NUTRITIONAL VALUE OF THE VELVET BEAN FOR MILK PRODUCTION

Thesis for the Degree of M. S.
MICHIGAN STATE COLLEGE

Jose F. Maldonado

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ACKNOWLEDGMENTS

The author sincerely appreciates the cooperation of the Department of Dairy Husbandry and that of Mr. C. F. Huffman, Research Associate in Dairy Husbandry, in the conduction of the investigation herein reported.

Acknowledgement is also extended to Mr. C. A. Hoppert, Associate Professor of Biochemistry, whose help made the second part of this work possible. Also to Mr. C. W. Duncan, Experiment Station Chemist and his associates, for the chemical analyses used in this investigation.

PART I

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INTRODUCTION

The trend towards a greater utilization of roughages, which are low in fat, for livestock feeding and the removal of the fat portion from commercial meals, has brought about a greater interest in the problem of the essentiality of lipids in animal nutrition. This situation may affect milk and fat production of the dairy cow. Investigations at Cornell University indicate that a certain amount of fat in the ration is essential for normal milk secretion and many other reports claim the relationship of fat in the ration to butterfat percentage.

In view of this situation an investigation was carried out to determine the effect of feeding rations with varying fat levels on milk production and the quality of the fat produced. For such a purpose a promising tropical legume, velvet beans, has been compared with solvent extracted soybean oil meal.

REVIEW OF LITERATURE

NUTRITIVE VALUE OF THE VELVET BEAN

Sure and Read(1) classified the velvet bean plant as one of the most vigorous growing annual legumes in the United States. Its importance in the cotton belt of this country increased enormously from the early nineties to the present time. The acreage of velvet beans in that region increased from about one million to five millions from 1915 to 1917.

The United States Department of Agriculture introduced the velvet bean from India in about 1870(3). At first it was used merely as an ornament, but later, when it was observed that livestock ate it with a relish, its importance as a feed for farm animals developed.

The United States Census for 1930 reported the production of more than 2,100,000 bushels of seed among nine Southern states, without including the amounts used as forage and interplanted to other crops.

Composition of the velvet bean

The earliest chemical analysis of this seed was made by Clute(2), measured on an air dried basis. The following table obtained from the figures given by Morrison(4) compares the velvet bean with other popular protein-rich feeds:

	Cr. Protein	Fat	Fiber	N-free Extr.	Ash	T.D.N.
Cottons'd meal	43.2%	7.2%	10.6%	27.0%	5.5%	75.5%
Lins'd meal(solv)	36.9	2.9	8.7	38.3	5.6	72.3
Soybean O. meal (solv.)	46.4	1.6	5.9	31.7	6.0	77.6
Coconut O. meal	21.4	2.4	13.3	47.4	6.6	71.6
Palm Kernel meal (high in fiber)	16.8	9.5	24.0	35.0	4.3	70.2
Peanut O. meal	40.3	1.4	5.7	27.2	5.8	73.8
Velvet bean(whole)	23.4	5.7	6.4	51.5	3.0	76.7

The velvet bean contains about one-half the amount of protein of cottonseed meal, linseed or soybean oil meals, but practically the same amount of net energy.

The commercial analysis given by feed dealers (5) is

Crude protein	not less than	22 per cent
Crude fat	" " "	4.5 per cent
Crude fiber	" " "	4.0 " "
N-free extr.	" " "	51.0 " "

Miller and Barnes(7) analyzed the nitrogenous compounds of the velvet bean and found four per cent bound as protein and 0.51 per cent as non-protein. The later consists mainly of acid amide, basic and amino acid nitrogens. A large part of this is mainly 3-4-dihydroxyphenylalanine.

The importance of this compound has been emphasized by Miller(8,9). He found that when the velvet bean was powdered and mixed with water, a pink color developed very quickly. It passed through several shades of red and brown and finally became black. When the seed coats were completely removed and the powdered interiors mixed with water, the color appeared slowly.

Miller first thought it was an enzyme, but on further work failed to substantiate this idea since the reaction was not destroyed by heat or dryness. Moreover, heating the dry coats to 105 degrees Centigrade for two hours retarded color formation, but did not inactivate it. The substance was destroyed by boiling in water for fifteen minutes.

Following Torquati's methods, who separated a similar nitrogenous substance from Vicia faba, another legume, Miller separated the amino acid dihydroxyphenylalanine. He obtained positive reactions for this substance from 26 different varieties of velvet bean. This acid produces vomiting and purging in man when administered orally. Miller concluded that "when one considers that this substance is rather closely related chemically to adrenalin, it is quite possible that long, continued feeding of velvet beans might cause such harmful effects as have been observed."

Finks and Johns(13) also studied the causes of toxicity from velvet bean feeding. Waterman and Johns(14), while accepting the theory that the bean contains a toxic substance, tried to find other limiting factors, particularly unavailability of its proteins in the raw state. From their studies, which consisted in the isolation of the proteins and their digestion "in vitro" by pepsin and trypsin, they concluded that normal growth can be attained on the cooked proteins. The harmful effects noticed after cooking would be due, then, to the presence of the substance isolated by Miller.

Brannen(16) also improved the quality of the bean by heating it for one hour at fifteen pounds pressure. In the raw state 40 per cent of the seed in the ration was found to be injurious, while after heating, sixty per cent was safe.

The fact that velvet beans are much less toxic to ruminants than to swine and rats may be due to the fermentation of the toxic substances in the rumen(4).

Johns and Finks(10) conducted extensive research on the constitution of the proteins of velvet beans. In 1918 they found stizolobin as the principal protein. According to them it contained all the essential amino acids. Jones and Johns(11) and Jones and Waterman(12) also studied this protein and separated another globulin and an albumin. They found the following amino acid content of velvet beans:

	Stizolobin (a-globulin)	Beta globulin	Albumin
Glycine	1.66%	-	-
Alanine	2.41	-	-
Valine	2.88	-	-
Leucine	9.02	-	-
Proline	4.00	-	-
Phenylalanine	3.10	-	-
Tyrosine	6.24	-	-
Cystine	1.13	0.80%	1.02%
Arginine	7.14	8.19	6.13
Histidine	2.27	3.37	0.83
Lysine	6.51	8.50	8.20
Tryptophane	Present	-	-

Sure(15) showed that cystine is also a growth limiting factor in velvet bean proteins. Watermen and Jones(14) had previously claimed that no improvement resulted upon addition of this amino acid to the bean ration.

Sure illustrated his observations by means of charts. When he added cystine to a velvet bean-gelatin ration for rats, considerable continuous growth was produced. According to present data, not cystine but methionine is the deficient sulphur containing essential amino acid.

The velvet bean seed was found deficient for growth due to the character of its mineral matter. According to Sure and Read(1) young rats were unable to grow when velvet beans served as the sole source of mineral matter. When four per cent of the dextrin in the ration was replaced by an equal amount of a salt mixture, almost normal growth occurred. When one per cent common salt and 1.5 per cent calcium carbonate replaced the salt mixture, normal growth was also obtained for three months. This indicated that at least, calcium, sodium and chlorine are the limiting factors in the bean as far as mineral matter was concerned. The leaf, however, is rich in ash and may serve as a good supplement(17).

Sure and Read(1) and Brannen(16) reported an abundance of fat soluble vitamins in velvet beans. The former authors obtained normal growth in rats when receiving twenty per cent of the seed as the sole source of vitamin A. When the level was reduced to ten per cent inferior growth resulted.

Sure and Read also found that the velvet bean was low in the vitamin B complex. Salmon(18), in a study of the relation of age of the seed to its B complex, found that 0.79 gram of the recently harvested beans fed daily per 100 grams of weight to pigeons, protected them from polyneuritis. Storage for two years resulted in the loss of this factor.

In 1918 Ewing and Smith(8) studied the digestibility of ground velvet beans with steers when fed in combination with corn silage and alfalfa hay, From the data obtained they calculated the following coefficients of digestibility of the beans:

Dry Matter	- 78.76%	Ether extract	- 76.92%
Crude Protein	- 73.62%	Crude Fiber	- 64.38%
N- free Extr.	- 86.31%	Ash	- 58.42%

Value of the Velvet bean for Cattle

One of the most important advantages of this legume crop is its enormous yield of feed per acre. An interesting example of this is cited by Tracy(19). A dairyman in Northern Florida grazed 30 cows half a day during 27 days and then gathered ten Tons of seeds in the pods from 20 acres of velvet beans.

Green and Semple(20) reported that the velvet bean is only 50 per cent as valuable as a protein feed as cottonseed meal. From the standpoint of energy production they are about equal. Moore(21) claimed that it is 66 per cent as valuable as cottonseed meal when used in the pod for feeding beef cattle.

Templeton, Ferguson and Gibbens(22) also found cottonseed meal twice as valuable for milk production as 1.5 pounds of velvet bean and pod meal representing one pound of the shelled bean.

The value of the ground velvet bean as a supplement to cottonseed meal was studied by Fitzpatrick(23), Scott(24) and Hunt(25). The bean fed as 66 per cent of the grain mixture proved more economical for dairy cattle than wheat bran, coconut meal or molasses feed(23). Cows fed a mixture of cottonseed meal, wheat bran and velvet bean meal produced more milk than when corresponding amounts of corn silage or peanut meal plus the first two feeds of the ration were fed(24).

According to tests conducted with dairy heifers, one pound of soybean oil meal was equal to two of velvet bean meal(25).

Read and Sure(17) raised three generations of rats successfully on a diet consisting of whole milk and velvet bean seed. Three other generations were reared on a ration consisting of 40 per cent velvet bean hay, 60 per cent starch and a liberal supply of skim milk.

In a previous paragraph it was observed that feeding velvet bean over a level of 40 per cent, deleterious effects may occur and that if the beans were steamed, 60 per cent of them was safe(14). This question was also carefully studied by other authors(1,15).

Frequently cattle refuses to eat the bean during the first days of feeding(22), but this can be overcome by mixing it with other more palatable feeds(25). The seed is very tough and should be ground for dairy cows. The practicability of this has been studied by several investigators. Ewing and associates(3) studied the influence of the methods of preparation of the bean on milk and fat production, and on the palatability and economy of production. Grinding of the beans resulted in an increase of 5.57 per cent in milk and 3.94 per cent in the butterfat over the other methods of preparation(whole, cracked or cracked and soaked). They concluded that it pays to grind velvet beans. Morrison(4) stated that it is also practical to soak the whole bean in water for 24 hours. Ewing and coworkers accept cracking and soaking as economical when it can be done at a low cost.

Scott(26) reported claims that velvet beans cause abortion in cattle and blind staggers in horses. "The effects," he says, "are obtained when they are fed alone, as occurs when any other protein rich feed is used alone. The trouble can be avoided by feeding balanced rations."

In contrast to soybeans, the velvet bean does not produce undesirable effects on the milk and its products. Scott (27) fed two cows heavily on velvet bean demonstrating that there was an appreciable effect on the melting point, iodine number, saponification and Reichert-Meissl numbers of the butterfat produced.

-Summary-

In the study of the literature on velvet beans the following characteristics will be found which classify them as an unexcelled legume for the tropics(2):

1-It grows luxuriantly in poor soil.
2-Yields large amounts of seed.
3-It is eaten readily by all animals.
4-Particular adaptation to moist conditions.
5-Heavy production of forage and little loss of leaves during the curing process.

The future of such a legume for the hot, humid tropical regions is very promising. Although the studies on velvet bean have been mostly restricted to its botany and several feeding tests to determine its value for farm animals, more information is needed about them.

The seed, however, has certain limitations. It contains an amino acid, dihydroxyphenylalanine, which is toxic to some animals and to man. It is, however, probably destroyed by bacterial digestion in the rumen, which makes it a safe feed for dairy cattle.

The velvet bean, in common with other concentrates is also deficient in calcium, but the situation can be corrected by the use of wholesome roughage, such as the velvet bean vines.

Velvet beans are most favorable for milk production when fed as a meal. Cracking and soaking in water for twelve or twenty four hours is also recommended if it can be done at a low cost.

Heavy feeding of velvet bean is unwise since it is not a balanced food for milk production. When supplemented with feeds of a different nature it compares favorably with any other feed on the market.

THE EFFECT OF DIETARY FAT ON MILK AND FAT SECRETION

The term "to feed fat into milk" has always been a subject of great controversy. Steensberg(28) divided the general opinions concerning this question into the English and American group and the German, Dutch, Swedish and Danish one.

The former group maintain that the fat per cent of milk is independent of feeding and that it may increase, but at the same time milk secretion decreases, so that the total amount of butterfat remains the same. The latter group claim that certain feedstuffs have a definite influence upon the percentage of fat without decreasing milk production, so that the total amount of butterfat is increased.

Steensberg attributes the widely differing opinions to the different methods of experimentation. The English and American investigations were of short duration.

Anderson and Williams(29) cited the works of Stohmann reported in 1868, which has been overlooked by most investigators. This work showed that goats receiving a fat-poor ration produced 30 per cent less butterfat than others on high-fat rations.

Wilson and associates(30) demonstrated that the fat per cent is changed by feed to a greater degree than the amount of milk. Their data indicate that two-thirds of the increase in the average gross yield of butterfat was due to an improved fat percentage and only one third to increased milk flow.

Juretschke(31) fed about 2.5 kilograms of coconut cake, rape cake and peanut cake, respectively, per 500 kilograms of body weight, to different cows receiving a basal ration of hay, straw, brewer's grain and wheat bran. The additions were made in three different periods of 20 days each. Milk yield and the amount of fat decreased due to advancing lactation, but it was irregular in the different periods, suggesting a possible but not clearly defined, beneficial effect of coconut cake. He concluded, however, that milk secretion is indirectly affected by feeding and that large amounts of dietary fat do not increase butterfat yield.

In 1894 Wood(32) fed three cows pure fat in the form of cottonseed oil, corn oil, palm oil, coconut oil, oleo oil and stearin during different periods. The first effect was an increased fat percent in the milk, which later returned to normal. Milk production, however, was not affected. Speir(33) obtained results similar to those of Wood.

Sebelien(34) claimed that food has no effect on the richness of milk provided the cows are properly nourished. He cited Fleischmann's works to support his views, where it was shown that variations in the fat content of milk from time to time on the same ration, were much greater than many changes which had been used to show the effect of the change in the diet.

Beglarian(35) was of a similar opinion after studying the effect of linseed oil and ground flaxseed in the ration of cows.

Soxlet(36), however, using emulsified sesame oil, linseed oil and tallow separately, obtained a marked increase in milk fat during periods varying from four days to a week in length. No account was made for milk production. Soxhlet was the first to show the inadequacy of the quotation "to feed fat into milk". He believed that increased fat content of milk did not take place by transmission of food fat into milk, but that it forced into the milk body fat.

