 4; 1 being the best and 4 the poorest ranking.

	Comparative Gradings			
Observations	Corn ration	Wheat Ration	Oats Ration	Mixture
Appearance	1	4	3	2
Closeness of calving date to the expected date	1	4	2	3
Weight of calves	1	4	2	3
Vigor of calves at birth	1	4	2	3
Milk production	1	4	2	3
No. calves born in 2 years	8	6	8	6
No. calves that lived	8	0	6	3
No. calves born dead	0	1	1	2
No. calves born alive, but died	0	5	1	1

Hart and Humphrey (61) (62) found that the nitrogen of the corn plant was about equal to the nitrogen of the alfalfa plant for feeding growing or lactating dairy cattle.

Larsen and co-workers (67) found that the percentage availability of oil meal and gluten feed in establishing a nitrogen equilibrium was 52.4 per cent for oil meal and 76.4 per cent for gluten feed. They concluded that gluten feed protein in most cases showed a higher relative value than oil meal protein.

Rats

Hogan (9) found that corn protein was not sufficiently complete to support life without being supplemented with the amino acid tryptophane, nor would it induce growth in the rat without being supplemented with both tryptophane and lysine.

McCollum, Simmonds and Pitz (68) concluded that "the proteins of the maize kernel contain all the amino acids essential for growth, but the proportions of some of them are such that they are not utilized to a high degree as the sole source of protein". They obtained about two-thirds normal growth over a period of 6-7 months on a diet in which all the protein was derived from 91 per cent of ground maize in the ration.

Nevens (66) found that corn protein had a lower biological value than alfalfa when fed to rats.

Feeding Trials in which Oats Have Been Used as the Principal Source of Protein

Dairy Cows

Hart, McCollum, Steenbock and Humphrey (1) have found, in data already reviewed that the oat protein is not as satisfactory as the corn protein for growth, reproduction and lactation in dairy cows. They concluded, however, that a fair degree of efficiency was secured with the oat protein.

Huffman (69) was unable to secure normal growth, reproduction and lactation in dairy cows fed entirely on the oat plant. The animals were undersized, of poor appearance and none of the calves born on this diet lived.

In these two experiments certain dietary factors probably were as important in producing the results obtained as was the quality of the protein of the ration.

Rats

McCollum, Simmonds and Pitz (70) demonstrated that rats fed on

rolled oats alone would die. At a later date McCollum and Simmonds (71) concluded that the oat protein was more efficient for maintenance than were the proteins of corn and wheat. Four per cent of the oat protein was as efficient in maintaining rats as was 6 per cent of the protein of corn or wheat. The low esteem in which oats was held by McCollum and co-workers during their early investigations was due at least in part to the high level at which rolled oats was fed. It was found that when fed at lower levels the results obtained were much more satisfactory.

Funk (72) concluded that "oats in the dry state or subjected to germination proved to be an inadequate diet for young rats".

McCollum and Simmonds (73) in comparing the biological value of the oat protein to that of milk found it to be about 75 per cent as efficient.

Mitchell (74) found that when oat protein was fed at a 5 per cent level it had a biological value of 78.6. When fed at a 10 per cent level the biological value was 64.9 per cent. Milk proteins, under similar conditions, had biological values of 93.4 and 84.7 per cent respectively. Funk (75) kept rats alive for a considerable length of time on oats alone; but if the oats were autoclaved the animals died at an early date. Older rats lived longer than young rats on the oat diet.

At the Ohio Experiment Station (76) nutrition studies made by feeding whole oats to rats indicated that oats are deficient in the essential proteins.

G. A. Hartwell (77) fed oat meal to rats and supplemented the diet with butter and a salt mixture. This authority concluded that the protein of the oatmeal was of good quality as regards growth in rats, but that it was not adequate for gestation and lactation. These deficiencies were supposed to be due to a lack of quantity of protein rather than to the quality of the protein.

THE EFFICIENCY AND ECONOMY OF THE HOME-GROWN RATION FOR MILK PRODUCTION

For more than 25 years the increasing costs of high protein concentrates have presented a serious problem to the dairy farmer. Whether the dairy farmer should buy protein-rich concentrates or feed home-grown feeds will depend upon two things - First, the efficiency of the protein in the home-grown ration when compared with purchased protein-rich concentrates, and secondly, the economy with which each type of feed produces milk.

Lane (78) fed 2 lots of 2 cows each on a home-grown ration and a ration containing purchased feeds. The reversal method was used and the feeding period was for 32 days. The home-grown ration consisted of 13 pounds of alfalfa and 30 pounds of corn silage per day. The other ration was composed of 5 pounds of mixed hay, 30 pounds of corn silage, 6 pounds of wheat bran, and 5 pounds of dried brewer's grains. The home-grown ration contained as much protein, but 2.65 pounds less total digestible nutrients than the ration containing the purchased protein. During the periods the animals received the concentrates in the ration, they produced 4.15 per cent more milk and 4.16 per cent more butter.

From the standpoint of economy the alfalfa-corn silage ration showed the better results. While on this ration the cows produced 100 pounds of milk and a pound of butter at a cost of 55.9 cents and 11.1 cents respectively, while on the ration containing the concentrates the cost was 85.9 cents and 16.7 cents for 100 pounds of milk and one pound of butter respectively. At the time of this trial (1902) when mixed hay was worth $16.00 per ton, wheat bran $26.00 per ton, and dried brewer's grains $20.00 per ton, the alfalfa hay was worth $24.52 as a substitute for the constituents of the concentrate ration - exclusive of the corn silage. A smaller profit was returned when crimson clover was substituted for alfalfa hay in similar trials. It should be pointed out, however, that the fact that the two rations used in this experiment were not balanced in total digestible nutrients - a fact that would render the results of little value.

At the same station a ration composed of

36 pounds cow pea silage
10 pounds crimson clover
6 pounds corn and cob meal -

was fed against a ration composed of -

36 pounds corn silage
5 pounds mixed hay
4 pounds dried brewer's grains
2.5 pounds cottonseed meal

The production was about the same, but the economy of production was in favor of the home-grown ration. During these trials the cows were producing about 25 pounds of milk per day.

Lane (79) fed a ration composed of cow pea hay and corn silage against a ration composed of corn stalks, corn silage, wheat bran, dried brewer's grains, and cottonseed meal. The home-grown ration contained

.14 pounds less protein, but 1.89 pounds more total digestible nutrients than the ration containing the purchased proteins. The reversal method was used. The ration containing the purchased proteins produced 8.3 per cent more milk and 15.2 per cent more butter than the home-grown ration. The cost of producing 100 pounds of milk and one pound of butter was 59.8 cents and 8.82 cents respectively for the home-grown ration, and 60.5 cents and 12.6 cents respectively for the ration containing the purchased protein.

Billings (80) continuing the work of Lane in a third series of trials at the New Jersey Station, using 60 day feeding periods and feeding a home-grown roughage ration of alfalfa hay and corn silage against a ration supplemented with purchased protein, found the latter to be more economical. These rations were equally balanced in both protein and total digestible nutrients. He concluded that better results would be obtained if home-grown proteins constituted a large part, but not all, of the protein of the dairy cow's ration. This trial, compared to the previous trials at the New Jersey Station (54) (55) which were of short duration, would indicate that the home-grown ration is most satisfactory over a short period, but not so satisfactory for a long feeding period.

Caldwell (81) fed 2 lots of 6 cows each on a ration composed of alfalfa hay, corn silage, and corn meal; and a ration composed of corn silage, corn stover, wheat bran, corn meal and cottonseed meal. He concluded that the two rations were about equal in regard to efficiency of production. The costs were practically the same, being 4 cents less per 100 pounds of milk in favor of the home-grown ration.

Fraser and Hayden (82) studied the comparative efficiency of alfalfa hay and wheat bran for milk production. A basal ration composed of 6 pounds clover hay, 30 pounds of corn silage, and 6 pounds of corn meal was used. Eight pounds of wheat bran was fed against 8 pounds of alfalfa hay. The difference in production was so small as to be insignificant. The alfalfa ration was the cheaper of the two rations.

Beane (83) compared a home-grown ration with a ration supplemented with purchased proteins. Fifteen cows were fed for two 30-day periods by the reversal method. The home-grown ration consisted of alfalfa hay and corn meal. The other ration consisted of corn silage and a concentrate mixture of 3 pounds of malt sprouts, 1 pound of linseed meal, 1 pound of gluten meal, and 1 pound corn chop.

In the two 30-day periods the cows on the alfalfa-corn ration made a gain of 276.2 pounds of milk over the cows on the other ration. The cows were producing only about 15 pounds of milk per day.

Hart and Humphrey (2), (84), (85), (86), found that it was possible to maintain a positive nitrogen balance in cows producing as much as 35 pounds of milk per day on a ration of corn silage, alfalfa hay and either corn or barley as a concentrate feed.

At the Ohio Station (87) two cows fed alfalfa hay and ground corn completed their lactations and each gave birth to a living calf. One of the cows produced 11,040 pounds of milk and 382 pounds of butterfat in 13 months and gave birth to a 105 pound living calf. The other cow produced 11,276 pounds of milk and 351 pounds of fat in 12 months and gave birth to a 90 pound living calf.

McCandlish, Weaver and Lundes (88) reported the use of soybeans as a home-grown supplement in the dairy cow's ration. They fed 2 lots of 4 cows each for three 30-day periods. The lots were fed a basal ration of corn silage and alfalfa hay, and a grain mixture of equal parts by weight of cracked corn and ground oats. During the first and third periods the cows received old process linseed oil meal in addition to the basal ration and during the second period they received cracked soybeans in place of the linseed oil meal. The soybean periods produced 3345 pounds of milk and 140.94 pounds of butterfat, while the linseed oil meal produced 3484.5 pounds of milk, and 149.75 pounds of butterfat.

According to the results of these trials, basing calculations on the butterfat production, when linseed oil meal has a value of $45.00 per ton cracked soybeans are worth $60.00 per ton.

In similar trials with soybeans as a supplement, Olson (89) concluded, from the results of 6 trials, that ground soybeans were 20 per cent more valuable for milk production and 18 per cent more valuable for butterfat production than linseed meal in supplementing the ration.

It appears from the data presented in the literature reviewed that it is difficult to maintain high milk production over a comparatively long period by the feeding of corn silage, legume hay and a concentrate mixture composed of the common cereals. It also appears that by using a product of legume plants as a protein supplement for a concentrate mixture composed of cereals, a very satisfactory ration may be secured. The home-grown ration, however, seemed to produce milk and butterfat more economically.

THE SUPPLEMENTARY VALUE OF ALFALFA, CORN AND OATS

McCollum (90) after studying the supplementary value of various cereals with alfalfa leaves made the following statement. "Among the seeds studied, the oat kernel is best supplemented by the alfalfa leaf. A simple mixture of 60 per cent rolled oats and 40 per cent leaf induces in the rat nearly normal growth to the full adult size. Animals grown on this diet have shown moderate fertility and fair success in the rearing of young. However, they were not nourished in the optimal manner, for they fell considerably below the maximum capacity of well nourished animals in respect to fertility and successful rearing of young".

McCollum and Simmonds (91) found that some females would not reproduce when fed on a ration made up of 80 per cent oat meal and 20 per cent alfalfa leaf. They also found that in every case where the young could be reared to weaning, or to the point where they could eat the food, they made much more rapid growth than when taking the mother's milk.

Nevens (66) found that for maintenance corn and alfalfa failed to show any supplementary values when fed together.

It appears from the literature reviewed, that the protein of the corn plant is more efficient in animal nutrition than the protein of the oat plant. While this was a logical conclusion at the time the work was done, in the light of our present knowledge of necessary dietary factors the conclusion would not be logical. The difference in the dietary factors of the two rations would be as good an explanation as the difference in amino acid content of the rations.

It appears that oats and alfalfa supplement each other to a greater degree than do corn and alfalfa, and that the alfalfa protein has a higher biological value than the protein of the corn grain.

Dairy cows yielded a larger amount of milk when a ration of alfalfa hay was supplemented with some cereal grain.

WATER CONSUMPTION OF DAIRY COWS

Little is known regarding the water consumption of dairy cows, or the effect of water consumption on food consumption and milk production. It seems possible that the consumption of greater or lesser quantities of alfalfa might influence the water consumption, and in this way effect the milk production of dairy cows.

Scott (92) gives the following water consumption data on Montana range cattle at different periods during growth. The data are based on estimates.

Period of Growth	Season	Pounds of Water Consumed Daily	
Aged steer	Summer	100 - 125	
2 yr.-old steer	"	80 - 90	
Yearling steer	"	50 - 60	
Calf	"	40 - 50	water in milk additional
Dry cow	Winter	80	
2 yr.-old heifer	"	80	
Calf	"	60	

Larson and co-workers (93) in studying the role of water in the dairy cow's ration found the following to be true. 1. When cows were watered once in 24 hours they consumed 7 pounds less hay, 2 pounds less silage, and 7 pounds less water than when watered 3 times daily.

2. Digestibility is increased when the watering interval is lengthened.

3. The frequency of watering does not seem to have an appreciable effect on the consistency of the feces. Neither does it have much effect on the frequency of voiding feces.

4. Under normal conditions the cows voided urine 4 to 7 times per day. While on experiment they voided urine 3 to 6 times per day.

5. The amount of water consumed is directly related to the amount of milk produced, but had no effect on the composition on the whole milk or butterfat produced.

6. Animals that were receiving limited amounts of water, or water at 60 hour intervals showed more nervousness, and a more gaunt condition.

7. A larger amount of energy per 1000 pounds live weight was required when the animals were watered every 60 hours and when the water consumption was limited.

It seems from the literature reviewed, that very little is known regarding the daily water consumption of lactating dairy cattle, and the factors affecting rate of water consumption. Frequency of drinking and total water consumption seemed to have the greatest physiological effect on the dairy cow.

PHYSIOLOGICAL EFFECTS OF FEEDING ALFALFA HAY

Although alfalfa hay is one of the best roughages grown for the feeding of live stock, yet there are some indications that this feed is not without some harmful physiological effects, especially if fed in excessive amounts. It is credited with being the cause of kidney trouble and sterility when fed excessively to farm animals.

Henry and Morrison (60) state that if horses are allowed to gorge themselves on alfalfa hay they receive an excessive amount of nitrogenous material. This must be voided through the kidneys and thus overworking them. If excessive feeding is continued it may lead to a chronic inflammatory condition of the kidneys.

Hart and Humphrey (62) found that when alfalfa hay was the sole source of nitrogen in the dairy cow's ration it had specific diuretic properties. "Its ingestion was generally followed by a marked rise in the output of urine. The rise in renal activity caused a depression in milk flow which rose again when the change to the corn ration was made. This shrinkage was 5 to 6 pounds in 25 pounds of milk."

Steenbock (94) studied diuresis and its relation to milk flow. He administered urea in diuretic doses and found that it decreased milk flow temporarily." The impoverishment of the tissues called for increased water consumption, and milk flow returned to normal." Steenbock found that salt, while both a diuretic and a laxative, cannot produce a depressing effect on milk flow because it creates a thirst that stimulates water consumption and maintains the water balance in the body. He concluded "it is difficult to interpret the results sometimes obtained with alfalfa hay as due to diuresis alone if urea diuresis can be taken as a type".

Setola (95) concluded that in general the high protein roughages stimulated thirst.

At the Oregon Station (96) it was found that cows producing a moderate amount of milk while on a ration consisting largely of alfalfa, usually showed a positive calcium balance, a negative phosphorus balance, and frequently also a negative nitrogen balance while on metabolism trials. Whether nitrogen was positive or negative seemed to depend somewhat on the quality of the hay fed.

Reed, Fitch and Cave (63) found that the feeding of an exclusive alfalfa hay ration produced no noticeable reproductive troubles in the heifers used in the trials.

At the Nevada Station (64) it was not possible to determine the relationship between the feeding of alfalfa hay and sterility.

The California Experiment Station (97) reports that "data thus far collected shows proportionately less sterility in dairy cattle fed exclusively on alfalfa than those fed partly on alfalfa or in those receiving no alfalfa at all; thus negativing the popular opinion that alfalfa is the cause of sterility".

It appears that there are greatly conflicting opinions as to the physiological effects of alfalfa hay. The following conclusions may be drawn from the literature reviewed.

First - the consumption of large quantities of alfalfa seemed to stimulate thirst.

Second - large quantities of alfalfa hay in the ration of dairy cows seemed to have a specific diuretic effect.

Third - large quantities of alfalfa hay in the ration of dairy cows and heifers does not affect the reproductive efficiency of the animals.

DISCUSSION OF REVIEW OF LITERATURE

Home-grown rations, though very commonly fed to dairy cows, are not considered adequate for high milk production. The chief criticisms of the home-grown ration are that the protein content is not high enough and the quality of the protein is not sufficient to meet the demands of animals in heavy lactation.

The common cereals fed to dairy cows probably contain all the amino acids essential for maintenance and growth, but some of the essential amino acids are not present in quantities sufficient for maintenance and growth, as shown by biological determinations.

Alfalfa hay contains all the amino acids necessary for maintenance and growth. The quantities of the various amino acids found in alfalfa hay are not definitely known. Alfalfa alone does not appear to be an efficient feed for either cattle or rats when fed from the time the animals are weaned until they reach maturity.

When fed as the sole source of protein the corn plant seemed to have a higher biological value than the oat plant. In the light of present-day knowledge, however, other nutritional factors would probably affect greatly the results when diets from limited sources were fed.

Rolled oats and alfalfa seem to supplement each other to a greater degree than do corn and alfalfa.

There is some question in regard to the physiological effects of alfalfa hay on animals when fed in large quantities. Some evidence has been presented to show that alfalfa, when constituting the sole source of protein in the animal's ration has specific diuretic properties.

EXPERIMENTAL WORK

Object

The present prices of supplementary dairy feeds make it highly desirable that a ration of suitable quality for high milk production and satisfactory reproduction be worked out for Michigan conditions through the greater use of home-grown feeds. The present type of home-grown ration is considered too low in both quantity and quality of protein.

The alfalfa plant furnishes a cheap source of protein on most Michigan dairy farms. The leaf of the alfalfa plant is especially rich in protein. The value of the alfalfa leaf as a supplement for the common cereals in the feeding of dairy cows has not been studied.

Oats are a very popular cereal crop in Michigan, and one that can be grown in practically every section of the State. Oats are a very common constituent of the dairy ration.

It was the object of this experiment to determine the value of a simple grain mixture composed of ground oats and alfalfa leaf meal when compared to a complex grain mixture containing purchased protein.

Paralleling this feeding trial with dairy cows, a number of feeding trials were made using rats as experimental animals. In the trials with rats a variety of rations of a simple nature were compared to a complex ration made up of the same constituents included in the complex concentrate ration used in this experiment.

PLAN OF EXPERIMENT

Procedure

Part I.

Feeding Experiment with Dairy Cows

Animals Used

The animals used in this experiment were purebred cows from the college herd. Ten cows were used. They were divided into two groups of five cows each. The two groups were balanced as equally as possible in regard to age, weight, days in milk, average days in pregnancy, daily milk yield and fat percentage. This information is summarized in table I. Nine of the animals used in this trial were purebred Holstein-Friesian cows, and the other animal was a purebred Brown Swiss cow.

Season of Year

This experiment was begun March 25, 1929, and concluded July 22, 1929.

Management

<u>Shelter</u>

The animals were sheltered in the main dairy barn.

<u>Exercise</u>

The cows were permitted to exercise each day in a small dry lot, and when the weather permitted they were turned out after the night milking and left in the dry lot until the first morning milking.

<u>Milking</u>

The cows were milked four times each 24 hours. The milking hours were 5:30 A. M., 10:30 A. M., 5:30 P. M., and 10:30 P. M. The cows were milked with a De Laval milking machine, and were stripped by hand. The total milk from each cow was weighed and recorded after each milking.

Bedding

The cows on this experiment were bedded on shavings.

Weights of Animals

The animals were weighed at eight o'clock for three consecutive mornings just previous to the beginning of the experiment. They were weighed thereafter at eight o'clock on the last three mornings of each feeding period.

Length of Feeding Periods

The length of feeding periods was 30 days. At the end of each 30 days the rations were reversed. This was continued for four periods. In this way lot I was on the complex ration during the first and third periods and on the home-grown ration during the second and fourth periods. Lot II was on the complex ration during the second and fourth periods and on the home-grown ration during the first and third periods.

Watering

While in the stanchions the cows had free access to water from watering cups. There was no water available in the dry lot where the cows exercised.

Feeds and Feeding

The feeds used to make up the complex grain ration were: ground yellow corn 400 pounds, ground oats 250 pounds, wheat bran 150 pounds, cottonseed meal (choice) 100 pounds, old process linseed oil meal 100 pounds, common salt 10 pounds, and special steamed bone meal 10 pounds.

The feeds used to make up the simple, home-grown grain mixtures were: alfalfa leaf meal 300 pounds, ground oats 480 pounds, oat meal 220 pounds, and common salt 10 pounds. In the case of the simple ration the ground oats were supplemented with rolled oats. This was done because the ground oats were of very low quality, and the addition of the rolled oats would raise the protein content of the feed without introducing a new source of protein. The total digestible nutrient level of the simple ration was assumed to be 65 per cent because of the high fiber content of the low quality oats.

Alfalfa hay and corn silage were fed with each ration. The digestible crude protein content of the complex ration was 13.28 per cent, and the total digestible nutrient content was 75 per cent. The home-grown ration contained 11.1 per cent digestible crude protein, and it was assumed that this ration contained 65 per cent total digestible nutrients. The two rations were fed on an equal basis by feeding more pounds of the complex ration, and in every case the requirements of the animals were met according to the Savage Feeding Standard.

Roughages were fed according to the rule of feeding one pound of hay and three pounds of corn silage per 100 pounds live weight of each individual animal. Enough grain was fed to supply the required nutrients sufficient to bring the total up to the requirements of the Savage Feeding Standard.

The animals were fed grain four times each day, usually before milking. The roughages were fed twice daily; in the morning just after the first milking, and in the afternoon after the afternoon milking.

The animals were fed in individual mangers and any feed that was not consumed was weighed back each morning.

A summary of the grain mixtures is given in table II. The complex ration is designated as Ration I and the simple ration as Ration II.

Samples for Testing Milk

Samples were taken at ten day intervals, with the exception of the end of the last ten day period, when, through an oversight, the samples were not taken.

Metabolism

Metabolisms were run for the purpose of studying the nitrogen balances on three of the cows on experiment. One metabolism was run while the cows were on the complex ration and the other metabolism was run while the same cows were on the home-grown ration. The metabolisms were run during the last ten days of the last two 30-day feeding periods, and were seven days in length. The cows were placed in metabolism stalls and kept there for the seven days, except when exercised once each day and when weighed once each day. The urine and feces were collected, weighed and sampled each day. One cubic centimeter per 100 cubic centimeters of urine was taken each day in a composite sample, and toluol was used to prevent a loss of nitrogen. One gram per 100 grams of feces was taken as a sample each day and preserved, by the use of toluol, as a composite for the feces. The grain for the metabolism periods was thoroughly mixed and individual feedings were weighed and sacked separately previous to the time the metabolism started. A sample for analyses was taken immediately after mixing. The same procedure was followed in the case of the hay fed. A composite sample of the silage was taken during each metabolism.

A proportionate sample of milk (one or two cubic centimeters per pound, depending on the quantity given by individual cows) was taken at each milking and preserved as a composite.

The feed, feces, urine and milk were analysed for nitrogen by the Michigan State College Experiment Station chemists. The Kjeldahl method for nitrogen determination was used.

COLLECTION OF DATA

Milk Records

A daily record of each cow's production was kept during each period. Each milking was weighed on ordinary milk scales and recorded in pounds and tenths of pounds.

Butterfat Records

Samples of milk were tested every ten days for butterfat percentages. The average of the three tests was used to calculate the butterfat production.

Feed Records

A daily record was kept of the amount of hay, silage, and grain consumed by each cow during the experiment.

Water Consumption

The cows used in this experiment had individual drinking cups. A water meter was attached to the water pipes of each cup. By this method the amount of water consumed by each cow was registered in gallons by the meters. The meters registered to one-fourth of a gallon. Readings were made each 24 hours to determine the water consumption of each cow. The meters were read about 10:00 o'clock each morning. At that time the cows were always out in the lot while the barn was being cleaned, and a common drinking pause resulted which was convenient in separating each day's consumption.

The water consumption records were kept in an effort to determine what effect the consumption of larger or smaller amounts of alfalfa might have on the water consumption.

Temperature Records

In studying the effect of alfalfa on the water consumption it was necessary to ascertain the external temperature. This was necessary in order to determine whether any changes noticed in water consumption were due to the properties of the alfalfa or due to the external temperature. The temperature readings were obtained from the Weather Bureau at East Lansing, Michigan.

Metabolism Records

The following data were kept in regard to the nitrogen metabolisms -

1. Weight in grams of feed consumed.
2. Weight in grams of water consumed.
3. Weight in grams of feces collected.
4. Volume in cubic centimeters of urine collected.
5. Weight in grams of milk produced.
6. Daily body weights of the cows.

Frequency of Urination

A record was kept during each of the metabolism periods on the number of times each cow urinated. The purpose of this record was to determine whether or not the consumption of a large amount of alfalfa has a diuretic effect on dairy cows. If such an effect was really exerted it was thought that it might bring about an increase in the number of urinations per day.

Frequency of Drinking

A record of the frequency of drinking was kept while the cows were on metabolism. This was done in order to see whether or not the consumption of an increased amount of alfalfa would stimulate thirst in the cows to such an extent that they would take water more often.

Palatability of the Rations

The cows were under observation at all times in regard to appetite. The thoroughness with which the animals consumed their food was considered as an index of the palatability of the ration.

Health of Animals

The general health of the animals was observed from day to day. Any unusual condition such as failure to eat, constipation, etc. were recorded.

Weights of Animals

The weights of the animals were taken three days previous to the beginning of each feeding period. These weights were also used as a guide in determining the amounts of feed to be fed during the following period. Through an oversight the animals were not weighed at the end of the last feeding period.

EXPERIMENTAL RESULTS

Milk Production

The milk production for the four periods is given in tables III, IV, V, and VI. These tables show the daily production per cow, the daily production for each lot, and the total production for each lot for each period. Tables VII-a and VII-b show the production of milk by each lot of cows during each of the four periods. Tables VIII-a and VIII-b show the milk production during each period by the cows of each lot during the four periods while they were on the complex ration. Tables IX-a and IX-b show the production of each cow during the four periods while they were on the home grown ration.

These tables also show the total production made on each ration. During the first and third periods the complex ration produced the greatest amount of milk, while during the second and fourth periods the home-grown ration produced the most milk. During the first period the cows on the home-grown ration averaged 50.05 pounds of milk and the cows on the complex ration averaged 50.44 pounds. During the second period the home-grown ration produced an average of 48.5 pounds and the complex ration produced an average of 47.44 pounds of milk. During the third period the home-grown ration produced 45.29 pounds of milk and the complex ration produced an average of 45.01 pounds. During the fourth period the home-grown ration produced 38.73 pounds of milk and the complex ration produced 36.31 pounds of milk. Under the conditions of this experiment these differences probably are not significant.

During the four periods the complex ration produced 26,882.6 pounds of milk with a daily average of 44.8 pounds, and the home-grown ration produced 27,186.8 pounds of milk with a daily average of 45.3 pounds. The home-grown ration produced 304.2 pounds more milk than the complex ration. This is the equivalent of .5 pounds of milk per day.

Graph I shows the trend of milk production on each ration during the four feeding periods.

Butterfat Production

Table X shows the butterfat production of each cow during each period, the total butterfat production per lot for each period, and the total butterfat per lot during the four periods.

Table XI shows the butterfat produced by each cow, and by each lot while on the complex ration.

Table XII shows the butterfat production of each cow, and of each lot while on the complex ration.

The complex ration produced the most fat during the first and third periods, while during the second and fourth periods the home-grown ration produced the most fat. During the four periods the complex ration produced a total of 861.13 pounds of fat, and the home-grown ration produced 852.15 pounds of fat. The complex ration produced 8.98 pounds more fat during the four periods.

Fat Corrected Milk

The total milk production on each ration was corrected to a four per cent fat basis by the following formula which was developed by Gaines and Davidson (98) - .4 M plus 15 F equals Fat Corrected Milk; in which M is the quantity of milk produced and F is the quantity of fat in the normal milk. When this formula is applied the following results were obtained.

Production on Ration I (complex ration):

(22,882.6 x .4) plus (861.13 x 15) equals 23,669.99 pounds of fat corrected milk.

Production on Ration II (home-grown ration):

(27,186.7 x .4) plus 852.15 x 15) equals 23,656.97 pounds of fat corrected milk.

The complex ration produced 13.02 pounds more of four per cent milk during the four feeding periods. The difference in production, on a four per cent milk basis, is remarkably small.

Feed Consumption

Table XIII shows the total feed consumption of each animal for each period during the experiment.

Table XIV shows the total feed consumption while the cows were on ration I.

Table XV shows the total feed consumption while the cows were on ration II.

Table XVI is a summary of the amounts of hay, silage and grain consumed while the cows were on ration I.

Table XVII is a summary of the amounts of hay, silage and grain consumed while the cows were on ration II.

The following is a comparison of the total feed consumption by the cows while on each ration.

	Hay	Silage	Grain
	lbs.	lbs.	lbs.
Ration I	7,121.5	21,252.4	9,041.8
Ration II	6,843.0	20,483.0	10,185.9
Difference in favor of I			1,144.1
Difference in favor of II	278.5	769.4	

Since approximately 30 per cent of the grain mixture of ration II was alfalfa leaf meal the animals consumed a total of 2,712.3 pounds of leaf meal while on this ration.