Rhodin(37) repeated Soxhlet's work using longer periods (3 to 4 weeks) and obtained results similar to those of Wood(32). The increase in milk fat was temporary and milk secretion was not affected.

Heinrich(39), some years before, however, had shown that milk fat increased considerably in percentage and total amount, when coconut cake was fed. In this case the experiment consisted in comparing coconut cake to peanut cake, the former containing a larger amount of fat. Heinrich also noticed that individuality of the animal also plays a very important part.

Hagemann(38) failed to confirm Soxhlet's observations. The effect on milk yield was the same as reported by Wood, Rhodin and others.

Maercker(40) followed a different procedure. First he fed cows rations poor in fat and later supplemented them with palm cake and coconut cake in separate periods. In one case he used a coconut cake with 30.24 per cent of fat content. From the results obtained he concluded that the fat content of milk is markedly influenced by dietary fat, but that on the other hand, milk production is affected unfavorably. When he fed cocnut cake very rich in fat the increase in butterfat content was not sufficient to overcome the decrease in milk.

Jordan and Jenter(41) used a similar procedure. They fed a cow during 95 days a ration from which almost all the fat had been extracted. The animal, however, continued to produce milk similar to that which she yielded when fed a normal ration.

Jordan and associates repeated the above investigation(42), but increased the food fat to 1.4 pounds daily. The results again showed that the increased dietary fat did not raise milk fat nor affected milk yield above the normal level for the cow.

Morgan and coworkers(43) using sheep showed that fat in the food in the form of sesame cake or peanut oil at certain, definite levels may increase the butterfat content up to a certain limit, beyond which it varies with the individual. In an unusual large amount, they say, the fat percent may even be lowered. No mention was made as to the effect in milk yield, although it may be ascertained that no change occurred.

Hansson's extensive works(44) showed the European concept of this problem. His conclusion was that the individuality of the animal affects markedly the specific effect of any feed.

He observed also that palm-nut cake, coconut cake, cottonseed cake, linseed cake, pea and beans tend to increase milk secretion and fat content. On the other hand sesame cake, soybean cake, corn and roots although having a favorable effect on milk secretion, tend to lower its fat per cent slightly.

The experiments conducted by the Copenhagen Experiment Station(28) are perhaps the most complete in their nature. Early investigations there, in which coconut cake was compared to other cakes, showed that although the increase effected in butterfat percentage was slow, by the end of eight weeks coconut cake had caused an increase of two-tenths of a per cent. Similar results were secured with palm cakes and the rare babassu cake.

The Copenhagen Station also extended a German study in which the importance of feeding fairly fat-rich cakes to increase butterfat production had been emphasized. According to this work a cow weighing 500 kilograms would have to receive from one to one and a half kilogram of a cake daily to produce an increase of one-tenth per cent in milk fat. Due to its short duration and possible criticisms, the Danish made the same study but for a longer period of time.

Four groups of cows were fed the same feeds regarding energy requirements, but each group received a different mixture of them. The preparatory period and the one after the experimental, which they called "after period", lasted for 56 days each. During these periods all the lots received the following grain mixture:

30 Kg. Coconut cake
10 Kg. Palm cake
30 Kg. Sunflower cake
10 Kg. Peanut cake
10 Kg. Soybean cake
10 Kg. Sesame cake

During the experimental period, which lasted for 86 days, the first lot received the basal ration. Lot II was fed one half of the basal and one half of coconut cake. Lot III received one half of the basal and one half of the general allowance as palm nut cake. Lot IV was fed a mixture of 25 per cent sunflower cake, 25 per cent peanut cake, 25 per cent soybean cake and 25 per cent of sesame cake. All the animals received in addition 40 kilograms of beets, five kilograms of straw and from 4.5 to 4.9 kilograms of the corresponding mixture daily.

The result obtained indicated that milk secretion decreased in all the lots due to advance in lactation, but it was always higher in Groups II and III that received the heavy allowance of coconut and palm cakes. Fat percentage was markedly higher in the first three lots of cows during the experimental period. Lot I, however, produced milk with a higher fat content than Lots II and III, although the total production was inferior.

The data, therefore, pointed towards a marked advantage of heavy feeding with coconut and palm nut cakes during a long time, even when the energy intake is the same. The appropriate amounts of these feeds to feed is not certain, since they are known to affect butter quality.

There was no explanation as to the nature of the production of more fat, although there is supposed to exist a favourable relationship between the fats present in the feeds studied and the milk.

Steensberg claimed that there are other feeds producing similar results, although not as pronounced. Ryebran increased fat per cent in some cows from 4.1 per cent to 4.6 and in others from 4.3 to 4.6 per cent. Soybean cake and cottonseed cake and peas also belong to this group. Sunflower cake, corn and oats decrease the fat content of milk. Steensberg observes that studies in Denmark showed that sesame cake as the sole source of grain in the ration decreased fat percentage from 3.79 to 3.03.

Very little progress was made in America on the problem of the relation of dietary fat to milk production from 1901 to 1920. However, considerable research has been made since.

Woll(45) tested the effect of coconut meal with cows. His results showed that sometimes it may act favorably on the per cent of fat in the milk, but not always. He could raise it with a heavy allowance of a coconut meal containing eight per cent fat, but on the other hand milk production was decreased. When carried to a common basis, i.e., the total digestible nutrients required per pound of butterfat produced, coconut meal was inferior to the control ration.

Maynard and McCay(46) replaced the fat of the ration of four cows by an isodynamic amount of starch during a thirty day period. In contrast to the results of certain investigators, no effect was noticed in the per cent of milk fat, but milk secretion was depressed.

Sheehy(47) reported extensive works done in Ireland with different oils replacing equivalent amounts of feed in the dairy rations. The data showed that such treatment had no permanent influence on milk secretion nor on butterfat percentage in most cases and as had been reported before(43), that an excess oils may have a depressing effect if fed continuously for several days. According to Sheehy a maintenance ration containing 0.44 pound of fat with a production ration supplying 1.8 per cent more, maximum yield of butterfat can be supported.

Allen(48) used a different method of studying the problem. Instead of feeding fats of vegetable origin, he used milk and cream plus the basal ration. The animals, therefore, received fats of the same constitution as that which they produced. Allen's object was to test the immediate effect of food on the milk produced. Consequently, The experimental periods lasted only six days. Fat percentage in milk under this treatment increased markedly twenty-four hours after the first feeding of milk or cream. Skim milk produced no effect, thus showing the importance of the fat itself. However, less than 20 per cent of the butterfat fed was recovered in the milk. As to the effect on milk production no conclusions are derived.

The possibility of a deficiency of productive energy in low fat rations was eliminated by Bender and Maynard(49). They fed experimental goats a diet containing an overabundance of proteins and enegy, but only 0.45 per cent ether extract. The tests lasted from 15 to 40 days, during which a decrease in milk secretion and butterfat yield of 35 per cent to 70 per cent occurred. Substituting this ration for one with seven per cent ether extract caused the yield of milk and fat to increase. Linseed oil and coconut oil replacing equivalent amounts of starch, also caused the decrease in milk yield to stop and then to rise slightly.

Maynard and McCay(50) reported similar results with cows. Later Williams and Maynard(51), while studying the effect of dietary fat on the blood lipids of lactating goats, again confirmed the depressing effect of fat-free rations on butterfat yield. Butter oil and coconut oil, moreover, increased its percentage, while milk secretion was maintained.

Sheehy(52), in contrast to most investigators, did not observe any favorable effect by feeding high fat rations to cows. His data showed that neither olive, linseed, cottonseed, coconut, peanut, palm nut, soybean and sperm oil, nor beef fat had any specific relation to butterfat. Palm nut, cottonseed and linseed cakes responded in a similar manner, even if fed up to six pounds daily. He concluded from his study of the numerous investigations in this field, that "because one or more cows occasionally respond to certain feeds by way of an increase or a decrease of butterfat, there is no proof of a specific quantitative effect of feeds on butterfat."

Allen's work is one of the most recent on this problem(53). The investigation was a continuation from a previous one(48), but besides butterfat, lard, tallow, linseed oil, cottonseed oil, corn oil, peanut oil, soybean oil and coconut oil were also used individually. The results showed a favorable effect on the fat content of milk regardless of the breed, stage of lactation, milk yield or season of the year. The tests, however, dealt with the immediate effect of heavy fat feeding and are not reliable when applied to long-time results.

Lanzilotti(54) claimed that there is a favorable effect produced on both milk and fat by feeding oil cakes. Lynn(55) was of the same opinion. Honcamp and coworkers(56) stated that there is some increase in fat per cent by feeding coconut and other cakes, but that there is no proportionality between the dietary fat and the fat content or the yield of milk. Buschmann(57) on the other hand, failed to find any alteration in the fat content of milk by a similar procedure. A large amount of oil, however, decreased it slightly. Brower (58) and Schmidt and Vogel(59) were of the opinion that there is an increase in fat yield due to feeding fat-rich feeds.

Moczarski and Bormann(60) claimed that although milk production is not affected, fat yield is lowered by an excess of food fat in the form of rape cake.

-Summary-

The review of literature indicates that dietary fat is an essential nutrient in the diet of lactating animals. This was observed by Stohmann(29) as early as 1866. Maynard and coworkers(48,49,50,51)confirmed the necessity of fats in the ration in recent works.

An excess of fat may depress butterfat yield. Juretschke (31) was the first to make this observation. Maercker(40) fed coconut cake with a content of 30.24 per cent of fat and milk secretion decreased. Similar results were secured by Buschmann (57) and Moczarski and Bormann(60).

European investigators claim that the feeding of cakes rich in fat increases milk and butterfat yield. In the Scandinavian and other European countries, however, exceptions to that view have been reported, as may be seen from the works of Juretschke(31), Speir(33), Sebelien(34), Beglarian(35), Hagemann(38), Buschmann(57) and Moczarski and Bormann(60). The exceptions, however, can not be accepted as conclusive because data on the length of the experimental periods has not been obtained. The length of the experimental periods is very important, since German investigators(28) claim that a definite increase in butterfat production is obtained only after eight weeks of heavy fat feeding.

The American investigators have studied mainly the problem of the relation of food fat to milk secretion from the point of view of the need of fat "per se" for normal metabolism and for the immediate effect which heavy fat feeding has on butterfat production. Extensive works which may throw light on the problem of increasing butterfat production over the normal yield of an animal by feeding certain feeds, are very scarce. The study made at the Copenhagen Experiment Station(28) is the only example of such an attempt. Their results indicated that certain feeds such as coconut cake and palm nut cake have a decided favourable effect on butterfat yield, while sesame cake, corn, sunflower cake and oats decreased the fat percent.

EXPERIMENTAL WORK

PURPOSE OF THE EXPERIMENT

The objects of this investigation are as follows:

1. To determine the value of a tropical feeding stuff(velvet beans) for milk production, using a different procedure from the ones commonly employed.
2. To study the effect of dietary fat on milk secretion and on the fat content of the milk.

PLAN OF THE EXPERIMENT

Selection of the animals

<u>Number of animals used</u>- Three experimental, two-year old dairy heifers will be used. Two of them, cow 76 and 77, are Jerseys, and the other, cow 207, is a Holstein. Since the data obtained will be analyzed from the standpoint of 4% Fat-corrected milk, the breed of the animals used will be of no great concern.

Besides these two cows, three more will be used as controls. They are, in numerical order, numbers 78, 85 and 115. The purpose of using these animals will be to summarize their records of performance and use the average to check the data secured from the experimental animals. Their age and other requirements, however, meet the specifications.

<u>History of the animals</u>- Cows 76, 77 and 207 have received alfalfa hay alone since about one year of age. Their constitution, size and condition do not show unfavorable effects, however, which may be ascribel to such a treatment.. They freshened during late fall within a few days of each other. Since the data will be collected from the first butterfat test made of their milk, freshening would have no influence on the outcome of the experiment. The conditions, therefore, will be very uniform in this respect.

Management and environment- All the animals will be housed in the Dairy experimental barn and will receive the same treatment. Milking times, feeding, exercise will be kept uniform. Water will be supplied freely from water cups. Every aspect of environment will be as uniform as possible.

Feeds used

Alfalfa hay- The hay that will be used during the experiment is a second cutting, number one as to leafiness, number two as to color. Its chemical composition and digestible nutrients are recorded in Table I of the Appendix. The productive energy or starch equivalent of this hay when calculated according to the figures of Fraps(32), is 73 per cent and on this basis were the requirements of the experimental animals calculated. The composition of the ash was found to be 0.937 per cent Calcium, 0.144 per cent phosphorus and 0.251 per cent of magnesium.

As can be seen, this feed is so low in fat content that the amount is negligible. Moreover, according to the works of Fraps and Rather(37,34,35) the other extract content of hay is mostly unsaponifiable matter(80%), so that the amount of fat fed in the alfalfa will be still lower.

Starch- Care will taken to maintain the intake of nutrients well above the recommended requirements(4). After milk secretion is depressed by feeding alfalfa alone, the energy intake will be raised with corn starch.

Soybean oil meal- The soybean meal to be used in this experiment has an extremely low fat content. Its composition and digestible nutrients are presented in Table I of the Appendix. The productive value of this feed, calculated according to Fraps(62) is 67.15 per cent.

Corn- The corn that will be fed to the control animals is U. S. grade number 2. The chemical composition and digestible nutrients are shown in Table I of the Appendix.

Velvet beans- The velvet bean to be studied was bought from a commercial firm in Florida and threshed with the cooperation of the Department of Farm Crops. One ton gave approximately fifty per cent of shelled beans. A composite sample was analyzed by the Chemistry Experiment Station. The figures are presented in Table I. The coefficients of digestibility used are those reported by Ewing and Smith(5). The digestible nutrients may be seen to be practically the same as for soybean oil meal(expeller method), cottoseed meal and other feeds. The starch equivalent used was calculated from the Kellner figures for bean meal(61). The amount of total digestible nutrients is slightly lower than that given by Morrison.

According to the content of ether extract of the seed, an allowance of six pounds daily will supply nearly three-tenths of a pound of fat which is supposed to meet the requirements of an average cow.

Bone meal and salt- All the animals will be fed bone meal and salt to supply deficiencies in a ration of hay or of hay and only one grain.

Feeding plan

The best way of studying the function of a nutrient is to determine first what effects the absence of that substance will produce in the animal body. This will be kept in mind as the most important item in the experiment. After this point has been reached, the favorable effects produced by the addition of the nutrient in question will be observed in the experimental animals.

For the sake of simplicity and accuracy the experimental period will be divided up into two stages, outlined as follows:

Period I(Depletion Stage)-

Part A- Alfalfa feeding- The three experimental cows will receive alfalfa hay freely according to their nutritive requirements, beginning at their freshening date. Since they had been fed from an early age on hay, no major change which may affect experimental results can be encountered. In addition to hay each cow will receive 100 grams of bone meal and 100 grams of common salt.