The following table shows the amounts of digestible crude protein and total digestible nutrients consumed while the cows were on each ration.

	Hay	Silage	Grain	Total
Ration I				
	lbs.	lbs.	lbs.	lbs.
Protein	754.88	233.78	1,200.75	2,189.41
Total Digestible Nutrients	3674.69	3761.67	6,781.35	14,217.71
Ration II				
Protein	725.36	225.31	1,130.63	2,081.30
Total Digestible Nutrients	3530.99	3625.49	7,022.16	14,178.64

While the cows were on the complex ration they consumed 108.11 pounds more of digestible crude protein and 39.07 pounds more of total digestible nutrients than they consumed while they were on the home-grown ration.

<u>Water Consumption</u>

Tables XVIII, XIX, XX, and XXI show the daily water consumption for each cow and the daily water consumption per lot for each feeding period.

Table XXII shows the water consumed by each cow while on ration I, and the total consumption while on ration I.

Table XXIII shows the water consumed by each cow while on ration II and the total consumption while on ration II.

While on the complex ration the cows drank a total of 9617.25 gallons of water, and while on the home-grown ration they drank 10,402.50 gallons of water. While on the home-grown ration the cows drank 785.25 gallons of water more than they drank while on the complex ration during the four periods.

Palatability of the Rations

Using ration I as a standard for palatability, ration II did not seem to measure up to normal in palatability. The cows did not clean the grain ration up as quickly or as completely as in the case of ration I. This was especially true of animals 150, 174, and 187. These three cows were the heaviest milk producers in the experiment, and were receiving the largest amounts of concentrates. Due to the bulky nature of ration II it may have been impossible for the cows to consume the extra amount of fiber supplied by the leaf meal and oats in the grain ration. The fact that the highest producing cows did not clean up all of the grain mixture at all times might indicate that a grain ration composed of ground oats and alfalfa leaf meal would be too bulky for the feeding of exceptionally high producing cows. The fact that milk flow was maintained to approximately the normal rate of secretion for the cows used in the experiment would seem to indicate that such a ration would give very good results when fed to Holstein cows producing not over 65 pounds of milk daily.

The quality of the alfalfa leaf meal used seemed to influence the palatability of the diet. On June 26 some poorly cured, home-grown alfalfa leaf meal was substituted for the purchased leaves. Although the protein content of the two quantities of leaves was the same the ration did not seem as palatable, and animal 187 went off feed, consuming none of the ration for three days. After that she did not clean up her feed completely until the home-grown leaves were removed from the ration on July 11. After this date animal 187 cleaned up her ration completely.

Health of Animals

The animals, while on ration II, seemed to be in just as good physical condition as they were on ration I.

During the fourth period while on ration I, animal 230 became constipated and went completely off feed from July 16 to July 21. Her water consumption decreased to the point where she drank no water at all. On July 18 and 19 she produced no milk. On July 19 she was given three pounds of Epsom Salts. This brought about the passage of some feces. The cow was given a considerable amount of common salt on July 20. This seemed to stimulate a desire for water and on July 21 she drank a normal quantity of water. On July 22 she seemed to be normal again and gave 10 pounds of milk on that day.

All other cows used in the experiment seemed to be in normal condition throughout the experiment.

Weights of Animals

Table XXIV shows the weight at the beginning of the experiment for every cow in each lot, the average weight of each lot at the beginning

of the experiment, the weight of each cow, and the average of each lot at the end of each of the first three periods. The weights on the fourth period were not taken. At the end of the first period there was a difference of four pounds in favor of the complex ration. At the end of the second period there was a difference of 26 pounds in favor of the home-grown ration. At the end of the third period there was a gain of 29 pounds in favor of the home-grown ration.

The following is a summary of the weights of the two groups of animals while on the two rations.

	Weight at Beginning of Experiment	Weight at End of 1st Period		Weight at End of 2nd Period		Weight at End of 3rd Period	
Rations		I	II	I	II	I	II
Lot I	1200		1207	1220.8			1212.8
Lot II	1215	1218			1205.8	1242.8	

<u>Nitrogen Metabolism</u>

Table XXV shows the feed consumed, milk produced, and feces and urine excreted during the metabolism on ration I.

Table XXVI shows the feed consumed, milk produced, and urine and feces excreted during the metabolism on ration II.

Table XXVII shows the nitrogen composition of feeds consumed, milk produced, and urine and feces excreted during the metabolism on ration I.

Table XXVIII shows the nitrogen composition of feeds consumed, milk produced, and urine and feces excreted during the metabolism on ration II.

Table XXIX is a summary of the metabolism results on the three cows while on each ration.

There were positive nitrogen balances for animals 225, 226, and 229 of 32.17 gms., 18.49 gms., and 24.29 gms. respectively while on the complex ration, and 20.40 gms., 35.27 gms., and 30.57 gms. respectively while on the home-grown ration.

Atmospheric Temperature during the Experiment

Table XXX shows the mean daily temperature during the experiment. Graph I shows the trend of the mean temperature during the experimental periods. There was a close relationship between the mean daily temperature and the amount of water consumed per day.

Frequency of Drinking and Frequency of Urination

Table XXXI shows the frequency of drinking and frequency of urination during the metabolism period. During the seven days on the complex ration the cows drank on the average, 8.23 times each 24 hours and urinated 7.98 times each 24 hours. During seven days on the home-grown ration the cows drank 5.24 times each 24 hours and urinated 6.66 times each 24 hours.

DISCUSSION OF EXPERIMENTAL RESULTS

A simple home-grown ration and a complex ration containing purchased protein were compared by feeding dairy cows that were producing at a high lactation level. The home-grown grain ration consisted of ground oats and alfalfa leaf meal. The complex ration consisted of ground yellow corn, ground oats, wheat bran, cottonseed meal, linseed meal, and bone meal. Oats were used in this experiment because they are grown in practically every section of Michigan. Alfalfa leaf meal was used, because alfalfa is one of the most abundant and one of the cheapest sources of protein obtainable on the average farm. The complex ration used was one that was fed to the herd cows in the College herd. Both of these grain mixtures were supplemented with alfalfa hay, corn silage, and salt.

Two lots of five cows each were used in this experiment. The feeding period lasted 30 days each, and the double reversal system was used. The experiment covered four feeding periods.

During the four feeding periods the home-grown ration produced 304.2 pounds of milk more than did the complex ration, while the complex ration produced 8.98 pounds more fat than did the home-grown ration. These differences probably were not significant.

When the total milk production on each ration was converted to four per cent milk it was found that there was a difference of 13.02 pounds of four per cent milk produced by the 10 cows in favor of the complex ration during the entire feeding period. This difference probably is not significant.

While on the complex ration the cows consumed 278.5 pounds of alfalfa hay and 769.4 pounds of corn silage in excess of the number of pounds consumed while the cows were on the home-grown ration; but consumed 1,144.1 pounds less grain than did the cows while on the home-grown ration.

While the cows were on the complex ration they consumed 108.11 pounds more of digestible crude protein and 39.07 pounds more of total digestible nutrients than they consumed while they were on the home-grown ration. The animals, while on ration I consumed approximately 5 per cent more total protein than while they were on ration II.

Each ration seemed to maintain the animals in body weight and the home-grown ration seemed equal to the complex ration in maintaining the normal health conditions of the animals.

The home-grown ration was not consumed as readily, due in part to palatability and in part to the greater amount of bulk supplied by the alfalfa leaf meal and oats.

Both rations seemed to maintain the cows in very positive nitrogen balances, there being no significant differences between the efficiency of the two rations in this respect.

When the cows were on the home-grown ration they consumed more water than when they were on the complex ration. This may have been caused by the greater amount of alfalfa material in the home-grown ration. Such a conclusion is based on the belief that nitrogenous roughages stimulate thirst to a greater extent than do carbonaceous roughages.

There seemed to be no positive relation between the amount of alfalfa material in the ration and the frequency of drinking or the frequency of urination. No abnormal physiological effects were noticed during the experiment.

The consumption of water while the cows were on this experiment varied directly with the atmospheric temperature.

Due to the high price of the alfalfa leaf meal at the present time, the use of this material as a protein supplement in the ration of the dairy cow would not be economical. The future possibilities of the alfalfa leaf meal as a protein supplement, rather than its present importance was the prevailing idea in conducting this experiment.

Michigan is the largest producer of alfalfa hay of any state east of the Mississippi River. In some sections of the state a surplus of alfalfa hay is produced that has a sales' value of approximately ten dollars per ton. At such a price, if some cheap and efficient method were invented for removing the alfalfa leaves from the stems, the leaves would probably furnish an economical source of protein compared to the prices of some commonly purchased protein concentrates.

Part II.

Feeding Trials with Rats

It was impossible to study the long time effects of the various rations on growth, reproduction and lactation in the dairy cow, during the limited period of time devoted to this problem. In order that some knowledge might be gained of the effects of the various rations on growth, reproduction, and lactation, feeding trials with rats were used to parallel and supplement the work with dairy cows.

In the feeding trials with rats the object was to place animals on a certain diet, and continue the animal on this diet through growth, reproduction, and lactation. It was also planned to carry the offspring of these animals through the same procedure, -- thereby getting the possible residual effects of the rations from generation to generation.

Animals Used

The rats used in this experiment were albinos and piebald, or striped animals. While both breeds were used throughout the experiment care was taken that no crossbred animals were used in any case.

Previous History

Part of the rats used in this experiment were from stock that had been used for several years in the biological chemistry laboratory at Michigan State College. Also, part of the rats were from stock that recently was brought to Michigan State College. Other animals used were offspring resulting from the crossing of the rats from the two sources mentioned.

Age of Animals at Beginning of Experiment

The first animals started on experiment were approximately 28 days of age when they were placed on the experimental diets. The offspring from these animals, when used in the experiment, were usually weaned at 28 days of age and placed on experiment if they had attained sufficient size and vigor to justify their removal from the mother.

Management

Method of Comparison

In making growth comparisons, it was customary to place two animals, a male and a female, from different litters, together. By this method males could be compared with males and females could be compared with females. This method also permitted the placing of litter mates on different rations, so that the effect of nutrition could be studied when heredity was held as nearly constant as possible.

When all females of a litter were placed on the same diet they were usually all confined together.

Cages Used

When lots consisted of only two animals they were placed in circular wire cages about 10 inches in diameter and 12 inches high. These cages had screen bottoms to permit the feces and urine to pass through. Pregnant females were usually isolated in flat bottom maternity cages about 12 inches square, and were bedded with filter paper. Some pregnant females were isolated in cages approximately 12" x 12" x 24". Similar cages were used where more than two animals were placed in one lot. Wood shavings were used for bedding in such cases.

Method of Feeding

Feed was kept before the animals at all times. No attempt was made to measure the amount of food consumed by each animal.

Watering

Water was kept before the animals at all times.

Rations Fed

The check ration used in these feeding trials was composed of the same constituents as the herd ration fed to the College dairy herd, with the exception of corn silage which was omitted. The check ration had the following composition:

Alfalfa meal	20 per cent
Ground yellow corn	28 per cent
Ground rolled oats	26 per cent
Wheat bran	15 per cent
Cottonseed Meal (choice)	4 per cent
Linseed oil meal	5 per cent
Special steamed bone meal	1 per cent
Common salt	1 per cent

This ration will be referred to as B 32.

Ration B 30. This ration was composed of:

Alfalfa meal	20 per cent
Rolled oats	79 per cent
Salt	1 per cent

Later 50 grams of yeast was added to each 1000 grams of this ration.

Ration B 31. This ration was composed of:

Alfalfa meal	20 per cent
Ground yellow corn	59.5 per cent

	Corn gluten meal	19.5 per cent
	Common salt	1.0 per cent

Later 50 grams of yeast was added to each 1000 grams of this ration.

Ration B 45.	Alfalfa meal	20 per cent
	Ground Yellow corn	12 per cent
	Corn gluten meal	22 per cent
	Ground rolled oats	15 per cent
	Ground barley	15 per cent
	Ground wheat	15 per cent
	Common salt	1 per cent
Ration B 46	Alfalfa meal	20.0 per cent
	Ground rolled oats	78.5 per cent
	Cystine	.5 per cent
	Common salt	1.0 per cent
Ration B 47	Alfalfa meal	20.0 per cent
	Ground rolled oats	78.5 per cent
	Tyrosine	.5 per cent
	Common salt	1.0 per cent
Ration B 52	Alfalfa meal	20 per cent
	Ground rolled oats	70 per cent
	Linseed oil meal	5 per cent
	Dextrin	4 per cent
	Common salt	1 per cent

Ration B 68 This ration is composed of B 52 plus one per cent cod liver oil.

Ration B 69 This ration is composed of the original ration B 30 plus one per cent cod liver oil.

Ration B 70 This ration is composed of ration B 30 plus yeast and one per cent cod liver oil.

All the rations fed contained approximately 15 per cent crude protein.

Length of Growing Period

The period during which growth rates were compared was from the time the animals were placed on the diet until the end of the eighth week of the feeding trial.

Mating Age

The females were mated at the end of the eight weeks growing period. In the case where the male and females were permitted together during the growing period, mating occurred before the growing period was completed. This condition occurred in the case of females 117, 118, 119, and 120. The growth weights of these animals were not considered.

COLLECTION OF DATA

Weights

The animals were weighed, in grams, when they were placed on experiment and once each week until they were taken off of the experiment. The litters were weighed as soon as they were cleaned, whenever it was possible to do so. In some cases the young may not have been weighed until 18 hours after birth, due to the fact that the animals were cared for only once each day. All animals of a litter were weighed together until they were 28 days of age.

Growth

Growth weights were recorded, in grams, every seven days, for both old and young stock.

Length of Time from Mating to Parturition

The length of time from mating to pregnancy was observed in most cases.

Birth Weights of Young Animals

The birth weights of young animals were recorded in all but a few of the first litters born.

Size of Litters

The number of young born was recorded in every case. In cases where more than seven were born in a single litter the number was reduced to seven.

Mortality among Young Rats

The mortality among the animals was checked on each weighing day; the number of live animals being recorded for weight averages.

EXPERIMENTAL RESULTS

Animals Included in Experimental Results

Data were recorded on both males and females until they were 28 days of age. Due, however, to the fact that this experiment dealt primarily with growth, reproduction, and lactation, the male animals were not considered after they were 28 days of age, when compiling the experimental results. Growth table XXXII shows the weekly weights, the total gain of each animal and the average weight of the animals on each ration during the eight weeks growing period.

The following is a summary of the growth made by the rats on the various rations.

Ration	No. of Animals	Average Initial Weight	Average Total Gain	Ratio of Initial Weight to Average Total Gain
B 32	13	49.77	89.69	1:1.80
B 30	9	51.00	72.55	1:1.42
B 30 plus yeast	3	53.00	74.33	1:1.40
B 31	5	52.80	66.60	1:1.26
B 31 plus yeast	3	49.33	76.00	1:1.54
B 45	3	44.33	99.33	1:2.24
B 46	1	64.00	71.00	1:1.11
B 47	4	61.25	81.00	1:1.32
B 52	1	59.00	95.00	1:1.61
B 68	1	43.00	82.00	1:1.91
B 69	2	51.00	84.00	1:1.65
B 70	2	50.00	112.50	1:2.25

The summary reveals the fact that ration B 70, composed of alfalfa, rolled oats, yeast, and cod liver oil, made the greatest gain, 112.50 grams. B 45, a complex cereal mixture plus alfalfa was second with a gain of 99.33 grams, and B 52 composed of alfalfa, rolled oats, and oil meal, was third with a gain of 95 grams. Ration B 32, the check ration, was fourth. Too much significance cannot be attached to these comparisons, however, because of the small number of animals on the three rations making the highest gains. The oats and alfalfa ration (B 30) and the corn and alfalfa ration (B 31) ranked decidedly lower than the check ration (B 32). The oats and alfalfa ration (B 30) produced a total gain of 71.75 grams, while the same ration with the addition of yeast produced a total gain of 75.50 grams. The corn and alfalfa ration (B 31) produced a total gain of 66.60 grams, while the same ration with the addition of yeast produced a gain of 76.00 grams.

From the standpoint of the ratio of average initial weight to the average total gain ration B 70 ranked first with a ratio of 1:2.25, ration B 45 ranked second with a ratio of 1:2.24, ration B 68 ranked third with a ratio of 1:1.91, and ration B 32 ranked fourth with a ratio of 1:1.80.

The oats and alfalfa ration (B 30) had a ratio of 1:1.46 while the same ration with the addition of yeast had a ratio of 1:1.35. The corn and alfalfa ration (B 31) had a ratio of 1:1.26, while the same ration with the addition of yeast had a ratio of 1:1.54.

<u>Length of Time from Mating to Parturition</u>

The length of time from mating to parturition for animals on which this information was tabulated is shown in Table XXXIII. In many cases records were available for only one mating period, while in other cases the data were available for two mating periods. The following summary shows the average length in days from mating to parturition for each ration. The number of non breeders, the known resorption of embryos, and probable resorption of embryos are shown.

Ration	No. of Animals	No. Parturitions	Av. Length of Mating Periods days	No. Resorptions	No. Probable Resorptions	No. Non Breeders	Rank Shortest to Longest Time
B 32	17	16	31.9	-	1	3	5
B 30	6	5	49.2	1	-	-	10
B 30 plus yeast	5	8	31.9	-	-	-	4
B 31	2	2	46.5	-	-	-	9
B 31 plus yeast	6	10	28.3	-	-	1	1
B 45	3	4	29.5	-	-	-	2
B 46	1	1	35.0	-	-	-	6
B 47	3	3	31.3	-	-	-	3
B 52	1	2	43.5	-	-	-	8
B 68	1	no litter at end of 57 days					12
B 69	1	1	57.0	-	-	-	11
B 70	2	2	37.0	-	-	-	7

The summary shows that the corn, alfalfa and yeast ration (B 31 plus yeast) required the shortest mating period - 28.3 days. The complex cereal ration (B 45) ranked second with 29.5 days. The ration composed of oats, alfalfa and tyrosine (B 47) ranked third. The oats, alfalfa and yeast ration (B 30 plus yeast) and the check ration (B 32) were equal, with 31.9 days. The oats and alfalfa ration (B 30) required an average of 49.2 days and the corn, alfalfa ration (B 31) required 46.5 days from mating date to parturition. The normal gestation period of the rat is 21 days.

Size of Litter, Birth Weights, and Mortality of Young Rats to 28 Days of Age

The size of litters, birth weights, and mortality of young rats to 28 days of age are shown in table XXXIV. The animals are listed according to the rations on which the mothers were fed. The average weights of the young animals at 28 days of age are also given. The following is a summary of the size of litters, birth weights, weight at 28 days of age, and total mortality to 28 days of age for the litters on the various rations.

Ration	Av. No. in Litter	Av. Birth Weight gms.	Av. Wt. at 28 days gms.	Total Mortality	Percentage Mortality
B 32	(12) 6.42	(12) 6.54	(14) 34.76	7	0.91
B 30	(2) 5.50	(1) 8.00	-	1	.91
B 30 plus yeast	(12) 6.42	(12) 5.51	(6) 28.21	50	64.93
B 31	(2) 7.00	(2) 5.57	(2) 26.52	3	21.42
B 31 plus yeast	(9) 6.22	(9) 5.92	(7) 33.65	16	28.57
B 45	(4) 6.00	(4) 5.70	(3) 33.83	7	29.17
B 46	(1) 6.00	(1) 5.83	(1) 34.17	0	.00
B 47	(4) 5.25	(4) 6.16	(2) 32.91	13	61.90
B 52	(2) 7.00	(2) 5.52	(2) 32.12	1	14.28
B 68	no litters				
B 69	(1) 7.00	5.12	not 28 days old		
B 70	(2) 7.00	(2) 5.93	(1) 35.80	2	14.28

While the data are not complete the summary gives a fairly good indication of the results obtained on the various rations. The numbers in parentheses in the summary indicate the number of litters included in that particular part of the data.

Of the rations on which more than two litters were reared, the check ration produced equally as large litters, greater weight at 28 days of age, and much lower mortality.

DISCUSSION OF EXPERIMENTAL RESULTS

In feeding trials with rats several simplified rations were compared to a complex ration, having the same constituents as the ration fed to the College dairy herd, except that corn silage was omitted.

The simplified rations given most consideration were those composed of ground rolled oats and alfalfa meal, and ground yellow corn and alfalfa meal. Other modifications of these two rations were also studied.

Young rats were started on the various rations at approximately 28 days of age. The first eight weeks following were considered the growing period, and at the completion of this growing period the females were mated. Female offspring were continued on the same diets their mothers received. Observations were taken on the growth, weight, length of time from mating to parturition, number of young in litters, average birth weight of young, weight of young rats at 28 days of age, and mortality among the young rats from birth to 28 days of age.

The ration composed of alfalfa, corn, oats, wheat and barley (B 45) and the ration composed of alfalfa, oats, yeast and cod liver oil (B 70) produced greater growth than the check ration (B 32). The rations of alfalfa and oats, and alfalfa and corn did not produce satisfactory growth. The alfalfa and oats and the alfalfa and corn rations were not favorable for reproduction. The addition of yeast to these two rations materially shortened the length of time from mating to parturition.

The check ration gave the least mortality of any ration where more than one litter was produced. The alfalfa and oats, and alfalfa and corn ration, produced a high rate of mortality among the nursing young rats.

In the case of oats, alfalfa and yeast the mortality among the young rats up to 28 days of age was 64.93 per cent in the 12 litters.

Supplementing rations B 32, B 30, and B 30 plus yeast with cod liver oil did not show any improvement.

The complex cereal mixture (B 45) and the alfalfa, oats, and linseed oil meal rations seemed to be a fairly satisfactory ration, though indications were based on a small number of animals studied.

All of the experimental rations that were studied by the use of a reasonably large number of animals seemed to be deficient in some principal that is conducive to heavy lactation. The critical period in the life of the rat seemed to be the first 28 days of its life, or while it was nursing. The fact that in most cases a part of each litter was reared to weaning age would seem to indicate that the milk which was secreted was of sufficient quantity to sustain life and promote satisfactory growth in young rats.

The reason for the failure of the experimental rations to stimulate normal lactation was not determined. The cause of the failure may have been due to deficiencies in the protein content, the vitamin content or the mineral content of the ration. Further study along these three phases of the problem would probably bring out some very interesting facts.

CONCLUSIONS

Part I.

1. A simple home-grown ration composed of ground oats, alfalfa leaf meal, alfalfa hay, and corn silage was practically as efficient for milk and butterfat production as a complex ration containing purchased protein during four 30-day feeding periods.

2. The simple home-grown ration maintained the body weights of the cows during the experiment as satisfactorily as did the complex ration.

3. The simple home-grown ration did not seem as palatable as the complex ration.

4. The simple home-grown ration maintained three of the cows on positive nitrogen balance, equally as efficient as did the complex ration.

5. The consumption of the home-grown ration caused an increased consumption of water. This may have been due to the large quantity of alfalfa in the form of hay and leaf meal in this ration as compared to the complex ration.

6. Atmospheric temperature seemed to have a positive effect on water consumption.

7. The simple home-grown ration seemed to produce no abnormal physiological effects.

Part II.

1. When fed to growing rats, simplified rations, did not produce growth equal to that produced by the complex check ration.

2. Simple rations composed of alfalfa and oats and alfalfa meal and corn were not satisfactory for reproductive processes. The addition of yeast to these rations gave very satisfactory results.

3. Lactating females fed simplified rations apparently were not able to secrete enough milk to grow out the yohng to a satisfactory weight.

4. Especially high mortality resulted among young rats whose mothers were on the alfalfa, oats and yeast diets.

5. The addition of vitamins A and D in the form of cod liver oil, the apparently only possible vitamin deficiencies, did not correct the deficiencies in lactation shown by the females while on the simplified rations.

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A P P E N D I X

Table I. Showing Animals Used in the Experiment

Lot I.

Animal No.	Breed	Age	Weight	Days in Milk	Days in Pregnancy	Daily Milk Yield lbs.	Per cent Butterfat in Milk
168	Purebred Holstein	3-6-18	1388	117	0	55.7	3.4
187	" "	3-7-21	1280	40	0	63.4	3.1
229	" "	3-6-28	1200	88	0	44.5	3.2
225	" "	5-2-18	1125	161	0	48.3	3.4
226	" "	5-2-16	1008	118	0	54.6	3.3
Average		4-2-24	1200	105	0	53.3	3.27

Lot II.

Animal No.	Breed	Age	Weight	Days in Milk	Days in Pregnancy	Daily Milk Yield lbs.	Per cent Butterfat in Milk
232	Purebred Holstein	3-4-0	1100	114	20	48.4	3.0
230	" "	3-6-22	1075	184	83	38.7	3.5
189	Purebred Brown Swiss	5-5-5	1250	45	0	48.1	4.1
174	Purebred Holstein	5-9-27	1150	37	0	56.6	3.0
150	" "	7-1-21	1500	48	0	67.6	3.5
Average		5-0-0	1215	86	20	51.9	3.41

Table II. Showing Grain Rations Fed

Ration I (Complex ration)

		Digestible Crude Protein	Total Digestible Nutrients
Ground yellow corn	400 pounds	27.23	326.8
Ground oats	250 "	19.62	176.0
Wheat bran	150 "	18.75	91.4
Cottonseed meal	100 "	37.00	78.2
Linseed oil meal	100 "	30.20	77.9
Common salt	10 "		
Steamed bone meal	10 "		
Average percentage		13.28	75.00
Ration II (home-grown ration)			
Alfalfa leaf meal	300 pounds	45.33	180.00
Ground oats	480 "	37.68	326.40
Ground rolled oats	220 "	28.16	183.04
Common salt	10 "		
Average percentage		11.1	68.94
Estimated per cent total digestible nutrients due to poor quality of oats			65.00

Table III. Showing Milk Production during First Period

	Lot I. (complex ration)						Lot II. (home-grown ration)					
Cow No.	226	225	229	187	168	Daily Total	232	250	189	174	150	Daily Total
1929												
Mar. 25	49.9	43.2	43.9	65.5	54.5	257.0	46.0	34.9	49.0	60.9	67.5	258.3
26	50.3	47.2	45.6	61.9	49.9	254.9	43.7	33.5	46.8	59.3	62.1	245.4
27	50.0	43.2	42.7	62.8	50.4	249.1	45.2	33.6	47.3	58.5	59.4	244.0
28	52.1	44.1	40.4	61.8	50.0	248.4	44.9	34.6	51.6	57.9	56.1	245.1
29	51.7	44.1	43.6	60.9	49.9	250.2	45.1	34.0	50.0	56.4	59.9	245.4
30	51.4	45.6	44.1	63.5	50.9	255.5	46.8	35.9	48.9	52.6	60.5	244.7
31	51.5	43.5	42.6	60.8	51.4	249.8	46.6	35.9	49.4	51.2	66.0	249.1
Apr. 1	50.8	43.5	41.8	60.6	48.9	245.6	46.7	35.8	48.9	50.6	64.9	246.9
2	51.8	45.4	40.3	62.0	52.2	251.7	49.7	37.8	50.2	54.1	62.5	254.3
3	51.5	46.2	40.4	59.3	52.0	249.4	49.0	36.3	49.0	56.3	64.7	255.3
4	54.6	46.6	37.3	61.3	52.0	251.8	49.8	38.3	47.2	58.5	55.6	249.4
5	53.4	45.5	39.7	59.8	54.7	253.1	51.9	39.6	51.5	55.9	35.0	233.9
6	52.4	46.6	41.9	64.2	53.7	258.8	51.9	38.8	51.9	55.5	54.9	253.0
7	49.0	46.3	43.4	60.9	52.6	252.2	53.3	41.5	51.4	52.7	60.1	259.0
8	51.7	45.8	43.0	57.6	52.0	250.1	52.9	40.5	49.1	52.7	61.2	256.4
9	54.7	45.4	44.8	57.9	51.4	254.2	51.9	39.8	48.4	52.3	64.5	256.9
10	52.7	46.4	44.1	60.6	51.7	255.5	53.3	38.8	48.9	51.0	64.4	256.4
11	52.2	47.1	42.3	57.8	53.7	253.1	52.6	38.8	47.8	48.1	63.8	251.1
12	52.5	45.3	40.3	61.2	48.8	248.1	50.8	39.0	48.8	48.2	60.7	247.5
13	55.9	46.4	43.3	60.8	52.9	259.3	52.0	41.7	46.4	49.4	61.0	250.5
14	44.4	47.5	39.5	61.0	54.6	247.0	50.2	39.1	50.6	51.2	61.2	252.3
15	50.9	45.2	42.1	58.6	53.1	249.9	48.1	38.1	45.6	50.7	60.2	242.7
16	54.2	46.2	41.9	63.0	55.2	260.5	53.3	40.6	47.3	53.4	60.8	255.4
17	49.8	45.6	42.8	61.0	55.7	254.9	52.6	39.0	47.0	53.7	60.0	252.3
18	53.2	46.1	40.0	59.1	53.4	251.8	51.6	37.5	48.1	49.5	63.2	249.9
19	54.0	44.5	41.1	61.6	51.5	252.7	48.7	39.8	44.9	53.4	62.9	249.7
20	54.1	44.9	41.6	60.9	54.3	255.8	48.9	36.6	49.6	52.9	62.1	250.1
21	52.9	44.4	40.1	60.0	50.2	247.6	50.4	38.2	44.3	54.4	62.1	249.4
22	51.5	44.0	39.9	59.7	53.7	248.8	48.7	37.5	45.7	55.3	66.6	253.8
23	53.8	44.2	41.4	58.6	51.9	249.9	49.4	36.2	45.2	53.7	64.3	248.8
Totals						7566.7						7507.0