A ration of alfalfa hay alone, particularly when of high quality as will be used for the experiment, can meet the requirements of animals satisfactorily, especially if they are not exceptionally high producers. Moreover, the low fat content of such a ration will probably deplete the essential fatty acids stored in the body. From this action and subsequent effects of fat feeding the value of this nutrient will be determined.

The alfalfa period will last until the cows have dropped in milk production, so that no time specifications can be made.

Part B- Alfalfa and starch feeding- The depression of milk secretion in the experimental animals suggests two possibilities: Either it is due to the absence of fat in the ration, or else, to a possible insufficient supply of energy, or to a combination of both. Since one of the objects of the experiment is to study the necessity of dietary fat by the lactating animal, all other aspects should be normal.

During this part of Period I the allowance of productive energy will be increased without altering fat intake. For such a purpose corn starch will be fed in addition to the average quantity of hay the cows are receiving, plus the mineral supplements. Alfalfa and starch feeding will last for fifteen days.

Part C- Alfalfa and soybean oil meal feeding- The possibility of a deficiency in the quality or the quantity of protein intake will be eliminated in this stage. For such a purpose soybean oil meal (solvent process) containing a very low amount of fat will used. A small proportion of the hay will be replaced with isodynamic amounts of the soybean oil meal, thus preventing extreme overabundance of energy intake.

A temporary increase in milk secretion is expected from this treatment, but since there is always a deficient essential nutrient, production will drop down again. Individuality of the animal may affect the time needed to produce these changes, so that the length of this part will not be definite, but determined by the performance of the cow.

Bone meal and salt feeding, treatment, etc., will be the same.

Period II(Velvet bean stage)-

It is apparent from the review of literature that fat is an essential item in the lactating cow's ration. The symptoms produced by its absence are decreased milk and fat production. The object of this period is to study the effect that feeding a ration with an optimum content of fat, will have on the production performance, health, condition, etc., of the experimental animals. For this purpose velvet beans were selected. The feeding procedure in this period will consist in replacing the allowance of soybean oil meal by the same weight of ground velvet beans. This amount is assumed to supply the requirements of essential fatty acids for maintenance and milk production. The nutritional value of this feed will be determined at the same time.

Period II will extend for thirty days, during which a better appreciation of the experimental results can be made.

All other conditions will be equal to those of Period I.

Collection of data

Milk production- A daily record will be kept of the milk produced by each cow. This will be averaged every three days and the results taken as the figures to calculate nutritive requirements and butterfat yield. Milk records will be kept from the date that the first butterfat test is made.

Fat production- Babcock tests will be made of each three-day composite sample of milk. From this figure and the average milk production for the same time, the butterfat produced and 4% Fat-corrected milk will be calculated. Fat-corrected milk will be calculated according to the established equation

(Milk produced x 0.4) plus (Lbs. butterfat x 15).

Graphs will be prepared to show the variations in fat percentage and production of Fat-corrected milk for every six-day period instead of three day ones. This will show the changes more markedly.

Weight of the animals- Every animal will be weighed daily at eight o'clock in the morning and the average for three days which coincide with the Babcock tests, will be used as the figure for that period. Graphs will also be presented for the six-day averages.

Calculation of the feed requirements- The digestible protein and total digestible nutrients required for each three-day period by every cow will be computed in two ways: According to the Morrison standards(4) and as starch equivalents as given by Wood(69). This step will serve only as a guide, since care will be taken to supply an overabundance of energy.

Feed records- The daily food intake will be recorded for each animal and this converted to energy and T.D.N. equivalent.

Body measurements- Weekly measurements of the barrel (depth, width and circumference) will be taken also. The unit used will be the centimeter to record the changes more efficiently. The object is to determine the effect of feeding grain and hay versus hay alone on the barrel capacity of the animal.

Physical condition- Regular notes will be made of the health and condition of the animals to determine the action that each one of the feeds may have.

Qualitative test for acetone bodies in the urine will also be made weekly for each animal according to the method described by Hawk and Bergeim(67). The urine samples will be taken during the early morning or in the evening before the last milking of the day. The object of these tests is to determine any possible relation between feeding and ketosis.

PROCEDURE FOLLOWED

The experiment is described chronologically in Table II of the Appendix. It differed in length with each cow due to her individuality. The change from one period to another was decided by the depression in milk secretion; consequently some cows required a longer time to show the effects of fat deficiency than others. Number 77, for example, needed only three weeks, while No. 76 required nearly a month and a half of soybean oil meal feeding.

Almost every step stated in the plan of the work was carried out. However, towards the later part of the soybean oil meal feeding period it was decided to determine the effect of the grains on the character of the feces from each cow. A method previously reported(68) was used. Several determinations were made irrespective of dates, but always at the same time of the day. An average of these determinations on each feed was used as the representative figure. The character of the feces was not determined until the cows had received the experimental feed at least seven days.

Tests were also performed for the flavor of the milk produced during the soybean meal and velvet bean feeding periods, respectively. The results are not tabulated since only one test in each period was made.

The conditions under which the experiment was carried out were normal throughout all the periods, except during the time between March 30 and April 4, when cows 77, 78 and 267 were fed a hay of poor quality by mistake. The effects were noticed immediately as indicated by the records.

EXPERIMENTAL RESULTS

The data collected during the course of the experiment is presented in the Appendix in the form of tables and graphs. Only the last twelve days of the alfalfa period are included in the discussion of the results to eliminate the possibility that stored factors during pregnancy may have had on the outcome of the experiment.

Milk Production

Tables III , IV and V present the milk records of cows No. 76, 77 and 267, respectively. Tables VI, VII and VIII show the performance of the three control animals. Moreover, Figures I and II present it in graphical form for the experimental animals and for the control cows, respectively. An analysis of the data is presented.

Cow 76- Milk produced by cow 76 during the first part of Period I(Alfalfa feeding) amounted to 333.2 pounds or an average of 27.7 pounds for a twelve day period. During part B which lasted fifteen days this animal produced 332.1 pounds of milk or an average of 26.1 pounds per day. There was a sudden increase in milk yield following the change to alfalfa and starch, but production dropped after three or four days, due either to the unpalatability of the starch or to fat deficiency. A change to starch and glucose feeding during the last six days of the period, did not improve milk yield, however, thus showing that unpalatability was not the factor in question.

During part C cow 76 produced 1112.5 pounds of milk or an average of 26.5 pounds daily for 42 days. There was a sudden increase in milk production also, but this time it was sustained for a longer period than with starch. By the end of the fifteenth day of soybean oil meal feeding, or the seventieth of lactation, milk yield dropped slightly and then remained at a uniform level until the end of the period. Several factors may have influenced milk production in this period. The marked increase in protein intake and decreased roughage allowance may have been the most important.

Period II or the velvet-bean stage lasted only twelve days due to the development of ketosis in the animal. After this time the cow dropped markedly in milk yield and velvet bean feeding had to be stopped. She was then fed sugar and recovered in a few days. Milk yield also returned to normal. No conclusions as to the real value of the velvet bean can be derived from the results with this cow. It is shown, however, that there is an unknown factor in the feed or in the individual which has to do with the metabolism of carbohydrates.

<u>Cow 77</u>- Milk produced by cow 77 during part A of Period I amounted to 257.2 pounds or an average of 21.4 pounds daily for twelve days. The milk production graph for this animal shows the same configuration as that of cow 76. Maximum yield occurred at the middle of the period and then dropped to twenty pounds of milk daily towards the end.

The change to starch or to glucose and starch feeding exerted no influence, however. Production decreased slightly during this stage, the average being 20.1 pounds daily for the fifteen days.

Soybean oil meal caused a slight increase in yield. During the fifteen days of this third part of period I, cow 77 produced 320.1 pounds of milk or an average of 21 pounds daily.

Her response to velvet bean feeding may be consudered as insignificant also, as far as milk yield is concerned. During this period cow 77 produced 843.2 pounds of milk or an average of 20 pounds daily for the forty-two days that velvet bean feeding lasted. Exception must be taken, however, to the deleterious effects produced by the change to poor hay feeding during the last days of the experiment. After the animal was changed back to the former hay used, milk yield increased to normal. An increase of the velvet bean allowance towards the middle of the period caused a slight increase in milk yield. Contrary to the effects produced in cow 76, cow 77 showed no abnormality from such a heavy feeding of velvet bean.

Cow 267- Milk produced by cow 267 during the first part of Period I amounted to 373.1 pounds or 26.0 pounds daily for the twelve days. The effect of starch feeding was similar to that produced in cow 76. Glucose and starch feeding, moreover, did not halt the decrease in milk production.

By the end of the forty-fourth day of lactation cow 267 was changed to soybean oil meal and alfalfa. During this period she produced 846.2 pounds of milk or 25.6 pounds daily during the 33 days it lasted. The effect of this change may be noticed in Table V. Milk production in this case followed a similar course to that of cow 76, with a sudden increase after the change. High yield was maintained for eighteen days, but it dropped down afterwards to 22 pounds by the end of the period.

The effect of velvet bean feeding on milk production was more favorable in case of this cow than in case of the other two. She produced 773.4 pounds of milk or an average of 25.8 pounds daily during thirty days. Exception must be taken also for the effects produced by the change to poor hay. The data shows, however, that before this alteration, milk production had increased to a higher level than on any occassion during soybean oil meal feeding.

Milk produced by the controls- Tables VI, VII and VIII and Figure II present the data on the milk produced by cows 78, D5 and A15. They show the normal performance of animals fed the same ration throughout a period of three months and a half, in contrast to that of animals receiving deficient rations.

Percentage and yield of Butterfat

Tables III, IV and V and Figure III present data relative to percentage and yield of butterfat of the animals used in this investigation.

Cow 76- The average fat percentage for cow 76 during part A of Period I was 4.3. During the starch feeding period it dropped to an average of 3.92 per cent. Soybean oil meal feeding, however, increased it to 4.32 per cent. Velvet bean feeding caused a favorable change by increasing it to 4.52 per cent. This indicates, therefore, a superiority of velvet beans, but the feeding period was so short in case of this cow that the results may not be significant.

Butterfat yield followed the trend in percentage. Cow 76 produced an average of 1.20 pounds of fat daily during part A of Period I. During part B she produced one pound daily. Soybean oil meal increased the yield to 1.10 pounds daily. Fat production was no greater during the velvet bean meal period than during the soybean oil meal period.

Yield of Four percent-Fat corrected milk is also presented in Table II for cow 76 and graphically in Figure I. The graph shows that there was a gradual decrease in fat-corrected milk during the alfalfa hay period. A marked drop, however, occurred during starch feeding. Soybean oil meal produced a sudden increase for the first twelve days, but it dropped down to a uniform level to the end of the period. Velvet beans showed no increase over that of the previous period, although it lasted for twelve days only.

Cow 77- The average fat percentage for cow 77 during the first part of Period I was 4.85. During the starch feeding period it dropped to 4.76 per cent. Soybean oil meal did not effect any change in it. The change to velvet bean, however, brought about a sudden and marked increase in fat percentage and it was maintained throughout the feeding period of 42 days. The average for this period was 5.1 per cent, which was 0.4 per cent higher than that during soybean oil meal feeding.

Butterfat yield was correspondingly increased by feeding velvet beans. Soybean oil meal had previously increased it slightly, but the increased yield was not supported. Starch produced a decrease in butterfat production by decreasing both milk yield and fat percentage.

Production of Fat-corrected milk was also increased by velvet bean feeding. The trend in production of Fat-corrected milk was somewhat different from that followed by cow 76. Soybean oil meal caused an immediate increase followed by a similar decrease at the end of the twelfth day. Velvet beans caused also an immediate increase in Fat-corrected milk, but this time it remained at a higher level throughout the length of the feeding period.

Cow 267- The average fat percentage for cow 267 during the first part of Period I was 3.28. During starch feeding it fell to 3.1 per cent. Soybean oil meal increased it to 3.44 per cent. Velvet bean did not effect any change in fat percentage, but supported it at the same level as soybean oil meal.

Butterfat yield was slightly increased by velvet bean feeding over that of the soybean oil meal period due to increased milk yield. The results might have been more pronounced, however, if poor hay had not been fed by mistake during the middle of the velvet bean period. Just before the poor hay feeding the butterfat production had increased to over a pound daily.

Yield of Fat-corrected milk was equally irregular during the experiment. Starch feeding did not improve it over the level of the previous period. It dropped, instead, from an average of 26 pounds daily to only twenty pounds. Soybean oil meal caused a gradual increase to 25 pounds, but it was unable to support it at this level, falling down to twenty-one pounds by the end of the fifteenth day. Velvet bean feeding markedly increased production of Fat-corrected milk twelve days after its feeding began.

Butterfat production by the controls - The data for the three control animals are presented in Tables VI, VII and VIII and Figures IV and VI. These data may be used as a check or demonstration of the butterfat percentage and yield of butterfat and Fat-corrected milk by animals under a uniform treatment throughout the experiment, and their normal variations compared to cows which have received different feeds.

Liveweight

The data on liveweight are presented in Tables III, IV and V and graphically in Figure VII for the three experimental animals.

The effects of the different treatments were not so definite or marked on liveweight as on milk production.

Cow 76 showed no particular change in liveweight throughout the experiment. The changes were so slight that they may be considered within the normal variations.

Cow 77 followed a similar course, although velvet bean feeding showed a somewhat favorable action. By the end of this period she had increased to the same level as shortly after freshening.

Cow 267 showed the most favorable effect on body weight by velvet bean feeding. This animal increased from 984 pounds at the end of the first period to 1060 pounds during the velvet bean feeding period.

Feed consumed

All the feeds used, except corn starch, were eaten with a relish by the cows. It was necessary to replace a part of the corn starch with sugar in order to keep up energy intake. The numerous complaints in the literature on low palatability of velvet beans were not confirmed in this experiment. The cows ate the beans from the start, except cow 76 which went off-feed due to ketosis.

Condition of the animals

Cow 76 developed a marked ketosis after fifteen days on the velvet bean ration. The remaining animals used in the investigation were normal. Control cow 78 became very fat due to excess energy fed.

Consistency of the feces

The character of the feces produced by each animal was studied only during the soybean oil meal and velvet bean feeding periods. Cow 78 was the only animal studied in the control group.

The average of the readings are presented in the following table:

Cow No.	Feeding Period	
	Soybean o. Meal	Velvet Bean
76	10.35°	10.37°
77	11.35°	9.66°
267	12.86°	14.00°

78(Control) Average of 4 readings- 13.6°

Soybean oil meal and velvet beans had about the same laxative power as corn. Only in cow 77 were the feces harder, as indicated by a lower figure, during the velvet bean feeding period. In cow 267, however, the feces were softer than during soybean oil meal feeding. No alteration occurred in the consistency of the feces of cow 76.