Table IV. Showing Milk Production during Second Period

	Lot I. (home-grown ration)						Lot II. (complex ration)					
Cow No.	226	225	229	187	168	Daily Total	252	250	189	174	150	Daily Total
1929												
Apr. 24	55.4	45.3	42.6	55.2	49.8	246.3	47.9	38.6	44.9	54.0	60.7	246.1
25	50.4	44.1	42.1	51.9	52.0	240.5	48.4	38.0	44.8	52.2	65.1	246.5
26	47.4	44.7	42.7	51.6	48.6	235.0	54.0	37.8	45.4	55.8	65.2	254.2
27	57.4	46.0	45.5	59.9	58.3	267.1	51.3	39.6	48.8	51.8	61.9	253.4
28	52.9	42.4	42.6	59.4	50.5	247.8	48.8	35.3	42.7	53.9	60.0	240.6
29	53.6	44.3	42.2	60.2	51.0	251.3	49.4	38.7	47.2	52.3	64.8	252.4
30	51.9	41.5	39.8	55.8	50.0	239.0	46.8	35.4	44.7	52.5	60.9	240.3
May 1	49.6	42.6	41.7	61.0	54.3	249.2	45.0	39.2	44.2	53.2	63.5	245.1
2	55.0	46.2	39.6	62.2	52.6	255.6	47.8	35.9	45.7	51.5	58.4	259.3
3	54.4	41.5	41.8	58.1	50.1	245.9	47.2	36.0	44.8	50.0	61.0	239.0
4	53.5	42.8	40.3	58.5	54.4	249.5	46.2	35.8	46.2	49.3	63.2	240.7
5	37.9	42.2	38.6	58.1	48.4	225.2	47.4	34.2	44.5	48.7	59.9	234.7
6	47.3	41.1	41.5	59.6	55.1	244.6	45.1	37.6	43.7	48.7	61.4	236.5
7	42.9	43.3	39.6	59.0	51.5	236.3	47.1	35.8	43.7	47.0	60.7	234.3
8	52.6	45.3	39.9	62.5	54.1	254.4	45.7	36.3	44.2	49.6	61.9	237.7
9	48.2	45.8	40.7	60.8	52.4	247.9	46.0	34.8	43.4	46.3	71.4	241.9
10	51.7	44.0	40.6	60.8	53.0	250.1	48.0	34.4	43.2	50.4	59.1	235.1
11	42.5	40.2	40.7	58.3	51.0	232.7	47.9	34.7	43.1	50.8	57.5	234.0
12	53.0	43.4	42.8	60.9	53.2	253.3	46.5	34.6	44.3	51.5	58.2	235.0
13	46.2	41.7	41.8	58.0	53.2	240.9	49.5	36.4	41.0	49.7	58.9	235.5
14	49.8	42.9	41.6	56.7	52.1	243.1	47.6	33.5	43.7	50.7	56.5	232.0
15	50.0	41.0	38.4	58.1	49.6	237.1	46.2	30.4	41.1	48.5	52.9	219.1
16	47.5	39.4	39.6	53.2	47.2	226.9	48.4	34.3	43.3	48.9	63.8	238.7
17	49.0	41.1	39.4	56.9	50.7	237.1	46.5	34.4	43.7	48.6	56.1	229.3
18	53.2	42.3	44.9	52.5	52.8	245.7	48.9	30.5	45.6	51.4	64.3	238.7
19	49.1	37.0	39.8	52.0	50.6	228.5	46.3	35.8	43.3	48.1	55.3	228.8
20	48.0	39.8	39.8	53.2	53.0	233.8	45.6	33.2	45.9	50.6	56.8	230.1
21	48.5	39.8	43.4	53.9	53.3	238.9	44.6	32.4	42.4	50.1	57.5	227.0
22	48.5	39.7	42.8	54.6	50.5	236.1	45.4	33.2	45.1	48.2	59.9	231.8
23	50.6	39.8	40.8	52.9	51.6	235.7	44.8	33.0	40.1	45.4	56.2	219.5
Totals						7275.5						7117.3

Table V. Showing Milk Production during Third Period

	Lot I. (complex ration)						Lot II. (home-grown ration)					
Cow No.	226	225	229	187	168	Daily Total	232	230	189	174	150	Daily Total
1929												
May 24	48.2	40.2	39.0	54.0	49.3	230.7	41.5	33.6	42.1	47.9	56.8	221.9
25	49.2	39.6	39.9	52.7	52.1	233.5	43.6	33.4	42.4	46.8	58.7	224.9
26	46.6	38.7	40.5	57.9	49.6	233.3	42.8	29.2	42.9	44.0	56.1	215.0
27	54.4	39.8	41.7	48.5	52.3	236.7	44.0	28.8	41.4	41.5	60.4	216.1
28	44.3	38.8	38.6	55.6	51.9	229.2	45.0	32.7	44.1	47.1	58.1	227.0
29	47.2	38.3	45.0	56.7	50.9	238.1	42.8	29.0	45.8	47.1	57.9	222.6
30	44.0	38.7	41.6	55.0	48.7	228.0	46.1	31.8	43.2	49.3	59.5	229.9
31	44.5	38.7	42.2	57.3	46.8	229.5	44.7	30.1	41.0	43.8	52.4	212.0
June 1	46.6	37.0	40.8	49.5	51.7	225.6	45.8	28.5	42.5	47.9	57.5	222.2
2	47.8	36.9	43.0	55.3	49.1	232.1	44.7	28.2	41.9	47.2	51.9	213.9
3	50.5	37.4	38.1	53.5	48.3	227.8	45.7	29.4	42.1	48.7	52.0	217.9
4	48.8	38.9	38.6	54.2	50.1	230.6	44.1	26.8	43.0	49.0	53.2	216.1
5	49.7	37.4	39.1	53.5	48.6	228.3	44.7	29.9	42.5	48.6	58.9	224.6
6	49.3	39.2	43.3	52.3	51.7	235.8	43.1	27.1	39.9	46.5	53.1	209.7
7	45.1	39.5	35.3	47.3	50.7	217.9	42.5	29.8	42.9	47.2	58.9	221.3
8	48.5	39.6	38.3	41.4	46.1	213.9	43.7	24.0	41.4	48.1	57.7	214.9
9	48.7	38.5	37.2	45.1	47.1	216.6	47.5	27.2	40.9	46.7	50.3	212.6
10	48.0	38.9	40.5	45.8	47.8	221.0	45.0	27.2	43.3	46.2	57.8	219.5
11	47.4	37.2	39.0	43.0	47.0	213.6	42.8	26.9	41.8	44.1	60.2	215.8
12	47.9	39.1	40.0	50.7	48.8	226.5	42.4	26.1	42.1	48.0	55.3	213.9
13	45.4	37.7	35.9	48.0	49.6	216.6	44.5	24.5	42.5	46.0	57.4	214.9
14	51.0	37.9	39.8	49.3	47.7	225.7	43.4	20.8	41.3	47.5	58.9	211.9
15	49.5	38.3	39.4	46.1	50.0	223.3	43.1	26.2	46.3	47.2	55.6	218.4
16	57.0	38.3	36.4	51.7	48.3	231.7	44.9	22.1	39.5	47.0	54.8	208.3
17	51.8	37.4	37.9	51.0	48.8	226.9	46.5	26.3	41.2	46.9	58.5	219.4
18	47.9	38.1	37.7	50.4	47.7	221.8	46.3	27.1	39.4	44.8	58.8	216.4
19	48.7	37.9	40.0	47.3	43.8	217.7	46.7	23.8	40.2	45.2	55.6	211.5
20	42.4	37.4	39.4	48.6	46.3	214.1	44.7	25.4	36.1	46.5	54.5	207.2
21	42.0	36.2	38.4	50.9	44.8	212.3	45.7	25.5	39.8	43.4	54.5	208.9
22	48.0	34.6	40.0	45.7	44.8	213.1	44.0	19.3	42.7	44.9	55.2	206.1
Totals						6751.9						6494.8

Table VI. Showing Milk Production during Fourth Period

Cow No.	226	225	229	187	168	Daily Total	252	230	189	174	150	Daily Total
	Lot I. (home-grown ration)						Lot II. (complex ration)					
1929												
June 23	46.2	35.2	38.2	40.9	47.0	207.5	45.9	24.8	40.8	41.3	57.3	208.1
24	46.1	33.2	36.3	34.6	42.2	192.4	44.3	21.5	35.5	44.7	57.0	203.0
25	39.8	34.1	35.0	40.8	40.9	190.6	42.7	18.9	37.2	43.6	56.2	198.6
26	45.3	32.5	35.7	32.9	43.6	190.0	41.2	19.6	35.2	42.3	55.1	193.4
27	44.9	32.6	36.9	41.7	45.3	201.4	42.2	18.9	34.4	40.5	52.2	188.2
28	43.0	34.6	35.2	35.8	44.6	193.2	43.1	19.5	33.2	42.7	51.0	189.5
29	38.3	32.9	35.3	35.6	45.3	187.4	42.7	22.2	35.3	37.7	52.8	190.7
30	51.1	35.5	38.2	44.5	46.8	216.1	46.4	21.2	37.3	46.9	56.3	208.1
July 1	41.4	29.6	35.2	39.8	40.0	186.0	39.8	19.2	31.8	40.5	46.5	177.8
2	43.3	31.8	37.4	41.1	43.8	197.4	40.0	19.4	34.0	42.1	59.4	194.9
3	39.6	31.9	37.3	39.2	44.5	192.5	42.4	17.3	32.7	41.6	52.3	186.3
4	39.7	32.5	38.4	39.5	43.4	193.5	43.0	18.3	36.5	40.4	53.7	191.9
5	32.4	33.9	39.5	42.1	42.5	190.4	42.4	18.7	43.5	39.6	52.5	196.7
6	41.4	31.9	37.0	38.1	43.9	192.3	41.4	14.1	34.2	37.8	55.5	183.0
7	42.2	32.1	35.1	38.5	43.7	191.6	45.8	16.9	36.9	38.0	54.3	191.9
8	41.7	35.3	37.9	40.4	41.9	197.2	42.1	15.7	31.9	41.0	54.6	185.3
9	44.9	31.6	37.2	39.4	42.5	195.6	40.5	16.3	34.8	38.2	49.9	179.7
10	38.2	31.3	37.0	35.6	42.6	184.7	43.3	22.4	36.9	45.2	47.4	195.2
11	47.5	35.1	38.4	45.0	43.1	209.1	42.2	15.5	33.0	40.8	44.5	176.0
12	43.6	33.3	37.7	41.2	42.7	198.5	40.5	13.9	33.3	38.5	53.1	179.3
13	44.2	33.4	37.3	40.9	41.8	197.6	42.4	15.0	33.0	39.6	46.7	176.7
14	43.5	30.7	36.0	44.4	40.4	195.0	40.1	13.2	29.9	35.5	51.7	170.4
15	40.7	31.4	37.6	40.3	40.1	190.1	40.1	6.4	30.3	38.5	51.1	166.4
16	45.0	33.6	37.2	42.1	41.5	199.4	41.4	3.6	29.6	39.1	50.2	163.9
17	39.1	28.0	34.4	37.1	42.3	180.9	39.5	1.6	30.3	39.6	48.5	159.5
18	43.5	30.9	34.6	41.5	40.7	191.2	39.6	0	30.6	36.6	48.8	155.6
19	40.3	29.5	32.4	41.9	37.3	181.4	40.2	0	33.2	40.0	45.7	159.1
20	45.1	32.5	34.3	43.1	38.8	195.8	40.0	0.2	31.0	39.2	48.6	159.0
21	39.4	31.0	35.8	40.7	40.1	187.0	38.7	1.0	30.7	36.9	49.7	157.0
22	45.6	29.2	34.4	36.9	39.6	185.7	36.3	10.0	29.1	36.8	49.3	161.5
Totals						5809.5						5446.7

Table VII-a. Milk Production during each Feeding Period

Lot I.

Period	Cow 226	Cow 225	Cow 229	Cow 187	Cow 168	Total
I.	1558.9	1560.0	1255.9	1824.7	1567.2	7566.7
II.	1498.0	1269.2	1237.6	1715.8	1554.9	7275.5
III.	1440.4	1146.2	1186.6	1518.3	1460.4	6751.9
IV.	1277.0	971.1	1092.9	1195.6	1272.9	5809.5

Table VII-b.

Lot II.

Period	Cow 232	Cow 230	Cow 189	Cow 174	Cow 150	Total
I.	1486.0	1131.7	1450.8	1610.3	1828.2	7507.0
II.	1420.3	1059.8	1320.6	1507.6	1809.0	7117.3
III.	1332.3	820.7	1256.2	1395.1	1690.5	6494.8
IV.	1248.2	425.3	1016.1	1205.2	1551.9	5446.7

Table VIII-a. Milk Production during each Period on the Complex (R 1) Ration

Lot I.

Period	Cow 226	Cow 225	Cow 229	Cow 187	Cow 168	Total
I.	1558.9	1360.0	1255.9	1824.7	1567.2	7566.7
II.						
III.	1440.4	1146.2	1186.6	1518.3	1460.4	6751.9
IV.						

Table VIII-b.

Lot II.

Period	Cow 232	Cow 230	Cow 189	Cow 174	Cow 150	Total
I.						
II.	1420.3	1059.8	1320.6	1507.6	1809.0	7117.3
III.						
IV.	1248.2	425.3	1016.1	1205.2	1551.9	5446.7
Total						26,882.6

Table IX-a. Milk Production during each Period on the Home-Grown (R 2) Ration

Lot I.

Period	Cow 225	Cow 226	Cow 229	Cow 187	Cow 168	Total
I.						
II.	1498.0	1269.2	1237.6	1715.8	1554.9	7275.5
III.						
IV.	1277.0	971.1	1092.9	1195.6	1272.9	5809.5

Table IX-b.

Lot II.

Period	Cow 252	Cow 230	Cow 189	Cow 174	Cow 150	Total
I.	1486.0	1151.7	1450.8	1610.3	1828.2	7507.0
II.						
III.	1332.5	820.7	1256.2	1595.1	1690.5	6494.8
IV.						
Total						27,186.8

Table X. Butterfat Production during each Feeding Period

	Lot I.						Lot II.					
Period	Cow 226	Cow 225	Cow 229	Cow 187	Cow 168	Total	Cow 232	Cow 230	Cow 189	Cow 174	Cow 150	Total
I.	48.33	43.11	41.08	55.29	50.93	238.74	41.16	37.35	49.76	37.04	52.47	217.78
II.	49.45	43.15	39.97	51.99	56.44	240.98	40.76	36.78	54.51	44.17	55.17	231.29
III.	46.52	37.82	40.70	44.05	46.73	215.80	41.30	34.47	43.09	36.69	57.48	213.03
IV.	37.03	33.31	37.16	34.67	38.19	180.36	40.57	13.40	34.55	37.12	49.66	175.30

Table XI. Butterfat Produced on Complex (No. 1) Ration

I.	48.33	43.11	41.08	55.29	50.93	238.74						
II.							40.76	36.78	54.41	44.17	55.17	231.29
III.	46.52	37.82	40.70	44.05	46.73	215.80						
IV.							40.57	13.40	34.55	37.12	49.66	175.30

Table XII. Butterfat Produced on Home-Grown (No. 2) Ration

I.							41.16	37.35	49.76	37.04	52.47	217.78
II.	49.43	43.15	39.97	51.99	56.44	240.98						
III.							41.30	34.47	43.09	36.69	57.48	213.03
IV.	37.03	33.31	37.16	34.67	38.19	180.36						

Table XIII. Total Feed Consumption

Cow No.	Kind of Feed	Period I	Period II	Period III	Period IV
		Lot I.			
		lbs.	lbs.	lbs.	lbs.
226	Hay	276.1	278.5	298.5	293.7
	Silage	900.0	900.0	900.0	900.0
	Grain	600.0	580.6	495.0	536.2
225	Hay	344.0	344.4	341.5	343.9
	Silage	990.0	900.0	990.0	990.0
	Grain	480.0	480.0	390.0	390.0
229	Hay	355.1	360.0	359.0	358.9
	Silage	1080.0	1080.0	1080.0	1080.0
	Grain	420.0	390.0	390.0	404.0
187	Hay	361.0	317.9	342.0	307.9
	Silage	1140.0	1118.1	1137.8	795.6
	Grain	615.0	656.9	524.0	424.1
168	Hay	417.5	403.9	399.5	412.5
	Silage	1200.0	1215.0	1212.1	1260.0
	Grain	555.0	585.0	510.0	470.0
		Lot II.			
232	Hay	327.0	330.0	326.5	345.0
	Silage	990.0	990.0	985.0	990.0
	Grain	538.2	420.0	475.5	390.0
230	Hay	327.7	328.3	329.0	278.0
	Silage	960.0	945.0	945.0	769.5
	Grain	435.0	360.0	360.0	224.8
189	Hay	342.1	385.8	373.5	388.0
	Silage	1049.8	1080.0	1080.0	1078.0
	Grain	568.1	420.0	479.0	343.0
174	Hay	299.1	342.8	335.2	358.5
	Silage	985.0	1035.0	1034.0	1035.0
	Grain	631.5	480.0	524.0	375.0
150	Hay	341.4	422.4	419.9	448.5
	Silage	912.5	1350.0	1305.0	1350.0
	Grain	673.5	555.0	584.5	495.0

Table XIV. Feed Consumption on Ration I

Lot I.

Cow No.	Kind of Feed	Period I	Period II	Period III	Period IV	Total
		lbs.	lbs.	lbs.	lbs.	
226	Hay	276.1		298.5		574.6
	Silage	900.0		900.0		1800.0
	Grain	600.0		495.0		1095.0
225	Hay	344.0		341.5		685.5
	Silage	990.0		990.0		1980.0
	Grain	480.0		390.0		870.0
229	Hay	355.1		359.0		714.1
	Silage	1080.0		1080.0		2160.0
	Grain	420.0		390.0		810.0
187	Hay	361.0		342.0		703.0
	Silage	1140.0		1137.8		2277.8
	Grain	615.0		524.0		1139.0
168	Hay	417.5		399.5		817.0
	Silage	1200.0		1212.1		2412.1
	Grain	555.0		510.0		1065.0

Lot II.

Cow No.	Kind of Feed	Period I	Period II	Period III	Period IV	Total
232	Hay		330.0		345.0	675.0
	Silage		990.0		990.0	1980.0
	Grain		420.0		390.0	810.0
230	Hay		328.3		278.0	606.3
	Silage		945.0		769.5	1714.5
	Grain		360.0		224.8	584.8
189	Hay		385.8		388.0	773.8
	Silage		1080.0		1078.0	2158.0
	Grain		420.0		343.0	763.0
174	Hay		342.8		358.5	701.3
	Silage		1035.0		1035.0	2070.0
	Grain		480.0		375.0	855.0
150	Hay		422.4		448.5	870.9
	Silage		1350.0		1350.0	2700.0
	Grain		555.0		495.0	1050.0

Table XV. Feed Consumption on Ration II

Lot I.

Cow No.	Kind of Feed	Period I	Period II	Period III	Period IV	Total
		LBS.	lbs.	lbs.	lbs.	
226	Hay		278.5		293.7	572.2
	Silage		900.0		900.0	1800.0
	Grain		580.6		536.2	1116.8
225	Hay		344.4		343.9	688.3
	Silage		900.0		990.0	1890.0
	Grain		480.0		390.0	870.0
229	Hay		360.0		358.9	718.9
	Silage		1080.0		1080.0	2160.0
	Grain		390.0		404.0	794.0
187	Hay		317.9		307.9	625.8
	Silage		1118.1		795.6	1913.7
	Grain		656.9		424.1	1081.0
168	Hay		403.9		412.5	816.4
	Silage		1215.0		1260.0	2475.0
	Grain		585.0		470.0	1055.0

Lot II.

Cow No.	Kind of Feed	Period I	Period II	Period III	Period IV	Total
232	Hay	327.0		326.5		653.5
	Silage	990.0		985.0		1975.0
	Grain	538.2		475.5		1013.7
230	Hay	327.7		329.0		656.7
	Silage	960.0		945.0		1905.0
	Grain	435.0		360.0		795.0
189	Hay	342.1		373.5		715.6
	Silage	1049.8		1080.0		2129.8
	Grain	568.1		479.0		1047.1
174	Hay	299.1		335.2		634.3
	Silage	983.0		1034.0		2017.0
	Grain	631.3		524.0		1155.3
150	Hay	341.4		419.9		761.3
	Silage	912.5		1305.0		2217.5
	Grain	673.5		584.5		1258.0

Table XVI. Summary of Hay, Silage and Grain Consumed while on Ration I (complex ration)

Cow No.	Hay	Silage	Grain
226	574.6 lbs.	1800.0 lbs.	1095.0 lbs.
225	685.5	1980.0	870.0
229	714.1	2160.0	810.0
187	703.0	2277.8	1139.0
168	817.0	2412.1	1065.0
232	675.0	1980.0	810.0
230	606.5	1714.5	584.8
189	773.8	2158.0	763.0
174	701.3	2070.0	855.0
150	870.9	2700.0	1050.0
Total	7,121.5	21,252.4	9,041.8

Table XVII. Summary of Hay, Silage and Grain Consumed while on Ration II (home-grown ration)

Cow No.	Hay	Silage	Grain
226	572.2 lbs.	1800.0 lbs.	1116.8 lbs.
225	688.3	1890.0	870.0
229	718.9	2160.0	794.0
187	625.8	1913.7	1081.0
168	816.4	2475.0	1055.0
232	653.5	1975.0	1013.7
230	656.7	1905.0	795.0
189	715.6	2129.8	1047.1
174	634.3	2017.0	1155.3
150	761.3	2217.5	1258.0
Total	6,843.0	20,483.0	10,185.9

Table XVIII. Water Consumption in Gallons during First Period

	Lot I. (complex ration)						Lot II. (home-grown ration)					
Cow No.	226	225	229	187	168	Total Gallons	252	230	189	174	150	Total Gallons
1929												
Mar. 25	12.00	16.50	18.50	5.00	20.25	72.25	18.00	5.00	16.50	23.75	23.50	86.75
26	15.00	11.75	10.75	20.25	21.00	78.75	18.25	22.75	12.75	19.75	23.00	96.50
27	13.50	25.75	17.75	19.50	25.25	101.75	22.50	4.25	16.00	18.25	19.00	80.00
28	13.50	3.25	10.75	17.50	13.00	58.00	9.00	17.00	16.25	24.25	18.00	84.50
29	12.50	14.25	14.75	19.50	16.25	77.25	16.25	13.25	14.50	19.00	23.00	86.00
30	13.00	14.50	15.25	19.00	21.50	83.85	18.00	14.00	17.00	19.00	20.50	88.50
31	14.00	13.00	15.00	16.25	16.75	75.00	15.00	13.50	15.25	16.50	20.50	80.75
Apr. 1	11.50	14.00	13.25	17.50	18.75	75.00	16.75	12.50	14.50	17.75	18.50	80.00
2	15.00	12.75	10.25	18.50	14.50	71.75	15.75	21.50	16.25	20.25	25.50	99.25
3	14.25	13.75	14.75	17.50	21.00	81.25	15.50	6.50	13.50	17.50	22.25	75.25
4	17.00	13.50	13.00	15.75	21.25	80.50	19.75	15.25	17.50	23.75	15.50	91.75
5	16.00	14.00	14.25	18.75	19.00	82.00	18.25	15.75	15.50	19.50	18.00	87.00
6	16.50	16.50	17.75	22.75	24.00	97.50	20.00	14.75	19.00	22.00	23.75	99.50
7	17.25	14.25	15.50	17.25	20.00	84.25	17.25	16.00	15.50	20.50	22.50	91.75
8	13.75	13.25	9.75	14.50	17.50	68.75	15.25	15.00	12.25	17.75	22.75	83.00
9	13.75	14.25	17.25	23.25	20.25	88.75	17.25	15.25	20.00	18.75	26.00	97.25
10	14.75	13.00	9.50	15.50	15.75	68.50	16.00	13.50	16.00	22.00	22.50	90.00
11	13.25	15.25	16.25	17.00	17.50	79.25	16.25	14.25	14.75	14.50	20.50	80.25
12	15.00	9.00	13.25	19.00	19.75	76.00	14.50	14.00	13.00	19.75	22.50	83.75
13	15.75	20.50	14.25	17.00	21.00	88.50	16.50	17.25	19.50	22.75	23.25	99.25
14	15.00	10.00	11.25	17.00	16.75	70.00	17.00	12.50	15.75	19.50	22.00	86.75
15	16.75	15.25	16.25	18.25	20.25	86.75	17.00	19.00	15.50	19.75	21.00	92.25
16	12.25	15.25	12.25	19.75	19.00	78.50	16.00	14.00	15.75	21.25	20.50	87.50
17	14.50	11.00	14.25	18.00	18.50	76.25	15.00	14.50	14.25	17.00	19.00	79.75
18	15.25	15.50	12.25	18.00	18.00	79.00	16.50	15.50	15.75	23.00	24.50	95.25
19	15.00	11.75	13.25	18.00	18.50	76.50	14.00	10.25	14.25	22.75	18.50	79.75
20	14.50	15.00	13.50	19.25	19.50	81.75	17.75	18.75	15.25	20.25	23.50	95.50
21	12.50	11.50	13.25	15.75	16.25	69.25	14.75	14.00	13.50	20.00	24.00	86.25
22	16.50	13.50	13.00	20.25	24.25	87.50	21.00	14.50	17.50	26.00	23.75	102.75
23	12.25	10.75	10.00	12.50	12.50	58.00	9.50	10.75	11.75	16.00	18.00	66.00
Totals						2368.85						2661.25

Table XIX. Water Consumption in Gallons during Second Period

Lot I. (home-grown ration) | Lot II. (complex ration)

Cow No.		226	225	229	187	168	Total Gallons	232	230	189	174	150	Total Gallons
1929													
Apr.	24	18.00	15.00	10.25	16.75	19.25	79.25	15.00	14.00	14.00	18.00	16.25	77.25
	25	16.50	15.25	18.25	12.25	23.00	85.25	16.50	14.75	15.25	20.25	20.25	87.00
	26	16.00	10.00	10.50	15.50	17.25	69.25	13.50	15.50	11.25	16.50	19.25	76.00
	27	17.00	18.25	16.75	20.75	23.75	96.50	15.25	12.50	14.25	17.00	22.00	81.00
	28	17.25	15.25	15.00	19.75	18.75	86.00	15.50	14.25	14.75	19.50	19.00	83.00
	29	14.25	15.25	13.75	18.25	22.50	84.00	12.25	13.75	13.50	16.00	18.50	74.00
	30	14.75	13.50	15.50	18.75	18.50	81.00	14.00	9.00	10.00	14.25	21.25	68.75
May	1	12.75	17.25	15.75	21.50	20.75	88.00	15.25	15.75	19.00	20.00	18.50	88.50
	2	17.75	12.50	14.00	19.25	20.50	84.00	13.00	13.75	13.25	17.75	18.00	75.75
	3	14.00	13.50	10.50	18.50	16.00	72.50	15.25	10.50	12.00	16.75	17.25	71.75
	4	15.25	17.50	18.75	21.75	20.50	93.75	13.25	16.00	15.75	18.00	23.25	86.25
	5	12.00	18.00	13.75	18.50	20.25	82.50	16.00	10.25	14.75	19.00	17.00	77.00
	6	18.75	12.00	15.00	16.00	21.00	82.75	14.25	14.50	14.25	15.25	22.50	80.75
	7	13.00	18.00	15.75	24.50	24.00	95.25	14.25	13.25	12.00	17.25	16.25	73.00
	8	16.25	16.00	0.00	20.25	17.25	69.75	16.25	17.00	16.25	18.75	21.25	89.50
	9	14.00	18.00	14.75	18.25	18.00	83.00	11.50	11.25	11.00	15.50	16.25	65.50
	10	18.00	17.50	16.00	22.75	19.75	94.00	17.50	14.75	14.50	21.50	21.25	89.50
	11	15.50	17.00	13.75	19.50	22.50	88.25	15.75	14.00	17.75	17.00	17.25	81.75
	12	15.50	13.50	15.25	21.00	18.75	84.00	15.75	13.00	14.00	17.50	17.75	78.00
	13	16.00	17.00	16.25	20.75	21.00	91.00	16.75	15.00	14.50	19.50	17.50	83.25
	14	18.00	16.50	17.75	23.25	21.75	97.25	16.25	18.25	15.75	20.00	20.75	91.00
	15	17.25	16.50	12.75	15.50	17.00	79.00	13.75	8.75	14.50	14.50	18.25	69.75
	16	17.00	18.00	16.25	21.25	20.00	92.50	15.75	13.50	17.00	20.50	19.75	86.50
	17	19.75	16.75	16.25	19.75	22.00	94.50	13.50	11.75	14.75	18.25	23.00	81.25
	18	15.25	12.50	15.00	20.25	17.25	80.25	14.50	13.00	11.50	17.25	17.25	73.50
	19	15.00	15.25	10.50	19.00	18.50	78.25	14.25	13.25	16.50	16.00	19.75	79.75
	20	16.75	17.25	17.00	16.75	20.00	87.75	16.25	12.50	10.50	18.00	20.25	77.50
	21	15.50	13.75	13.00	22.00	24.25	88.50	16.50	12.75	20.50	20.00	23.25	93.00
	22	18.00	17.00	17.75	21.25	18.25	92.25	13.50	15.25	11.50	13.25	15.75	69.25
	23	12.50	9.25	12.25	13.25	15.75	63.00	11.50	11.25	11.50	14.00	15.50	63.75
Totals							2572.25						2392.75