Body measurements

The weekly barrel measurements throughout the experiment are presented in Table XV for cows 76, 77, 207 and 78. The three experimental cows showed a decrease in barrel capacity, as was indicated by the measurements, during the first part of Period I(Alfalfa feeding), and a further drop during part two. It stayed at a uniform level throughout the third part. Velvet bean feeding, however, caused a slight increase in the measurements of cow 76 and a gradual increase in cow 77 and 207. Control cow 78 showed uniform measurements throughout the investigation.

Acetone bodies in the urine

The weekly qualitative tests for acetone bodies in the urine were made for all the cows except D5 and A15. All the animals were normal in this respect throughout the experiment except 76. Cow 76 developed a marked ketosis shortly after the beginning of the velvet bean feeding period. A quantitative analysis of the urine for acetone bodies showed 200 milligrams per 100 milliliters. The symptoms exhibited were severe drop in milk secretion and body weight, loss of appetite and froth in the mouth. A change from velvet bean to sugar feeding brought about a rapid recovery in health and milk production.

DISCUSSION

This investigation was carried out to determine the value of velvet beans for milk production when compared to soybean oil meal, and to study the relation of dietary fat to milk secretion when it is added to fat deficient rations. Two two-year old Jersey heifers and one Holstein were used as experimental animals. Three control cows were also used.

The experiment was divided into two major periods. The first one consisted in feeding fat deficient rations to the three experimantal animals. The second consisted in replacing ground velvet bean for the grain used in the previous part. The plan is described by dates in Table II. The control group received a uniform ration throughout the experiment.

The investigation lasted from 110 to 120 days and in case of numbers 77 and 207 the velvet bean feeding period lasted more than a month to determine more accurately the value of this feed. Cow 76 developed ketosis shortly after the beginning of the period so that it only lasted twelve days for her.

Data was collected for milk production, percentage and production of butterfat, liveweight, feed intake, weekly barrel measurements, condition of the animals, consistency of their feces, production of acetone bodies in the urine and quality of the milk produced. The results are presented in tables and graphs in the Appendix.

When six pounds of soybean oil meal low in fat were used in place of sugar, starch and some of the alfalfa hay, there was an increase in milk production. This effect in milk production was of short duration and was followed by a decrease in milk flow. The drop in milk was probably due to a fat deficiency in view of the work reported by Maynard and associates (46,49,50). The time required for milk production to decrease on the alfalfa-soybean oil meal ration varied with the individual cow. Cow 77 required about fifteen days, cow 76, forty-two days and Cow 267 thirty-three days for the effect of the fat deficiency to become apparent.

There was no definite effect from feeding velvet bean on the butterfat percentage of the milk produced by cows 76 and 267. The butterfat percentage of cow 77, however, increased four-tenths of a per cent over the average of the soybean oil meal period. These results are not in agreement with the observations made by other workers who found that the feeding of fat increases the butterfat percentage temporarily. The sudden increase in the fat per cent in cow 77 agrees with the reports by Wood(32), Rhodin(37) and Hagemann(38). The increased test, however, stayed at a high level throughout the feeding period.

Production of Four-percent Fat-corrected milk increased in cows 77 and 267 during the velvet bean period. The increased production in number 77 was due to increased butterfat percentage. In number 267 it was due instead, to increased total milk yield, fat percentage remaining the same.

The liveweight of the animals was not changed significantly during the velvet bean feeding period. Two cows, numbers 77 and 267, however, showed an increase in body weight during the last few days of the experiment.

No particular difference in flavor was observed in the milk produced either during the corn, soybean oil meal or velvet bean feeding.

The study of the character of the feces indicated that the velvet bean has practically the same degree of laxativeness as soybean oil meal and corn. Cow 77 was the only animal that showed an increased hardness of the feces during the feeding of velvet beans,

The barrel measurements of the cows used in the investigation decreased on alfalfa hay and on alfalfa-starch feeding. Soybean oil meal did not produce any change. The feeding of velvet beans, however, increased the barrel measurements of two cows, but in another the effect was not significant.

Feeding of low-fat rations or of one containing normal amounts was not related to the production of acetone bodies in the urine of the cows. In case of number 76 the condition was not studied carefully to determine the real nature of the ketosis produced.

SUMMARY AND CONCLUSIONS

1. Ground velvet beans compared favorably with soybean oil meal(solvent extracted) for milk production. Milk production was either unaltered or increased by feeding velvet beans. Butterfat percentage was markedly raised in one cow for a considerable length of time. The other two cows used showed no effect, however, in this respect.

2. An alfalfa hay, low fat soybean oil meal ration did not support milk production. When velvet bean replaced the soybean oil meal there was an increase in the yield of four-percent fat-corrected milk. These results indicate that dietary fat is essential for milk secretion.

3. Palatability was not a limiting factor in the results secured with velvet beans in this investigation. The cows ate six pounds per day with a relish. No deleterious effects were encountered except in cow 78, which suffered from ketosis. The bean, moreover, is not costive when compared to corn or soybean oil meal.

4. The data presented does not support the opinions of other investigators that the velvet bean possesses half the milk producing value of other protein rich feeds. Although the results of the investigation indicate that the velvet bean is superior to solvent extracted soybean oil meal for milk production, yet it is possible that more favorable results would have been secured had the velvet bean been fed in combination with other feeds.

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APPENDIX

TABLE I

Chemical composition and digestible nutrients of the feeds used**

Composition						
Feed	Water	Cr.Protein	Ether Extr.	Cr.Fiber	N-free Extr.	Ash
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Alfalfa hay	13.83	16.44	1.51	28.30	32.10	7.82
Soybean Oil Meal(solvent)	10.92	45.37	0.29	5.90	31.70	5.82
Velvet bean	11.64	23.25	5.41	8.58	48.13	2.99
Corn (No.2)	14.33	9.56	2.29	1.91	69.48	2.42
Barley	13.07	12.50	2.00	5.11	64.01	3.31
Bone Meal	2.87	7.75	0.65	--	- -	77.33

Digestible Nutrients (in 100 lbs.)						
Feed	Cr.Protein	Ether Extr.	Cr.Fiber	N-free Extr.	T.D.N.	Starch Equival.
Alfalfa Hay	11.83	0.18	12.18	22.78	48.0	33.0
Soybean O.Meal	38.56	0.24	4.01	31.06	73.6	68.0
Velvet bean	17.20	4.16	5.53	31.63	74.0	70.0
Corn	7.26	2.08	1.09	65.30	86.0	80.6
Barley	9.87	1.82	2.86	58.88	75.0	70.0

**-Note- Morrison's coefficients of digestibility(4) used.

TABLE II

Program of the Experimental Periods

	PERIOD I			PERIOD II
	Part A**	Part B	Part C	
Cow No.	Alfalfa Hay	Alfalfa Hay-Starch	Alfalfa Hay-Soybean O.Meal	Alfalfa Hay-Velvet bean
	Date	Date	Date	Date
76	Dec.24 - Jan.28	Jan.29 - Feb.12	Feb.13 - Mar.26	Mar.27 - Apr.7
77	Dec.24 - Jan.28	Jan.29 - Feb.12	Feb.13 - Feb.27	Feb.28 - Mar.26
267	Jan. 8 - Jan.28	Jan.29 - Feb.12	Feb.13 - Mar.17	Mar.18 - Apr.16

**- Last twelve days included in the discussion

TABLE III

COW NO. 76

Record of liveweight and production by 3-day period during the course of the experiment

Date	Days in lactation	Live Weight	Milk Produced	Fat Percent	Butterfat Produced	4% F. C. M.
		lbs.	lbs.		lbs.	lbs.
PERIOD I-Part A						
Dec.24-26	5-7	802	22.40	7.3	1.635	33.48
27-29	8-10	807	23.70	5.1	1.209	27.61
30-1	11-13	782	26.20	5.1	1.336	30.52
Jan. 2-4	14-16	794	26.90	4.8	1.291	30.11
5-7	17-19	802	28.50	4.7	1.339	31.48
8-10	20-22	810	29.00	4.7	1.363	32.04
11-13	23-25	808	29.30	4.4	1.289	31.05
14-16	26-28	780	29.30	4.6	1.347	31.92
17-19	29-31	794	28.40	4.4	1.249	30.09
20-22	32-34	757	28.20	4.1	1.156	28.62
23-25	35-37	781	28.50	4.3	1.225	29.77
26-28	38-40	784	26.60	4.4	1.170	28.19
Part B						
29-31	41-43	749	28.80	4.1	1.181	29.23
Feb. 1-3	44-46	755	25.80	3.8	0.980	25.00
4-6	47-49	736	25.50	4.1	1.045	25.87
7-9	50-52	740	24.50	3.8	0.931	23.76
10-12	53-55	760	26.00	3.8	0.983	25.22

TABLE III (continued)

Date	Days in lactation	Live Weight	Milk Produced	Fat Percent	Butterfat Produced	4% F. C. M.
		lbs.	lbs.		lbs.	lbs.
PERIOD I-Part C						
Feb. 13-15	56-58	758	27.80	3.9	1.084	27.38
16-18	59-61	760	27.80	4.2	1.168	28.64
19-21	62-64	755	28.20	4.3	1.213	29.47
22-24	65-67	750	27.90	4.3	1.200	29.16
25-27	68-70	743	28.20	3.8	1.071	27.34
28-2	71-73	723	26.50	4.1	1.086	26.89
Mar. 3-5	74-76	755	25.90	4.2	1.088	26.68
6-8	77-79	740	26.30	4.6	1.210	28.67
9-11	80-82	745	25.00	4.4	1.100	26.50
12-14	83-85	741	24.00	4.6	1.104	26.16
15-17	86-88	741	25.30	4.4	1.114	26.86
18-20	89-91	750	26.60	4.6	1.224	29.00
21-23	92-94	755	25.50	4.2	1.071	26.26
24-26	95-97	758	25.80	4.4	1.135	27.34
PERIOD II-						
Mar. 27-29	98-100	745	23.60	4.5	1.062	25.37
30-1	101-103	745	25.40	4.5	1.143	27.30
Apr. 2-4	104-106	745	25.80	4.9	1.264	29.28
5-7	107-109	759	25.20	4.2	1.058	25.95

TABLE IV

COW NO. 77

Record of liveweight and production by 3-day

period during the course of the experiment

Date	Days in lactation	Live Weight	Milk Produced	Fat Percent	Butterfat Produced	4% F. C. M.
		lbs.	lbs.		lbs.	lbs.
PERIOD I-Part A						
Dec. 24-26	13-15	752	23.10	5.1	1.178	26.91
27-29	16-18	735	23.20	5.0	1.160	26.68
30-1	19-21	718	24.20	5.1	1.234	28.19
Jan. 2-4	22-24	731	24.30	5.0	1.215	27.94
5-7	25-27	726	23.60	5.2	1.227	27.84
8-10	28-20	729	23.30	5.2	1.212	27.50
11-13	31-33	723	23.30	4.5	1.048	26.04
14-16	34-36	717	23.10	4.9	1.132	26.22
17-19	37-39	706	22.70	5.4	1.228	27.47
20-22	40-42	713	22.20	4.3	0.955	23.80
23-25	43-45	711	21.10	4.7	0.992	23.32
26-28	46-48	702	20.50	5.0	1.025	23.57
Part B						
29-31	49-51	670	20.70	5.5	1.138	25.35
Feb. 1-3	52-54	681	20.70	4.6	0.952	22.56
4-6	55-57	690	19.70	4.9	0.965	22.35
7-9	58-60	690	19.90	4.2	0.836	20.50
10-12	61-63	692	19.60	4.6	0.902	21.37

TABLE IV(continued)

Date	Days in lactation	Live Weight	Milk Produced	Fat Percent	Butterfat Produced	4% F. C. M.
		lbs.	lbs.		lbs.	lbs.
PERIOD I -Part C						
Feb.13-15	64-66	687	21.50	4.6	0.989	23.43
16-18	67-69	682	20.90	5.3	1.108	24.98
19-21	70-72	663	21.30	4.8	1.022	23.85
22-24	73-75	682	22.00	4.8	1.056	24.64
25-27	76-78	673	21.00	4.1	0.861	21.31
PERIOD II-						
28-2	79-81	676	19.60	5.3	1.039	23.42
Mar. 3-5	82-84	694	20.90	5.4	1.128	25.28
6-8	85-87	694	20.80	5.1	1.061	24.24
9-11	88-90	684	19.70	5.1	1.005	22.96
12-14	91-93	679	20.10	5.2	1.045	23.71
15-17	94-96	689	19.40	5.3	1.028	23.18
18-20	97-99	692	20.30	5.0	1.015	27.34
21-23	100-102	678	21.20	5.3	1.124	25.34
24-26	103-105	696	20.80	5.3	1.102	24.85
27-29	106-108	696	20.60	4.7	0.968	22.68
30-1	109-111	676	19.30	5.0	0.965	22.39
Apr. 2-4	112-114	688	18.10	5.1	0.923	21.08
5-7	115-117	719	19.50	4.8	0.936	21.84

TABLE V

COW NO. 267

Record of liveweight and production by 3-day

period during the course of the experiment

Date	Days in lactation	Live Weight	Milk Produced	Fat Percent	Butterfat Produced	4% F. C. M.
		lbs.	lbs.		lbs.	lbs.
PERIOD I-Part A						
Jan. 8-10	9-11	1053	27.90	3.7	1.032	26.64
11-13	12-14	1054	29.30	3.6	1.054	27.53
14-16	15-17	1032	30.20	3.2	0.966	27.02
17-19	18-20	1020	27.20	3.7	1.006	25.97
20-22	21-23	1022	27.20	2.9	0.789	22.71
23-25	24-26	1010	25.20	3.3	0.832	22.56
26-28	27-29	1012	24.70	3.3	0.815	22.10
Part B						
29-31	30-32	984	25.90	3.5	0.906	23.95
Feb. 1-3	33-35	982	25.30	3.3	0.835	22.64
4-6	36-38	965	23.20	3.3	0.766	20.77
7-9	39-41	952	20.70	2.6	0.538	16.35
10-12	42-44	972	25.60	2.8	0.717	20.99
Part C						
Feb. 13-15	45-47	990	26.00	3.0	0.780	22.10
16-18	48-50	986	26.80	3.2	0.858	23.59
19-21	51-53	977	26.20	3.3	0.865	23.45

TABLE V(continued)

Date	Days in lactation	Live Weight	Milk Produced	Fat Percent	Butterfat Produced	4% F. C. M.
		lbs.	lbs.		lbs.	lbs.
Feb.22-24	54-56	966	27.30	3.3	0.901	24.43
25-27	57-59	983	27.60	2.9	0.800	23.04
28-2	60-62	953	27.10	3.3	0.894	24.25
Mar. 3-5	63-65	989	23.70	3.5	0.821	21.91
6-8	66-68	988	27.50	3.4	0.935	25.02
9-11	69-71	973	24.80	3.5	0.868	22.94
12-14	72-74	969	22.00	4.0	0.880	22.00
15-17	75-77	984	22.90	3.5	0.802	21.63
PERIOD II						
18-20	78-80	975	26.10	3.2	0.835	22.96
21-23	81-83	983	27.50	3.6	0.935	25.02
24-26	84-86	998	26.80	3,6	0.965	25.67
27-29	87-89	1003	29.50	3.7	1.091	28.16
30-1	90-92	981	25.70	3.6	0.925	24.15
Apr. 2-4	93-95	995	22.80	3.3	0.752	20.40
5-7	96-98	1010	24.60	3.3	0.812	22.02
8-10	99-101	1065	26.30	3.5	0.920	24.32
11-13	102-104	1041	25.60	3.6	0.922	24.07
14-16	105-107	1052	22.80	3.7	0.844	21.78

TABLE VI

COW NO.78 (CONTROL)

Record of liveweight and production by 3-day period during the course of the experiment

Date	Days in lactation	Live Weight	Milk Produced	Fat Percent	Butterfat Produced	4% F. C. M.
		lbs.	lbs.		lbs.	lbs.
Dec.24-26	10-12	850	28.20	4.3	1.212	29.46
27-29	13-15	860	28.50	4.2	1.197	29.35
30-1	16-18	813	30.00	4.2	1.260	30.90
Jan. 2-4	19-21	823	31.90	4.9	1.563	36.20
5-7	22-24	840	32.30	4.3	1.388	33.74
8-10	25-27	835	32.50	3.7	1.202	31.03
11-13	28-30	850	31.80	3.9	1.240	31.32
14-16	31-33	844	30.80	4.4	1.355	32.64
17-19	34-36	847	31.20	4.6	1.435	34.00
20-22	37-39	829	32.00	4.9	1.568	36.32
23-25	40-42	818	31.20	4.8	1.497	34.94
26-28	43-45	821	30.30	4.4	1.333	32.11
29-31	46-48	813	29.90	4.5	1.345	32.13
Feb. 1-3	49-51	820	30.20	4.3	1.299	31.56
4-6	52-54	830	29.30	4.4	1.289	31.05
7-9	55-57	840	30.40	4.1	1.244	30.85
10-12	58-60	833	29.20	4.3	1.256	30.52
13-15	61-63	836	28.70	4.0	1.148	28.70

TABLE VI(continued)

Date	Days in lactation	Live Weight	Milk Produced	Fat Percent	Butterfat Produced	4% F. C. M.
		lbs.	lbs.		lbs.	lbs.
Feb.16-18	64-66	834	28.30	3.9	1.104	27.88
19-21	67-69	820	28.10	4.1	1.152	28.52
22-24	70-72	846	28.50	4.2	1.197	29.35
25-27	73-75	858	27.20	4.4	1.197	28.83
28-2	76-78	839	28.20	4.8	1.354	31.59
Mar. 3-5	79-81	833	28.00	4.2	1.176	28.84
6-8	82-84	840	28.00	4.1	1.148	28.40
9-11	85-87	860	27.70	4.3	1.191	28.94
12-14	88-90	857	27.20	4.8	1.306	30.45
15-17	91-93	852	26.30	4.4	1.157	27.87
18-20	94-96	855	28.60	4.6	1.316	31.38
21-23	97-99	860	26.60	4.3	1.144	27.80
24-26	100-102	870	26.90	4.3	1.157	28.11
27-29	103-105	865	26.90	4.3	1.157	28.11
30-1	106-108	850	25.00	4.7	1.175	27.62
Apr. 2-4	109-111	860	24.20	4.8	1.163	27.11
5-7	112-114	866	24.10	4.6	1.109	26.27

TABLE VII

COW NO. D5 (CONTROL)

Record of liveweight and production by 3-day period during the course of the experiment

Date	Days in lactation	Live Weight	Milk Produced	Fat Percent	Butterfat Produced	4% F. C. M.
		lbs.	lbs.		lbs.	lbs.
Dec. 12-14	8-10	1176	59.70	4.0	2.388	59.70
15-17	11-13	1182	60.60	3.6	2.182	56.97
18-20	14-16	1156	59.60	3.7	2.205	56.91
21-23	17-19	1147	58.20	3.5	2.040	53.92
24-26	20-22	1142	58.40	3.4	1.986	53.15
27-29	23-25	1149	57.40	3.4	1.952	52.24
30-1	26-28	1112	59.40	3.5	2.079	54.94
Jan. 2-4	29-31	1147	59.50	3.0	1.785	50.51
5-7	32-34	1141	58.50	3.1	1.813	50.59
8-10	35-37	1122	59.10	3.0	1.773	50.23
11-13	38-40	1126	60.40	2.6	1.570	47.71
14-16	41-43	1111	62.90	2.6	1.635	49.68
17-19	44-46	1127	59.30	3.0	1.779	50.40
20-22	47-49	1130	63.30	2.7	1.709	50.95
23-25	50-52	1103	49.50	3.0	1.485	42.07
26-28	53-55	1107	50.40	3.5	1.764	46.62
29-31	56-58	1090	55.20	3.0	1.656	46.92

TABLE VII(continued)

Date	Days in lactation	Live Weight	Milk Produced	Fat Percent	Butterfat Produced	4% F. C. M.
		lbs.	lbs.	.	lbs.	lbs.
Feb. 1-3	59-61	1093	59.80	2.7	1.615	48.14
4-6	62-64	1119	59.50	2.5	1.487	46.10
7-9	65-67	1119	58.50	2.4	1.404	44.46
10-12	68-70	1139	59.20	2.6	1.539	46.74
13-15	71-73	1166	60.00	2.8	1.680	49.20
16-18	74-76	1163	56.20	2.8	1.574	46.09
19-21	77-79	1163	56.80	2.9	1.647	47.42
22-24	80-82	1153	60.30	2.8	1.688	49.44
25-27	83-85	1157	59.30	2.5	1.482	45.95
28-2	86-88	1116	59.30	2.6	1.542	47.25
Mar. 3-5	89-91	1132	55.80	2.7	1.507	44.92
6-8	92-94	1137	57.80	2.6	1.503	45.66
9-11	95-97	1139	56.40	2.8	1.579	46.24
12-14	98-100	1153	57.00	2.8	1.596	46.74
15-17	101-103	1166	59.90	2.8	1.677	49.11
18-20	104-106	1165	59.70	2.6	1.552	47.16
21-23	107-109	1150	57.70	2.8	1.616	47.32
24-26	110-112	1173	59.70	2.7	1.612	48.96
27-29	113-115	1169	62.00	2.7	1.674	49.91

TABLE VIII

COW NO. A15 (CONTROL)

Record of liveweight and production by 3-day period during the course of the experiment

Date	Days in lactation	Live Weight	Milk Produced	Fat Percent	Butterfat Produced	4% F. C. M.
		lbs.	lbs.		lbs.	lbs.
Dec. 12-14	6-8	1016	37.80	3.3	1.247	33.82
15-17	9-11	1007	39.90	3.1	1.237	34.51
18-20	12-14	989	40.90	3.0	1.227	34.76
21-23	15-17	933	35.60	3.8	1.353	34.53
24-26	18-20	940	37.00	3.6	1.332	34.78
27-29	21-23	960	41.60	3.0	1.248	35.36
30-1	24-26	948	41.90	3.2	1.341	36.78
Jan. 2-4	27-29	972	41.90	3.0	1.257	35.61
5-7	30-32	977	42.30	3.2	1.354	37.23
8-10	33-35	967	43.20	3.1	1.339	37.36
11-13	36-38	987	43.90	3.2	1.405	38.63
14-16	39-41	983	44.40	3.0	1.332	37.74
17-19	42-44	990	43.40	3.1	1.345	37.53
20-22	45-47	999	41.60	3.1	1.290	35.99
23-25	48-50	993	39.00	3.5	1.365	36.07
26-28	51-53	996	40.50	3.3	1.336	36.24
29-31	54-56	965	41.30	3.1	1.280	35.72
Feb. 1-3	57-59	987	40.50	3.0	1.215	33.44
4-6	60-62	988	38.60	3.4	1.312	35.12

TABLE VIII (continued)

Date	Days in lactation	Live Weight	Milk Produced	Fat Percent	Butterfat Produced	4.0 F. C. M.
		lbs.	lbs.		lbs.	lbs.
Feb. 7-9	63-65	1005	40.50	2.5	1.012	31.38
10-12	66-68	1000	40.90	3.2	1.309	35.99
13-15	69-71	998	42.70	3.1	1.324	36.94
16-18	72-74	1000	42.10	3.0	1.263	35.78
19-21	75-77	1005	42.20	3.0	1.266	35.87
22-24	78-80	1016	41.70	3.0	1.251	35.44
25-27	81-83	1016	41.30	3.0	1.239	35.10
28-2	84-86	1001	40.40	2.9	1.172	33.74
Mar. 3-5	87-89	1027	39.50	3.2	1.264	34.76
6-8	90-92	1033	40.10	3.0	1.203	34.08
9-11	93-95	1024	38.30	3.3	1.264	34.28
12-14	96-98	1025	38.00	3.4	1.292	34.56
15-17	99-101	1027	38.00	3.4	1.292	34.56
18-20	102-104	1018	40.50	3.0	1.215	34.44
21-23	105-107	1033	42.10	3.0	1.263	35.78
24-26	108-110	1032	39.70	3.1	1.231	34.34
27-29	111-113	1039	41.80	3.2	1.378	36.79

TABLE IX

COW NO. 76

Feed ingested during the course of the experiment

Date	Days in lactation	Alfalfa Hay	Bone Meal	Salt	Corn Starch	Soybean oil Meal	Velvet bean Meal	T.D.N. Rec'd.	Starch Equiv. Rec'd.
		lbs.	gr.	gr.	lbs.	lbs	lbs.	lbs	lbs.
PERIOD I-Part A									
Dec. 24-26	5-7	21.3	-	-	-	-	-	10.22	7.10
27-29	8-10	20.5	-	-	-	-	-	9.84	6.80
30-1	11-13	24.2	-	-	-	-	-	11.62	8.06
Jan. 2-4	14-16	23.5	100	100	-	-	-	11.28	7.83
5-7	17-19	25.5	"	"	-	-	-	12.24	8.50
8-10	20-22	29.5	"	"	-	-	-	14.60	9.80
11-13	23-25	27.8	"	"	-	-	-	13.34	9.30
14-16	26-28	29.2	"	"	-	-	-	14.02	9.70
17-19	29-31	28.3	"	"	-	-	-	13.58	9.40
20-22	32-34	27.5	"	"	-	-	-	13.20	9.20
23-25	35-37	27.5	"	"	-	-	-	13.20	9.20
26-28	38-40	28.2	"	"	-	-	-	13.53	9.40
Part B									
29-31	41-43	26.5	"	"	4	-	-	16.72	12.83
Feb. 1-3	44-46	28.0	"	"	4	-	-	17.44	13.33
4-6	47-49	27.0	"	"	4	-	-	16.96	13.00
7-9	50-52	27.0	"	"	4*	-	-	16.96	12.50
10-12	53-55	28.0	"	"	4*	-	-	17.44	13.33

*- changed to 2 lbs. starch and 2 lbs. of glucose.

TABLE IX(continued)

Date	Days in lactation	Alfalfa Hay	Bone Meal	Salt	Corn Starch	Soybean oil Meal	Velvet bean Meal	T.D.N. Rec'd.	Starch Equiv. Rec'd.
		lbs.	gr.	gr.	lbs.	lbs.	lbs.	lbs.	lbs.
PERIOD I-Part C									
Feb.13-15	56-58	23.3	100	100	-	6	-	15.54	11.79
16-18	59-61	23.6	"	"	-	6	-	15.69	11.89
19-21	62-64	24.6	"	"	-	6	-	16.17	12.23
22-24	65-67	24.5	"	"	-	6	-	16.12	12.20
25-27	68-70	25.2	"	"	-	6	-	16.46	12.43
28-2	71-73	24.6	"	"	-	6	-	16.17	12.23
Mar. 3-5	74-76	24.0	"	"	-	6	-	15.86	12.03
6-8	77-79	25.0	"	"	-	6	-	16.36	12.76
9-11	80-82	24.0	"	"	-	6	-	15.88	12.03
12-14	83-85	23.2	"	"	-	6	-	15.50	11.70
15-17	86-88	24.2	"	"	-	6	-	15.98	12.10
18-20	89-91	25.3	"	"	-	6	-	16.50	12.46
21-23	92-94	25.0	"	"	-	6	-	16.38	12.78
24-26	95-97	21.0	"	"	-	6	-	14.44	11.03
PERIOD II									
27-29	98-100	26.0	"	"	-	-	6	16.92	12.86
30-1	101-103	24.5	"	"	-	-	6	15.72	12.03
Apr.2-4	104-106	25.0	"	"	-	-	6	16.44	12.53
5-7	107-109	22.0	"	"	-	-	6	15.00	11.50

TABLE X

COW NO. 77

Feed ingested during the course of the experiment

Date	Days in lactation	Alfalfa Hay	Bone Meal	Salt	Corn Starch	Soybean oil Meal	Velvet bean Meal	T.D.N. Rec'd.	Starch Equiv. Rec'd.
		lbs.	gr.	gr.	lbs.	lbs.	lbs.	lbs.	lbs.
PERIOD I-Part A									
Dec. 24-26	13-15	23.0	50	50	-	-	-	10.70	7.60
27-29	16-18	21.5	"	"	-	-	-	10.72	7.20
30-1	19-21	23.2	100	100	-	-	-	11.14	7.70
Jan. 2-4	22-24	22.9	"	"	-	-	-	10.99	7.60
5-7	25-27	27.5	"	"	-	-	-	13.20	9.20
8-10	28-30	28.0	"	"	-	-	-	13.44	9.70
11-13	31-33	27.2	"	"	-	-	-	13.06	9.10
14-16	34-36	25.8	"	"	-	-	-	12.38	8.60
17-19	37-39	24.2	"	"	-	-	-	11.62	8.10
20-22	40-42	26.0	"	"	-	-	-	12.48	8.60
23-25	43-45	26.8	"	"	-	-	-	12.66	8.90
26-28	46-48	24.3	"	"	-	-	-	11.66	8.10
Part B									
29-31	49-51	26.5	"	"	4.5	-	-	17.22	13.30
Feb. 1-3	52-54	27.6	"	"	4.5	-	-	17.55	13.70
4-6	55-57	27.2	"	"	4.5	-	-	17.56	13.60
7-9	58-60	27.5	"	"	4.5*	-	-	17.64	13.24
10-12	61-63	27.2	"	"	4.5*	-	-	17.56	12.99

*- changed to 2¼ lbs. starch and 2¼ lbs. glucose.