Table XX. Water Consumption in Gallons during Third Period

Lot I. (complex ration) Lot II. (home-grown ration)

Cow No.	226	225	229	187	168	Total Gallons	232	230	189	174	150	Total Gallons
1929												
May 24	13.75	14.25	15.75	18.75	20.25	80.75	15.75	15.50	16.75	20.00	19.00	85.00
25	14.50	13.00	15.25	15.50	18.75	77.00	15.75	15.75	14.75	15.75	21.50	83.50
26	18.00	17.00	18.00	23.50	23.25	99.75	21.00	20.75	22.25	21.00	28.25	113.25
27	19.75	18.75	17.75	19.00	21.00	96.25	19.25	16.00	17.75	17.75	24.75	95.50
28	16.00	16.50	17.50	19.75	19.75	89.50	19.00	17.75	19.00	19.75	19.75	95.25
29	14.75	19.25	15.00	21.25	22.25	92.50	19.75	14.75	19.00	22.75	25.25	101.50
30	17.00	19.00	18.25	20.25	20.00	94.50	16.00	15.75	17.50	21.25	20.50	91.00
31	12.25	13.00	18.50	15.75	18.50	78.00	16.25	14.75	19.50	16.75	18.50	85.75
June 1	11.75	11.50	13.00	15.75	16.50	68.50	15.00	12.50	15.25	17.00	20.25	80.00
2	15.00	17.00	13.75	19.50	22.25	87.50	22.00	14.50	22.25	24.25	22.25	105.25
3	12.00	10.75	14.25	19.00	17.25	73.25	16.00	15.75	18.00	17.00	19.25	86.00
4	13.25	13.50	13.50	16.25	15.75	72.25	17.50	14.25	14.75	20.50	19.75	86.75
5	16.00	16.00	12.75	21.50	20.25	86.50	19.50	15.25	16.75	15.25	18.75	85.50
6	19.25	16.00	14.50	14.00	20.00	83.75	17.25	14.75	18.50	24.00	24.50	99.00
7	13.25	11.50	13.25	15.25	15.00	68.25	11.00	11.75	13.25	16.50	17.75	70.25
8	15.25	13.50	3.75	14.00	18.75	65.25	19.75	13.75	17.75	22.00	24.00	97.25
9	17.00	14.00	21.50	19.25	20.50	92.25	20.00	16.75	18.50	18.50	15.25	89.00
10	18.00	20.00	18.75	17.00	20.00	93.75	17.00	15.00	20.50	18.50	22.50	93.50
11	17.00	13.50	15.00	14.75	18.75	79.00	15.25	14.75	14.00	17.75	20.00	81.75
12	15.00	14.75	13.75	17.00	19.25	79.75	17.25	11.75	16.50	17.75	18.75	82.00
13	15.00	14.75	15.00	17.75	15.25	77.75	16.50	14.25	13.25	18.00	19.75	81.75
14	15.75	14.75	16.25	15.25	17.00	79.00	14.00	10.50	16.00	14.50	17.75	72.75
15	17.75	16.50	15.50	18.50	17.00	85.25	16.00	12.50	19.25	18.25	22.50	88.50
16	18.00	17.75	17.50	20.25	21.75	95.25	21.00	17.50	15.25	22.00	21.75	97.50
17	16.75	18.25	18.25	17.75	21.75	92.75	18.00	15.50	22.75	20.00	22.25	98.50
18	17.25	19.75	18.25	19.75	20.75	95.75	20.25	18.25	19.00	18.50	22.50	98.50
19	17.50	19.00	27.25	18.00	18.00	99.75	16.75	14.25	15.50	20.75	21.00	88.25
20	15.00	18.00	6.00	18.25	20.75	78.00	18.50	15.25	22.25	19.50	23.75	99.25
21	15.00	12.75	14.50	17.00	20.25	79.50	21.00	13.25	16.75	19.75	20.25	91.00
22	12.00	12.50	13.50	14.00	14.75	67.75	12.50	10.50	10.50	16.00	19.00	68.50
Totals						2530.50						2720.50

Table XXI. Water Consumption in Gallons during Fourth Period

Lot I. (home-grown ration) Lot II. (complex ration)

Cow No.	226	225	229	187	168	Total Gallons	232	250	189	174	150	Total Gallons
1929												
June 23	14.00	9.25	11.75	11.00	18.25	64.25	18.25	12.25	15.00	28.00	17.50	91.00
24	15.00	14.25	11.75	13.75	17.50	72.25	18.50	13.50	16.00	6.25	20.25	74.50
25	15.00	14.50	19.25	8.25	16.50	73.50	13.75	9.50	12.00	17.25	16.50	68.00
26	14.00	14.00	12.00	11.25	18.75	70.00	13.25	11.00	23.75	14.25	18.50	80.75
27	12.25	11.00	16.25	17.25	16.00	72.75	15.75	11.00	0.50	15.75	19.00	62.00
28	15.25	16.00	15.25	6.50	17.25	70.25	13.00	9.00	12.25	14.25	14.75	63.25
29	11.50	11.25	11.75	9.00	16.00	59.50	14.00	10.00	14.50	11.00	14.50	64.00
30	16.50	16.25	16.50	15.50	18.00	82.75	14.00	14.00	23.50	17.00	22.25	90.75
July 1	14.50	14.50	17.00	15.25	17.25	78.50	18.00	12.50	4.50	19.25	19.00	73.25
2	17.00	15.00	16.50	12.75	17.25	78.50	16.00	12.00	14.00	16.25	18.50	76.75
3	16.00	15.50	14.75	12.25	16.50	75.00	12.50	12.25	11.50	15.25	16.50	68.00
4	13.50	15.50	16.00	15.25	18.00	78.25	18.50	11.75	14.00	17.50	19.50	81.25
5	16.75	17.50	17.25	17.25	20.00	88.75	18.00	13.50	16.50	18.75	21.25	88.00
6	11.75	14.00	15.75	16.75	17.75	76.00	15.00	12.50	13.00	13.25	17.25	71.00
7	17.00	18.50	17.50	20.25	19.25	92.50	18.00	12.00	15.50	20.75	22.75	89.00
8	17.75	18.00	16.25	18.75	17.50	88.25	16.50	14.50	15.50	18.25	11.00	75.75
9	16.25	16.00	16.50	23.25	18.75	90.75	15.50	11.75	14.75	17.50	28.25	87.75
10	16.75	17.50	16.50	21.75	19.75	92.25	18.25	14.50	19.00	19.50	21.50	92.75
11	17.75	18.50	18.50	19.50	18.00	92.25	18.50	12.25	17.75	19.00	20.00	87.50
12	18.00	8.00	17.50	20.50	22.75	86.75	18.25	15.25	16.50	19.50	24.00	93.50
13	16.75	27.00	16.00	15.50	25.00	100.25	13.00	11.75	15.00	15.00	16.50	71.25
14	16.75	12.50	16.50	17.50	9.50	72.75	19.00	10.00	15.50	16.50	20.50	81.50
15	19.50	19.75	17.00	17.00	18.50	91.75	17.00	6.50	17.50	18.00	18.50	77.50
16	17.00	16.50	18.25	19.00	19.25	90.00	17.00	7.00	12.00	17.00	18.25	71.25
17	19.00	20.00	17.00	18.25	20.00	94.25	15.50	7.00	17.00	18.00	23.00	80.50
18	16.00	13.75	13.75	17.25	17.75	78.50	12.50	6.00	13.00	16.00	17.25	64.75
19	15.75	14.50	16.00	18.50	19.25	84.00	17.00	.50	16.00	17.00	19.50	70.00
20	17.25	16.50	15.75	16.50	20.25	86.25	18.50	.50	17.50	18.00	17.00	71.50
21	15.75	15.50	14.75	17.75	15.25	79.00	12.00	13.00	8.75	11.50	16.50	61.75
22	12.25	8.00	13.50	18.25	16.00	68.00	16.25	11.50	14.25	15.50	16.50	74.00
Totals						2448.50						2326.00

Table XXII. Water Consumption, in gallons, by the Cows while on Ration I during each Period

Cow No.	Period I	Period II	Period III	Period IV	Total
226	434.75		473.00		907.75
225	414.00		473.00		887.00
229	413.00		466.25		879.25
187	532.75		538.00		1070.75
168	573.00		580.25		1153.25
232		449.50		484.75	934.25
230		404.50		324.00	728.50
189		430.25		441.50	871.75
174		529.25		504.50	1033.75
150		579.50		571.50	1151.00
Total gallons					9617.25

Table XXIII. Water Consumption, in gallons, by the Cows while on Ration II during each Period

Cow No.	Period I	Period II	Period III	Period IV	Total
226		480.75		475.50	956.25
225		469.75		465.75	935.50
229		434.25		477.50	911.75
187		582.50		483.50	1066.00
168		605.00		546.25	1151.25
232	497.00		531.50		1028.50
230	440.00		446.25		886.25
189	467.50		528.50		996.00
174	604.25		576.25		1180.50
150	652.50		638.00		1290.50
Total gallons					10402.50

Table XXIV. Weights of Animals for First Three Periods of the Experiment

Lot I.

Cow No.	Initial Weight	Weight at End of 1st Period	Weight at End of 2nd Period	Weight at End of 3rd Period
226	1008	1019	1035	999
225	1125	1136	1154	1139
229	1200	1205	1214	1226
187	1280	1302	1321	1315
168	1388	1375	1380	1385
Average	1200	1207	1220.8	1212.8

Lot II.

Cow No.	Initial Weight	Weight at End of 1st Period	Weight at End of 2nd Period	Weight at End of 3rd Period
232	1100	1117	1109	1132
230	1075	1076	1083	1129
189	1250	1253	1236	1275
174	1150	1143	1143	1187
150	1500	1499	1458	1491
Average	1215	1218	1205.8	1242.8

Table XXV. Daily Record of Feed Consumed, Milk Produced and Feces and Urine Excreted during the Metabolism on Ration I (complex ration)

Date	Body Weight	Grain	Silage	Hay	Feces	Urine	Milk
	lbs.	gms.	gms.	gms.	gms.	c.c.	gms.
Cow No. 225							
June 14	1130	5812	14,982	5176	32,542	10,000	16,792
15	1144	"	"	"	32,805	11,600	17,522
16	1137	"	"	"	34,272	10,320	16,995
17	-	"	"	"	34,405	14,500	16,379
18	1148	"	"	"	34,713	23,290	17,529
19	1145	"	"	"	31,629	19,900	17,014
20	1150	"	"	"	35,451	16,800	16,881
Cow No. 226							
June 14	1000	7444	13,620	4540	32,303	9,550	20,884
15	1012	"	"	"	32,230	9,520	23,574
16	1011	"	"	"	33,133	9,590	23,515
17	-	"	"	"	31,835	10,320	21,159
18	994	"	"	"	30,648	10,350	19,851
19	1007	"	"	"	30,763	9,690	22,086
20	1006	"	"	"	34,848	10,085	20,034
Cow No. 229							
June 14	1200	5812	16,344	5448	37,734	7,000	17,485
15	1225	"	"	"	37,448	7,000	16,921
16	1211	"	"	"	38,028	7,450	16,850
17	-	"	"	"	38,759	8,390	16,509
18	1235	"	"	"	40,812	10,960	18,003
19	1213	"	"	"	34,927	10,900	17,606
20	1240	"	"	"	40,631	9,620	17,957

Table XXVI. Daily Record of Feed Consumed, Milk Produced and Feces and Urine Excreted during the Metabolism on Ration II (home-grown ration)

Date	Body Weight lbs.	Grain gms.	Silage gms.	Hay gms.	Feces gms.	Urine c.c.	Milk gms.
Cow No. 225							
July 15	1155	5992	14,982	5266	33,246	14,100	14,347
16	1190	"	"	"	39,246	11,770	15,213
17	1188	"	"	"	38,146	12,760	13,625
18	1175	"	"	"	38,126	12,360	12,870
19	1160	"	"	"	31,566	9,550	13,526
20	1180	"	"	"	35,816	14,350	14,004
21	1190	"	"	"	36,816	18,050	13,607
Cow No. 226							
July 15	1027	8172	13,620	4540	40,736	9,700	20,068
16	1036	"	"	"	36,956	8,800	19,395
17	1012	"	"	"	35,456	8,900	17,183
18	1020	"	"	"	32,476	12,800	18,864
19	1000	"	"	"	35,046	10,560	19,215
20	1004	"	"	"	33,576	6,000	19,713
21	1010	"	"	"	35,227	10,450	20,075
Cow No. 229							
July 15	1222	6176	16,344	5448	35,097	8,500	16,525
16	1256	"	"	"	38,077	11,470	15,823
17	1245	"	"	"	32,257	10,650	16,187
18	1267	"	"	"	34,867	10,100	16,521
19	1227	"	"	"	33,957	8,400	14,739
20	1255	"	"	"	39,407	9,700	15,707
21	1262	"	"	"	37,603	8,950	15,906

Table XXVII. Nitrogen Composition of Feeds Consumed, Milk Produced and Urine and Feces Excreted during the Metabolism on Ration I.

	Material	Nitrogen
	Corn Silage	0.408 per cent
	Gr. Alfalfa	2.210 " "
	Grain	2.600 " "
Cow No. 225	Feces	0.343 per cent
	Urine	6.430 gm/L
	Milk	0.477 per cent
Cow No. 226	Feces	0.379 per cent
	Urine	10.560 gm/L
	Milk	0.484 per cent
Cow No. 229	Feces	0.322 per cent
	Urine	11.710 gm/L
	Milk	0.507 per cent

Table XXVIII. Nitrogen Composition of Feeds Consumed, Milk Produced, and Urine and Feces Excreted during the Metabolism on Ration II.

	Material	Nitrogen
	Corn Silage	0.384 per cent
	Gr. Alfalfa	2.300 " "
	Grain	2.500 " "
Cow No. 225	Feces	0.344 per cent
	Urine	8.400 gm/L
	Milk	0.520 per cent
Cow No. 226	Feces	0.340 per cent
	Urine	11.100 gm/L
	Milk	0.510 per cent
Cow No. 229	Feces	0.328 per cent
	Urine	12.000 gm/L
	Milk	0.490 per cent

Table XXIX.

Nitrogen Metabolism - June 14-20, 1929

Ration I.

Cow No.	Intake (grams) Silage	Alfalfa	Grain	Total Intake	Outgo (grams) Feces	Urine	Milk	Total Outgo	Balance	Daily Balance
225	427.88	800.73	1057.81	2286.42	808.85	684.21	568.16	2061.22	225.20	32.17
226	388.99	702.34	1354.81	2446.14	855.63	729.75	731.34	2316.72	129.42	18.49
229	466.78	842.81	1057.81	2367.40	864.18	718.06	615.15	2197.39	170.01	24.29

Nitrogen Metabolism - July 15-21, 1929

Ration II.