TABLE X(continued)

Date	Days in lactation	Alfalfa Hay	Bone Meal	Salt	Corn Starch	Soybean oil Meal	Velvet bean Meal	T.D.N. Rec'd.	Starch Equiv. Rec'd.
		lbs.	gr.	gr.	lbs.	lbs.	lbs.	lbs.	lbs.
PERIOD I-Part 2									
Feb. 13-15	64-66	20.5	100	100	-	6	-	13.84	10.83
16-18	67-69	24.0	"	"	-	6	-	15.88	12.03
19-21	70-72	24.5	"	"	-	6	-	16.17	12.83
22-24	73-75	23.3	"	"	-	6	-	15.54	11.72
25-27	76-78	26.8	"	"	-	6	-	16.76	12.83
PERIOD II-									
28-2	79-81	28.6	"	"	-	-	6	16.74	13.27
Mar. 3-5	82-84	25.8	"	"	-	-	6	15.66	12.63
6-8	85-87	25.2	"	"	-	-	6	16.54	13.10
9-11	88-90	25.0	"	"	-	-	6	16.44	13.00
12-14	91-93	21.5	"	"	-	-	6	14.76	11.90
15-17	94-96	22.8	"	"	-	-	6	15.58	12.30
18-20	97-99	22.2	"	"	-	-	7	15.84	12.30
21-23	100-103	21.0	"	"	-	-	7	15.26	11.90
24-26	103-105	20.6	"	"	-	-	7	15.07	11.76
27-29	106-108	22.3	"	"	-	-	7	15.88	12.33
30-1	109-111	19.2	"	"	-	-	7	14.40	11.30
Apr. 2-4	112-114	22.0	"	"	-	-	7	15.74	12.27
5-7	115-117	18.6	"	"	-	-	7	14.11	11.10

TABLE XI

COW NO. 267

Feed ingested during the course of the experiment

Date	Days in Lactation	Alfalfa Hay	Bone Meal	Salt	Corn Starch	Soybean oil Meal	Velvet bean Meal	T.D.N. Rec'd.	Starch Equiv. Rec'd.
		lbs.	gr.	gr.	lbs.	lbs.	lbs.	lbs.	lbs.
PERIOD I-Part A									
Jan. 8-10	9-11	36.0	100	100	-	-	-	17.28	12.00
11-13	12-14	36.0	"	"	-	-	-	17.28	12.00
14-16	15-17	36.5	"	"	-	-	-	17.56	12.16
17-19	18-20	34.5	"	"	-	-	-	16.56	11.50
20-22	21-23	37.0	"	"	-	-	-	17.76	12.70
23-25	24-26	36.0	"	"	-	-	-	18.24	12.60
26-28	27-29	37.[illegible]	"	"	-	-	-	17.86	12.40
Part B									
29-31	30-32	34.8	"	"	3.5	-	-	19.72	14.80
Feb. 1-3	33-35	36.8	"	"	3.5	-	-	21.16	15.50
4-6	36-38	36.5	"	"	3.5	-	-	21.02	15.70
7-9	39-41	37.3	"	"	3.5*	-	-	21.50	15.50
10-12	42-44	37.5	"	"	3.5*	-	-	21.60	15.70
Part C									
13-15	45-47	30.3	"	"	-	6	-	18.30	14.13
16-18	48-50	32.8	"	"	-	6	-	20.10	14.86
19-21	51-53	33.0	"	"	-	6	-	20.20	15.03
22-24	54-56	33.0	"	"	-	6	-	20.20	15.03

*- changed to 1¾ lbs. starch and 1¼ lbs. glucose.

TABLE XI (continued)

Date	Days in lactation	Alfalfa Hay	Bone Meal	Salt	Corn Starch	Soybean oil Meal	Velvet bean Meal	T.D.N. Rec'd.	Starch Equiv. Rec'd.
		lbs.	gr.	gr.	lbs.	lbs.	lbs.	lbs.	lbs.
Feb. 25-27	57-59	33.0	100	100	-	6	-	20.20	15.03
28-2	60-62	33.0	"	"	-	6	-	20.20	15.03
Mar. 3-5	63-65	33.0	"	"	-	6	-	20.20	15.03
6-8	66-68	33.0	"	"	-	6	-	20.20	15.03
9-11	69-71	33.0	"	"	-	6	-	20.20	15.03
12-14	72-74	33.0	"	"	-	6	-	20.20	15.03
15-17	75-77	32.0	"	"	-	6	-	19.72	14.60
PERIOD II									
18-20	78-80	33.0	"	"	-	-	6	20.28	15.20
21-23	81-83	32.5	"	"	-	-	6	20.04	15.00
24-26	84-86	30.8	"	"	-	-	6	19.22	14.50
27-29	87-89	31.0	"	"	-	-	6	19.53	14.55
30-1	90-92	26.3	"	"	-	-	6	17.06	12.96
Apr. 2-4	93-95	31.5	"	"	-	-	6	19.56	14.70
5-7	96-98	32.6	"	"	-	-	6	20.00	15.06
8-10	99-101	32.6	"	"	-	-	6	20.00	15.06
11-13	102-104	31.5	"	"	-	-	6	19.53	14.70
14-16	105-107	31.5	"	"	-	-	6	19.50	14.70
17-19	108-110	31.3	"	"	-	-	6	19.50	14.65

TABLE XII

COW No. 78 (CONTROL)

Feed ingested during the course of the experiment

Date	Days in lactation	Alfalfa hay	Bone meal	Salt	Corn	T.D.N. Rec'd.	Starch Equiv. Rec'd.
		lbs.	gr.	gr.	lbs.	lbs.	lbs.
Dec. 24-26	10-12	23.5	50	50	12	21.60	17.50
27-29	13-15	21.3	"	"	"	20.54	16.77
30-1	16-18	23.5	"	"	"	21.60	17.50
Jan. 2-4	19-21	23.0	100	100	"	21.36	17.33
5-7	22-24	23.0	"	"	"	21.36	17.33
8-10	25-27	21.0	"	"	"	20.41	16.67
11-13	28-30	24.0	"	"	"	21.84	17.67
14-16	31-33	23.0	"	"	"	21.36	17.33
17-19	34-36	21.5	"	"	"	20.64	16.83
20-22	37-39	22.0	"	"	"	20.88	17.00
23-25	40-42	23.0	"	"	"	21.36	17.33
26-28	43-45	21.5	"	"	"	20.64	16.83
29-31	46-48	22.0	"	"	"	20.88	17.00
Feb. 1-3	49-51	23.0	"	"	"	21.36	17.33
4-6	52-54	19.0	"	"	"	19.44	16.00
7-9	55-57	21.0	"	"	"	20.41	16.67
10-12	58-60	27.2	"	"	"	23.38	18.73
13-15	61-63	24.2	"	"	"	21.94	17.74
16-18	64-66	24.5	"	"	"	22.08	17.83
19-21	67-69	27.0	"	"	"	21.78	17.33
22-24	70-72	22.3	"	"	"	21.02	17.10
25-27	73-75	22.6	"	"	"	21.17	17.20
28-2	76-78	27.2	"	"	"	23.38	18.73
Mar. 3-5	79-81	23.3	"	"	"	21.50	17.43
6-8	82-84	24.3	"	"	"	21.98	17.77
9-11	85-87	23.2	"	"	"	21.50	17.33
12-14	88-90	23.3	"	"	"	21.50	17.33
15-17	91-93	24.3	"	"	"	21.98	17.77
18-20	94-96	24.0	"	"	9	21.84	17.67
21-23	97-99	23.3	"	"	9	21.50	17.43
24-26	100-102	24.0	"	"	9	21.84	17.67
27-29	103-105	24.5	"	"	9	19.64	15.51
30-1	106-108	23.0	"	"	9	18.78	14.91
Apr. 2-4	109-111	23.2	"	"	9	18.88	14.98
5-7	112-114	22.0	"	"	9	18.30	14.58

TABLE XIII

COW 28 (CONTROL)

Feed ingested during the course of the experiment

Date	Days in lactation	Alfalfa Hay	T.V.M. Phosph.	Corn	Beet Pulp	T.D.N. Rec'd.	Starch Equiv. Rec'd.
		lbs.	gr.	lbs.	lbs.	lbs.	lbs.
Dec. 12-14	8-10	35.0	-	10	-	23.40	19.72
15-17	11-13	25.5	-	10	-	20.84	16.56
18-20	14-16	24.3	-	10	-	20.20	16.16
21-23	17-19	27.5	-	10	-	21.80	[illegible]
24-26	20-22	23.6	-	10	-	19.92	15.92
27-29	23-25	24.0	-	10	-	19.82	16.06
30-1	26-28	27.2	-	10	-	21.66	17.12
Jan. 2-4	29-31	29.0	175	10	-	22.52	17.72
5-7	32-34	25.2	"	10	-	20.70	16.46
8-10	35-37	29.5	"	10	-	22.76	17.88
11-13	38-40	29.3	"	10	-	22.66	17.82
14-16	41-43	29.0	"	10	-	22.52	17.72
17-19	44-46	28.6	"	15	-	26.63	21.62
20-22	47-49	25.0	"	15	-	24.90	20.62
23-25	50-52	25.0	"	-	15	2?.63	19.61
26-28	53-55	26.0	"	15	-	25.38	20.75
29-31	56-58	30.0	"	15	-	27.20	22.09
Feb. 1-3	59-61	28.0	-	15	-	26.34	21.42
4-6	62-64	30.0	-	15	-	27.30	22.09
7-9	65-67	29.0	-	15	-	26.82	21.75
10-12	68-70	28.2	Bone	15	-	26.43	21.49
13-15	71-73	29.0	Meal	15	-	26.?2	21.75
16-18	74-76	29.0	100	15	-	26.82	21.75
19-21	77-79	29.5	"	15	-	27.06	21.92
22-24	80-82	28.6	"	15	-	26.63	21.62
25-27	83-85	29.3	"	15	Sugar	27.00	21.85
28-2	86-88	27.6	"	12	3	26.57	21.12
Mar. 3-5	89-91	30.3	"	12	3	27.58	21.65
6-8	92-94	29.5	"	12	3	27.48	21.75
9-11	95-97	29.3	"	12	3	27.40	21.65
12-14	98-100	28.3	"	15	3	29.48	23.77
15-17	101-103	27.8	"	15	3	29.72	23.94
18-20	104-106	29.0	"	15	3	29.82	23.97
21-23	107-109	28.0	"	15	3	29.34	23.67
24-26	110-112	28.3	"	15	3	29.48	23.77
27-29	113-115	28.5	"	18	-	29.52	24.01

TABLE XIV

COW NO. A15 (CONTROL)

Feed ingested during the course of the experiment

Date	Days in lactation	Alfalfa Hay	Bone Meal	Corn	Barley	T.D.N. Rec'd.	Starch Equiv. Rec'd.
		lbs.	gr.	lbs.	lbs.	lbs.	lbs.
Dec. 12-14	6-8	27.2	-	-	8	19.30	14.82
15-17	9-11	26.3	-	-	8	18.86	14.56
18-20	12-14	27.5	-	-	9.3	20.45	15.86
21-23	15-17	26.3	-	-	11.3	21.42	16.90
24-26	18-20	26.8	-	-	12	22.22	17.57
27-29	21-23	25.3	-	-	12	21.50	17.07
30-1	24-26	25.3	100	-	12	21.50	17.07
Jan. 2-4	27-29	28.3	"	-	12	22.94	18.07
5-7	30-32	25.8	"	-	12	21.74	17.24
8-10	33-35	26.6	"	-	12	22.13	17.50
11-13	36-38	29.0	"	-	12	23.28	18.70
14-16	39-41	27.5	"	-	12	22.56	17.80
17-19	42-44	27.6	"	-	12	22.60	17.84
20-22	45-47	28.5	"	-	12	23.00	18.11
23-25	48-50	28.0	"	-	12	22.80	17.97
26-28	51-53	27.5	"	-	12	22.56	17.80
29-31	54-56	26.5	"	-	12	22.13	17.50
Feb. 1-3	57-59	29.2	"	-	12	23.33	18.34
4-6	60-62	29.3	"	-	12	23.36	18.37
7-9	63-65	27.0	"	12	-	23.38	18.67
10-12	66-68	28.0	"	12	-	23.76	19.00
13-15	69-71	27.5	"	12	-	23.52	18.83
16-18	72-74	29.5	"	12	-	24.48	19.50
19-21	75-77	29.3	"	12	-	24.40	19.45
22-24	78-80	28.0	"	12	-	23.76	19.00
25-27	81-83	29.2	"	12	-	24.38	19.43
28-2	84-86	28.8	"	-	12	23.18	18.24
Mar. 3-5	87-89	29.2	"	-	12	23.33	18.34
6-8	90-92	29.2	"	-	12	23.33	18.34
9-11	93-95	29.5	"	-	12	23.52	18.47
12-14	96-98	29.0	"	-	12	23.28	18.30
15-17	99-101	29.6	"	-	12	23.54	18.49
18-20	102-104	28.6	"	-	10.5	23.00	18.00
21-23	105-107	26.6	"	-	10.5	21.80	17.32
24-26	108-110	28.6	"	-	10.5	23.00	18.00
27-29	111-113	29.3	"	-	10.5	23.09	18.22

TABLE XV

Barrel Measurements

COW 76

Date	Days in lactation	Depth	Width	Circumfer.
		Cm.	Cm.	Cm.
PERIOD I				
Jan. 13	25	63.5	59.2	210.0
" 20	32	64.2	63.5	205.0
" 27	39	63.0	58.2	199.0
Feb. 3	46	62.0	57.5	200.0
" 10	53	63.5	59.0	202.0
" 17	60	66.0	56.0	204.0
" 24	67	62.0	58.0	194.0
Mar. 3	74	64.5	55.0	195.0
" 10	81	61.0	56.0	193.0
" 17	88	62.2	55.0	194.0
" 24	95	61.5	56.5	200.0
PERIOD II				
Mar. 31	102	63.5	61.5	211.0
Apr. 7	109	61.0	61.0	202.0

Cow 77

Date	Days in lactation	Depth	Width	Circumfer.
		Cm.	Cm.	Cm.
PERIOD I				
Jan. 13	33	63.2	56.5	200.0
" 20	40	64.0	59.0	204.0
" 27	47	61.0	53.7	195.0
Feb. 3	54	61.5	56.2	193.0
" 10	61	62.5	54.5	193.0
" 17	68	64.0	53.5	195.0
" 24	75	58.5	52.5	183.0
PERIOD II-Mar. 3	82	61.5	53.0	187.0
" 10	89	61.0	53.0	190.0
" 17	96	62.5	52.5	191.0
" 24	103	65.0	53.0	195.0
" 31	110	64.0	55.0	195.0
Apr. 7	117	62.0	57.0	200.0