Cow No.	Intake (grams) Silage	Alfalfa	Grain	Total Intake	Outgo (grams) Feces	Urine	Milk	Total Outgo	Balance	Daily Balance
225	402.72	847.83	1048.60	2299.15	870.19	780.70	505.40	2156.29	142.86	20.40
226	366.11	730.94	1430.10	2527.15	848.21	746.03	686.02	2280.26	246.89	35.27
229	439.33	877.13	1080.80	2397.26	824.15	813.24	545.90	2183.29	213.97	30.57

Table XXX. The Mean Daily Temperature during the Four Feeding Periods

First Period			Second Period			Third Period			Fourth Period		
Day		Temp.	Day		Temp.	Day		Temp.	Day		Temp.
Mar.	25	53	Apr.	24	49	May	24	53	June	23	68
	26	44		25	58		25	54		24	68
	27	46		26	48		26	63		25	63
	28	43		27	56		27	71		26	59
	29	44		28	46		28	72		27	62
	30	50		29	44		29	76		28	62
	31	36		30	54		30	74		29	63
Apr.	1	34	May	1	52		31	68		30	74
	2	34		2	36	June	1	50	July	1	70
	3	52		3	36		2	47		2	59
	4	61		4	42		3	50		3	61
	5	70		5	43		4	54		4	70
	6	73		6	46		5	52		5	72
	7	70		7	41		6	58		6	74
	8	52		8	44		7	56		7	71
	9	48		9	46		8	54		8	70
	10	42		10	49		9	58		9	72
	11	42		11	58		10	62		10	68
	12	39		12	61		11	71		11	69
	13	42		13	54		12	61		12	74
	14	38		14	58		13	62		13	76
	15	40		15	67		14	60		14	65
	16	40		16	46		15	64		15	64
	17	40		17	50		16	66		16	66
	18	40		18	54		17	74		17	72
	19	38		19	44		18	77		18	66
	20	42		20	44		19	74		19	58
	21	46		21	50		20	72		20	59
	22	47		22	52		21	67		21	68
	23	48		23	60		22	68		22	71

Table XXXI. Frequency of Drinking and Frequency of Urination while on Metabolism

Ration I. (complex ration)

1929	Cow 225 Times Urinated	Cow 225 Times Drank	Cow 226 Times Urinated	Cow 226 Times Drank	Cow 229 Times Urinated	Cow 229 Times Drank
June 14	7	10	6	8	5	5
15	9	11	4	8	6	8
16	10	4	5	5	5	4
17	11	5	5	7	6	3
18	14	9	7	7	5	10
19	13	9	6	21	7	4
20	11	10	5	15	8	10
Total	75	58	38	71	42	44
Average	10.71	8.28	5.42	10.14	6.00	6.28

Ration II. (home-grown ration)

1929	Cow 225 Times Urinated	Cow 225 Times Drank	Cow 226 Times Urinated	Cow 226 Times Drank	Cow 229 Times Urinated	Cow 229 Times Drank
July 15	11	8	8	9	5	10
16	4	4	7	9	5	5
17	7	3	5	7	7	2
18	7	3	7	5	8	4
19	4	4	5	9	5	4
20	9	3	7	5	7	3
21	11	4	5	5	6	4
Total	53	29	44	49	43	32
Average	7.57	4.14	6.28	7.00	6.14	4.57

Table XXXII. Growth Weights of Animals during the 8 Weeks Feeding Period. Animals Grouped According to the Rations Fed.

Ration B 32

Animal No.	Initial Weight	1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week	7th Week	8th Week	Total Gain
	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	
62	52	61	80	92	104	118	124	130	140	88
68	59	74	97	118	138	150	157	154	167	108
69	54	67	86	105	125	138	144	140	146	92
84	45	50	63	70		84			96	51
85	46	53	66	77		102			109	63
87	69	84	108	110	135	149	149	152	156	87
90	53	61	77	83	102	112	118	120	130	77
115	56	58	70	93	112	118	126	137	145	89
116	57	59	73	101	118	125	131	145	155	98
117	86	107	116	116	112)					
118	83	107	115	115	114)					
119	83	103	109	110	114)	Mated				
120	92	110	117	117	114)					
132	39		55	76	98	107	125	137	148	109
	39		55	72	94	103	120	129	139	100
	39		55	70	91	98	114	129	143	104
	39		57	78	99	110	125	132	139	100
Average	49.77									89.69

Ration B 30

Animal No.	Initial Weight	1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week	7th Week	8th Week	Total Gain
58	58	75	84	98	112	120	118	127	140	82
65	50	62	79	98	118	133	144	158	166	116
77	37	47	54	70	76	83	87	92	99	62
78	35	47	65	67	77	80	86	93	101	66
80	42	50	55	73	79	85	91	92	104	62
92	61	70	76	83	89	100	105	108	112	51
105	61	74	86	91	101	113	112	116	134	73
107	50	52	68	69	83	85	94	103	112	62
129	65	81	103	114	128	129	134	140	144	79
Average	51.00									72.55

Ration B 30 plus yeast

Animal No.	Initial Weight	1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week	7th Week	8th Week	Total Gain
128	61	71	78	88	99	113	121	125	130	69
123	45	56	72	85	88	95	102	111	118	73
124	53	70	87	98	108	114	120	130	134	81
Average	53									74.33

Table XXXII. (continued)

Ration B 31

Animal No.	Initial Weight	1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week	7th Week	8th Week	Total Gain
	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	
60	58	65	77	90	96	108	117	123	128	70
67	47	50	57	65	77	88	99	102	107	60
113	54	59	78	86	102	113	118	128	133	79
121	60	69	80	88	85	101	110	111	119	59
122	45	68	70	79	89	93	106	107	110	65
Average	52.80									66.60
					Ration B 31 plus yeast					
125	51	57	70	81	96	104	115	130	130	79
126	54	55	67	79	88	97	116	128	131	77
127	43	47	57	68	75	84	92	106	115	72
Average	49.33									76.00
					Ration B 45					
96	53	60	73	83	112	132	145	158	162	109
138	40	52	64	72	89	92	106	123	134	94
139	40	50	66	79	95	103	116	127	135	95
Average	44.33									99.33
					Ration B 46					
97	64	81	93	100	103	115	120	124	135	71
					Ration B 47					
100	58	68	86	95	103	120	123	125	130	72
130	59	74	92	107	116	118	132	142	149	90
131	67	90	111	131	148	147	159	168	173	106
137	61	82	80	90	95	104	107	118	117	56
Average	61.25									81

Table XXXII. (continued)

Ration B 52

Animal No.	Initial Weight	1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week	7th Week	8th Week	Total Gain
	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	
109	59	62	84	100	112	123	130	142	154	95
					Ration B 68					
143	43	53	67	86	96	118	123	125	125	82
					Ration B 69					
144	57	75	90	106	113	133	138	140	142	85
145	45	56	77	100	113	125	130	129	128	83
Average	51.									84
					Ration B 70					
146	57	75	97	117	130	147	157	162	175	118
147	43	57	85	107	117	126	135	145	150	107
Average	50									112.50

Table XXXIII. Length of Time from Mating to Parturition. Animals Listed under the Various Rations Fed.

Ration B 32

Female No.	Days
62	25
68	25
69	non-breeder
84	35
85	30
87	weights indicated that embryos probably were resorbed
90	non-breeder
115	35
116	47
117	37
118	28
119	28
120	26
132	34, 30
133	29, 25
134	35, 26
135	non-breeder

Ration B 30

Female No.	Days
58	36
65	63
92	56
105	41
107	50
129	killed and examined, embryos resorbed

Ration B 30 plus yeast

Female No.	Days
78	37
80	25, 23
123	31, 45
124	33, 28
128	33

Ration B 31

Female No.	Days
60	30
67	63

Table XXXIII. (continued)

Ration B 31 plus yeast

Female No.	Days
113	non-breeder
121	21, 30
122	39,25
125	36, 30
126	24, 23
127	31, 24

Ration B 45

95	32, 25
138	33
139	28

Ration B 46

97	35

Ration B 47

100	27
130	28
131	39

Ration B 52

109	63, 24

Ration B 68

143	no litter at 57 days

Ration B 69

144	57
145	no litter at 57 days

Ration B 70

146	24
147	50

Table XXXIV. Size of Litters, Birth Weight, Weight at 28 Days of Age, and Mortality of Young Rats, Grouped According to Diets.

Ration B 32

Female	No. in Litter		Av. Birth Weight	Av. Weight at 28 days	Mortality
			gms.	gms.	
68	(8)	7	-	25.00	3
		7	7.00	40.00	
120		7	5.30	28.00	
119		5	7.10	37.20	
		5	-	41.40	
118	(9)	7	6.00	35.00	1
85		7	6.00	26.30	
	(8)	7	6.25	32.57	
116		4	7.50	43.00	1
115		7	5.71	18.67	1
84		1	5.00	-	
132		6	6.85	40.60	1
	(8)	7	7.37	not 28 days old	
133		7	6.43	34.77	
134		6	7.00	44.16	
			Ration B 30		
58	(8)	7	-	-	
		4	8.00	-	
			Ration B 30 plus yeast		
80	(8)	7	5.00	22.00	5
		7	5.71	25.17	1
77	(8)	7	5.30	-	7
78		6	6.17	21.33	
	(9)	7	5.00	23.43	

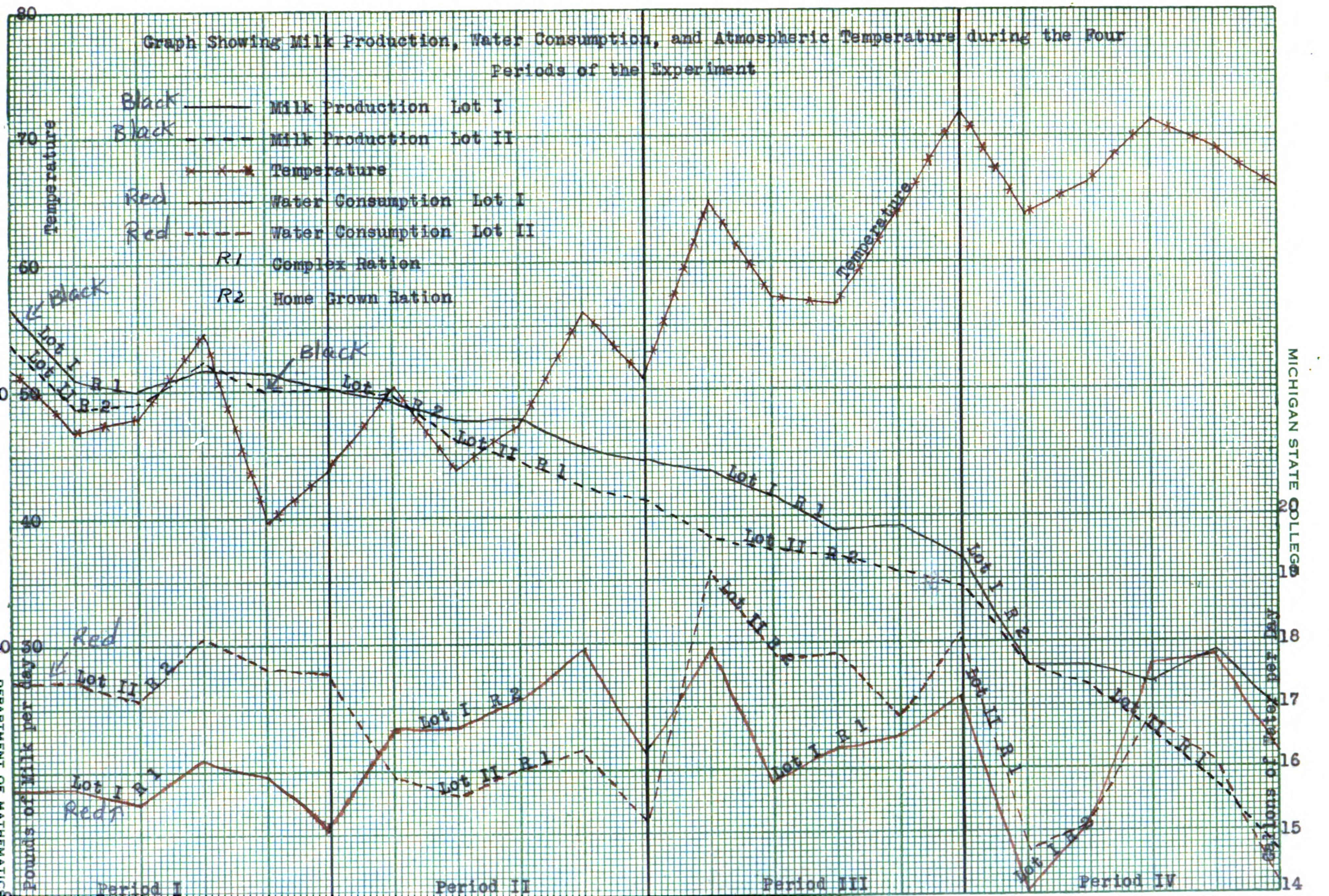
Table XXXIV. (continued)

Ration B 30 plus yeast

Female	No. in Litter		Av. Birth Weight	Av. Weight at 28 Days	Mortality
			gms.	gms.	
105		5	4.60		5
107		6	5.83		6
123		6	5.83		6
		7	5.43	29.33	4
124		5	6.80		5
		7	4.76		7
128		7	5.71	48.00	4
60		7	6.14	27.50	3
67		7	5.00	25.57	
			Ration B 31 plus yeast		
122		6	4.83		6
		6	6.00	35.40	1
121		6	5.00	23.80	1
126	(9)	7	5.55	26.00	
	(10)	7	5.60	36.33	1
127		6	7.00	33.83	
		7	5.43		7
125		6	6.66	40.00	
		5	7.20	40.20	
			Ration B 45		
95		7	5.71	36.00	
		7	6.00		7
139		6	5.33	31.50	
138		4	5.75	34.00 (27 days)	

Table XXXIV. (continued)

Female	No. in Litter		Av. Birth Weight gms.	Av. Weight at 28 Days gms.	Mortality
			Ration B 46		
97		6	5.83	34.17	
			Ration B 47		
100		2	7.00	44.00	
100	(8)	7	5.50		7
130		6	6.33	21.83	
131		6	5.83		6
			Ration B 52		
109		7	5.71	28.57	
	(9)	7	5.33	35.67	1
			Ration B 68		
143	no litters				
			Ration B 69		
144	(8)	7	5.12	not 28 days old	
			Ration B 70		
146	(8)	7	6.00	35.8	2
147		7	5.86	not 28 days old	


Graph Showing Milk Production, Water Consumption, and Atmospheric Temperature during the Four Periods of the Experiment
Black — Milk Production Lot I
Black - - - Milk Production Lot II
-x-x- Temperature
Red — Water Consumption Lot I
Red - - - Water Consumption Lot II
R1 Complex Ration
R2 Home Grown Ration
Temperature
Pounds of Milk per day
Gallons of Water per Day
Lot I R 1
Lot II R 2
Lot I R 2
Lot II R 1
Period I
Period II
Period III
Period IV
80
70
60
50
40
30
20
19
18
17
16
15
14
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