TABLE XV(continued)

COW 267

	Date	Days in lactation	Depth	Width	Circumfer.
			C.M.	CM.	C.M.
PERIOD I					
	Jan. 13	14	71.5	64.0	223.0
	" 20	21	70.0	65.0	221.0
	" 27	28	73.0	63.0	222.0
	Feb. 3	35	70.5	60.0	216.0
	" 10	42	71.0	58.0	210.0
	" 17	49	70.5	61.5	214.0
	" 24	56	68.0	56.5	213.0
	Mar. 3	63	70.0	60.0	216.0
	" 10	70	69.0	55.5	213.0
	" 17	77	66.0	56.0	211.0
PERIOD II					
	Mar. 24	84	68.0	61.0	216.0
	" 31	91	74.5	63.8	225.0
	Apr. 7	98	66.0	63.0	227.0
	" 14	105	70.0	64.0	221.0

COW 78(CONTROL)

Date	Days in lactation	Depth	Width	Circumfer.
		CM.	CM.	CM.
Jan. 13	30	70.0	58.0	210.0
" 20	37	70.2	55.5	211.0
" 27	44	69.2	53.0	207.0
Feb. 3	51	67.5	56.5	213.0
" 10	58	68.5	51.5	204.0
" 17	65	69.5	54.5	206.0
" 24	72	68.5	53.0	212.0
Mar. 3	79	67.5	53.0	208.0
" 10	86	66.0	55.0	210.0
" 17	93	67.0	54.5	210.0
" 24	100	68.0	54.0	212.0
" 31	107	71.5	60.5	218.0
Apr. 7	114	69.0	55.0	211.0

Figure I- Graph showing the Production of 4% Fat-corrected
Milk by the Experimental Cows

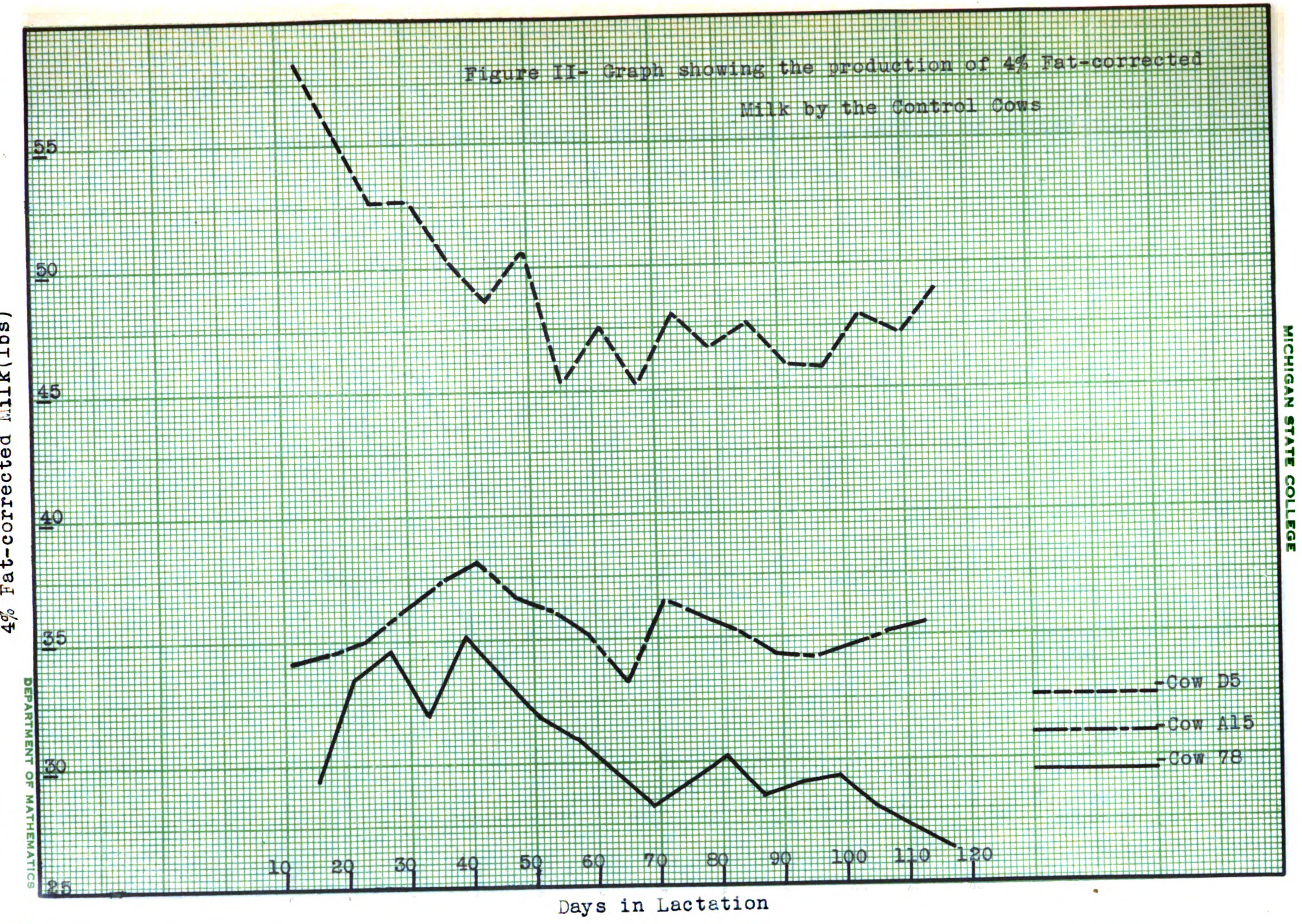
Figure II- Graph showing the production of 4% Fat-corrected
Milk by the Control Cows
4% Fat-corrected Milk(lbs)
55
50
45
40
35
30
25
10
20
30
40
50
60
70
80
90
100
110
120
Days in Lactation
-Cow D5
-Cow A15
-Cow 78
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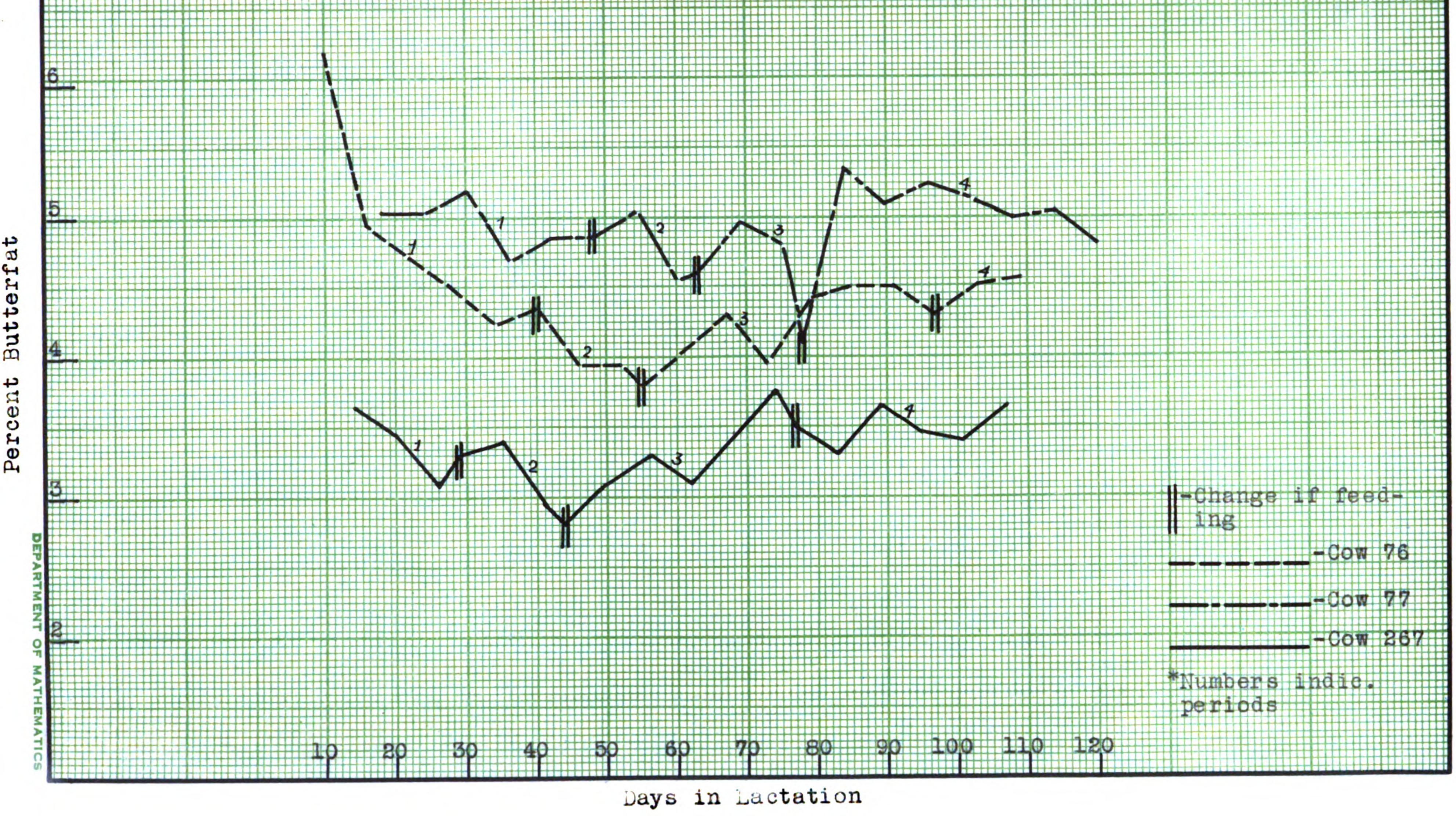
Figure III- Graph showing the variations in Percentage of Butter-fat in the Experimental Cows



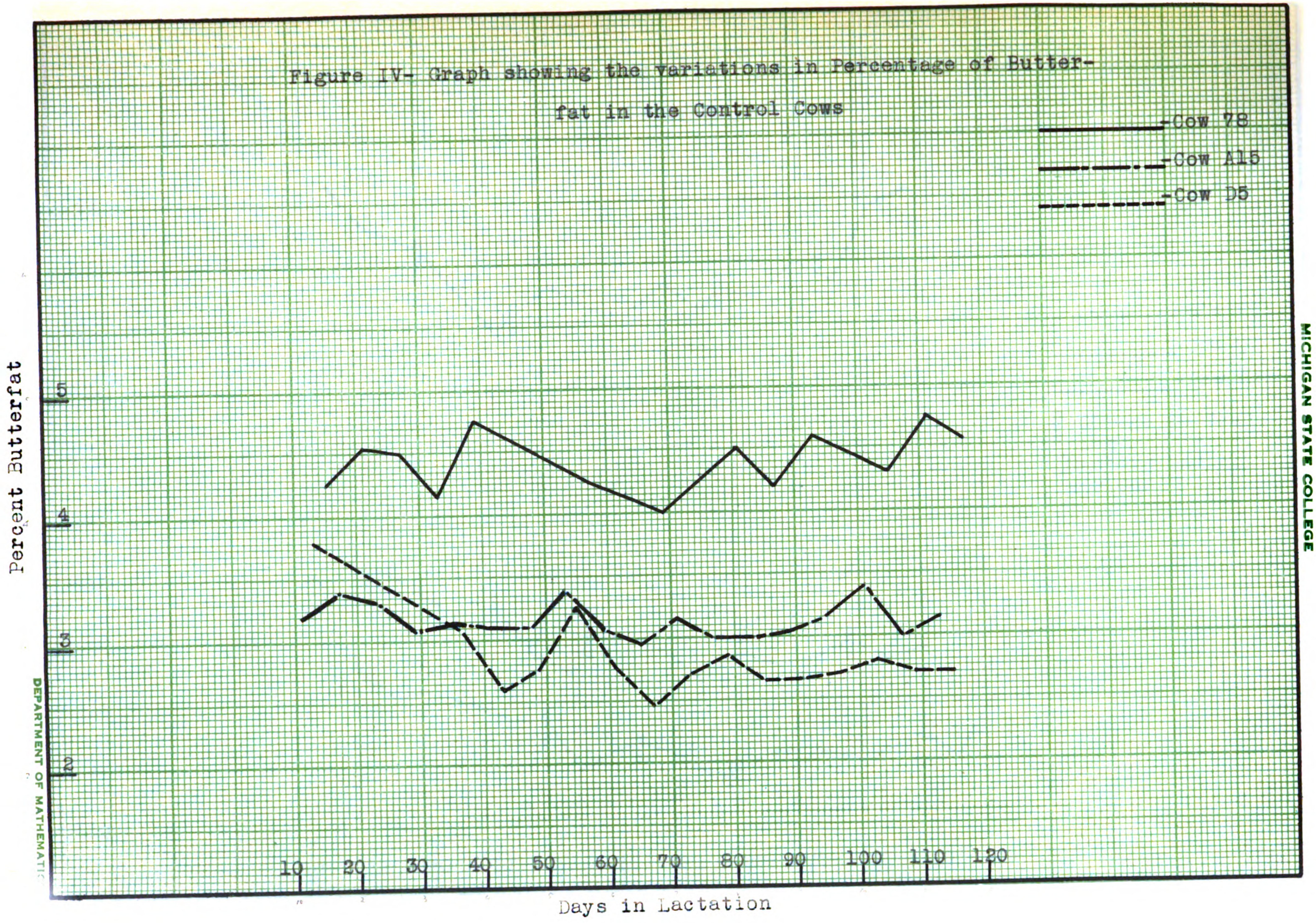


Figure IV- Graph showing the variations in Percentage of Butter-
fat in the Control Cows
-Cow 78
-Cow A15
-Cow D5
Percent Butterfat
5
4
3
2
10
20
30
40
50
60
70
80
90
100
110
120
Days in Lactation
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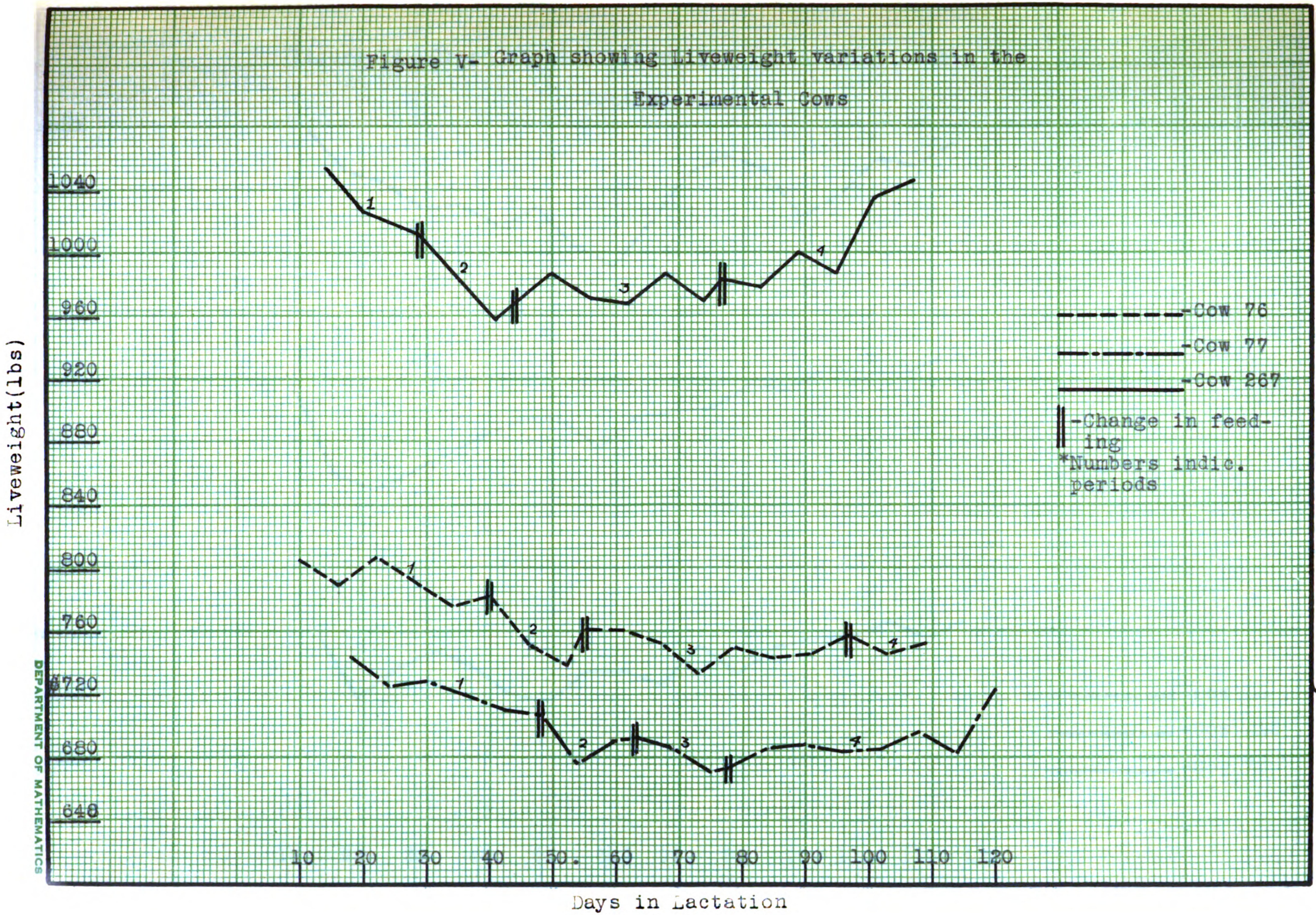
Figure V- Graph showing Liveweight variations in the
Experimental Cows
Liveweight(lbs)
1040
1000
960
920
880
840
800
760
720
680
640
Days in Lactation
10
20
30
40
50
60
70
80
90
100
110
120
-Cow 76
-Cow 77
-Cow 267
-Change in feeding
*Numbers indic. periods
1
2
3
4

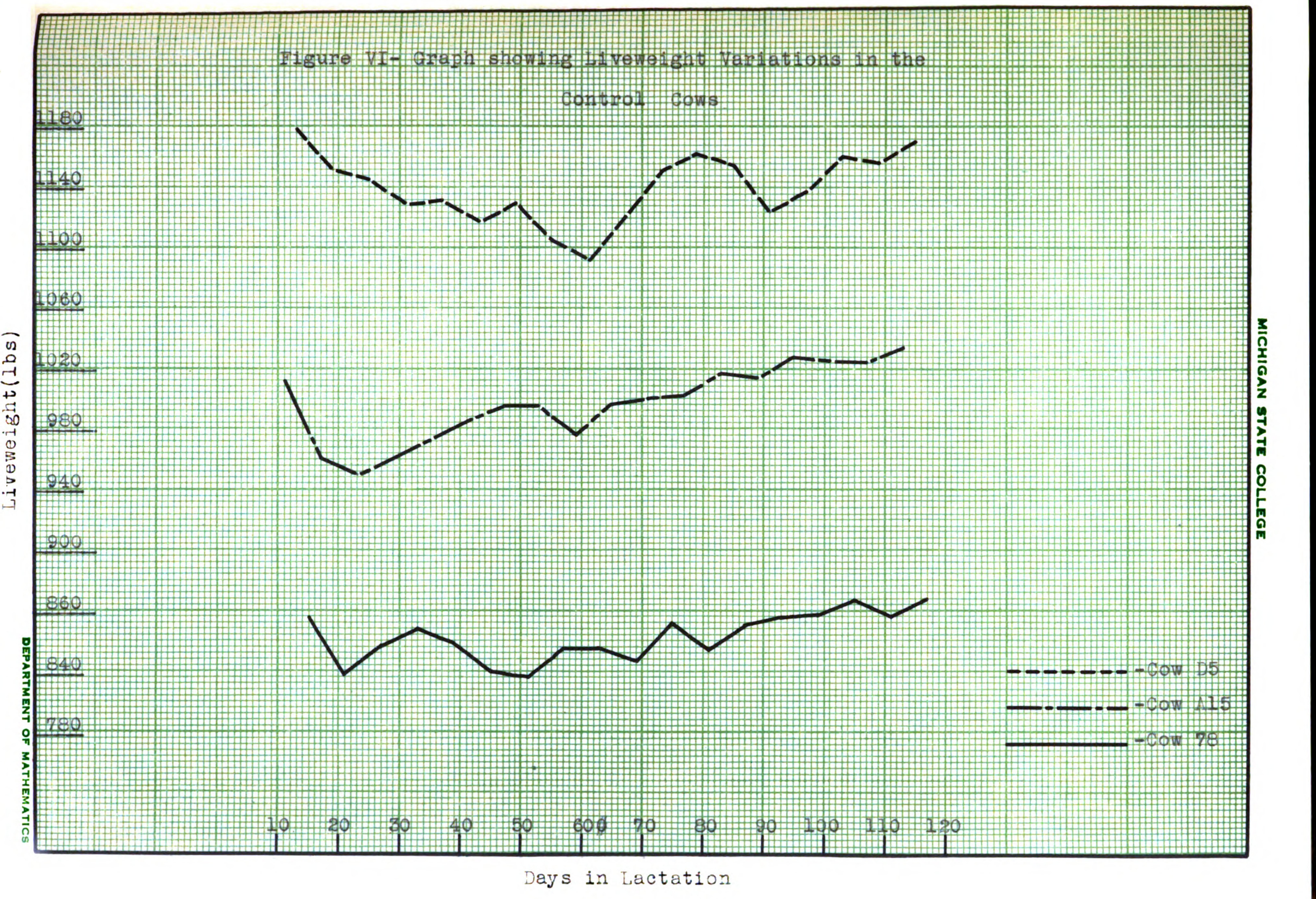

Figure VI- Graph showing Liveweight Variations in the Control Cows

PART II

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INTRODUCTION

In part one an experiment is reported in which cows were changed from a basal ration very low in fat to velvet beans which contained 5.41 per cent ether extract. The possibility of a difference in the biological value of butterfat from animals fed varying levels of fat has not been studied. It appeared desirable, therefore, to study the response of rats to the butterfats produced by one of the cows used in part one during different feeding periods, as well as the fat produced by a cow of the control group.

REVIEW OF LITERATURE

Early literature on the need of fats by the animal organism, is conflicting. In the early works the essential value of fats was usually associated with the value of accessory food substances carried by them.

Osborne and Mendel(1) stated that Stepp was one of the first investigators to study the importance of lipids. He fed mice with materials which had been thoroughly extracted with ether and alcohol. Within a few weeks the experimental animals died. The addition of alcohol-ether extracts of certain materials kept the mice alive. Stepp made the interesting observation that butterfat failed to replace the missing substance. A possible relation of this condition to a deficiency of essential fatty acids is untenable, since the life sustaining factor could be obtained from skim milk. Moreover, he admitted that the factor lacking was not a fat. This work, however, opened the way to a new branch of nutrition. There were other reports on the value of fats in the diet, but they were inconclusive(1).

McCollum and Davis(2) also determined the importance of fats in the diet of rats. However, their works showed the essential factor in question was a fat soluble substance and not the fats themselves.

Osborne and Mendel's report during the same year(3) is difficult to interpret. They studied the influence of butterfat on growth and found that rats could grow to 140 days of age, although very subnormally, on fat deficient diets. The weight figures coincided with those obtained by Burr and Burr in later years(6). The absence of ophthalmic symptoms demonstrated that vitamin A was not the causative factor. However, lard produced no response when added to the diet.

Robertson(4), while feeding a ration of boiled-peeled-mashed potatoes, defatted bran, white of egg and chlorophyll, observed that few weeks after the initiation of the diet the rats developed tail necrosis, inflamation of the penis and rectum, and languid movements. However, the condition improved four or five weeks after the initiation of the experiment. About the twenty-second week a sudden and rapid loss of weight occurred, with hyperirritability of the skin and incessant scratching. A month later the rats died.

Thirteen years following the report of Robertson, McAmis, Anderson and Mendel(5) proved that a small inclusion of fat in a balanced fat-free diet produced optimal growth in rats. Careful selection and housing of the stock were practiced, the rations were prepared accurately and exact records of the feed consumed were kept. The feed was moistened to a paste to prevent spilling. The addition of peanut oil improved the condition of rats which had been losing weight on the fat-free diet. The authors made no conclusion as to the nature of this response.

The work of Burr and Burr during the same year(6) settled the conflicting question of the necessity or essentiality of fats in the diet of the rat. They used three different fat-free diets consisting of different proportions of pure casein, sucrose, McCollum's salt mixture 185, supplemented with ether-extracted yeast and the non-saponifiable matter from seventy milligrams of cod-liver oil to supply the different vitamins. The nutritive ratio of the diet was changed from 1:3 to 1:7 as the animals advanced in age.

"Between the seventieth and ninetieth day of age", they say, "an abnormal condition of the skin is observed. Later on the tip of the tail may become inflamed and the whole of it soon is heavily scaled and ridged. Hemorrhagic spots may arise in the skin throughout the entire length of the tail.

The swelling of the tip may gradually be replaced by a true necrosis resulting in the loss of one to three centimeters of the tail. The hind feet become red and somewhat swollen at times, in some cases with long scales over the dorsal surfaces. The hair on the back of the body becomes filled with dandruff. There is a tendency to lose hair, especially about the face, back and throst. Sores often appear on the skin, causing the animal to rub his face continually with his fore feet. The early outward signs of an unhealthy condition are soon followed by a cessation of growth when the animal is about twenty-five percent underweight in comparison to the control receiving fat."

Besides the skin and tail lesions, Burr and Burr noted a marked uniform affection of the urinary tract and kidneys, although some animals died without this type of lesion. Comparisons to the symptomatology of vitamins A and B deficiencies and to pellagra, eliminated all doubts of complication with these diseases.

Neither glycerol nor the non-saponifiable portion of lard caused any improvement in the rats when added to the basal ration. However, thirteen drops of melted fatty acids fed daily to a group, protected them completely. Ten drops of lard daily cured the animals when in a very bad state of deficiency.

Evans and Lepkovski(7) failed to observe tail necrosis as a specific symptom of fat deficiency. They have never noted this in their studies. Burr and Burr(6) admitted, moreover, that this lesion is like the one described in the works of Smith and Bogin as a result of underfeeding.

The surprising results obtained by Burr and Burr when the free fatty acids of lard were fed to deficient rats, led the authors to search for the real fatty acid needed. The synthesis of fats from carbohydrates and the carbohydrate portion of the proteins is universally known. There would be no deficiency then, if the body could elaborate all the fatty acids in nature. The fact that a real deficiency occurs can be explained therefore, by the inability of the organism to synthesize some of them.

Burr and Burr(8) proved with further studies that none of the saturated fatty acids occurring in hydrogenated coconut oil cured the disease. However, pure methyl linolate was effective. Two years later(9) they found that linolenic acid, another unsaturated fatty acid, was equally effective. Oleic and alpha-eleostearic, an isomer of linolenic acid, proved ineffective. A preparation of methyl arachidonate had a slight depressing effect.

However, Turpeinen(10) fed thirty-three milligrams daily of arachidonic acid in the fat-free diets of rats and obtained practically the same results as one-hundred milligrams of methyl linolate, thus proving that it is three times as potent. The question, therefore, of the essentiality of arachidonic acid remains questionable. Wesson(11) suggested that this acid is an intermediate product in the metabolism of part of the fatty acids containing fewer than twenty carbon atoms.

Evans and associates(12,13) made interesting studies on the effect of a fat deficiency upon reproduction and lactation in the rat. According to their observations(12) normal reproduction is impossible without the essential fatty acids, even when vitamins A, D and E were supplied in abundance. Littering was retarded one to three days, eighty per cent of the young were born dead and the weight and number of the new born were very subnormal. Poor lactation was shown by the poor weights of the young at weaning. The addition of the essential fatty acids brought about surprisingly good results. Butterfat or twenty-five per cent of lard were equally efficient.

Maeder(27) confirmed these observations. He suggested that the causative factors of prolonged gestation were the lessened vitality or death of the fetuses, decreased tone of the abdominal and uterine musculature and possible lack of necessary hormonal stimulation. He observed, moreover, that the process of reproduction was early impaired in fat deficiency, but that ovulation was affected late and recovered promptly after fat feeding.

Male rats reared on fat-free diets lose their sex-interest(13). This is contrast to E avitaminosis, where sex-interest is preserved for a significant length of time. Small quantities of the essential fatty acids restored sex-interest, but fertility returned in certain cases only. Evans and associates stated that the sterility in that case was probably due to a grave degeneration of the testes. The impairment of male reproductive function resembled that of A avitaminosis.

Other investigations on fat deficient rats have been made by Burr and Beber(14,15,16) and by Burr and Wesson(17). These investigators reported that fat deficient rats have a higher specific dynamic action of food, a higher basal metabolic rate and higher respiratory quotients than normal. This later fact showed the synthesis of large amounts of fat in the body, but not of the essential type. In the presence of the essential fatty acids, fat formation from carbohydrates increased(17) with a subsequent deposition of that substance. A possible relation of fats to the thyroid gland is also claimed. In the absence of fatty acids they observed hyperthyroidism, even when iodine was fed. According to Burr and Wesson this view is supported by the high metabolic rates. However, their data also show that the iodine level in the body probably plays no part in the production of fat-deficiency symptoms.

In 1936, Sinclair(18) claimed that there is evidence of synthesis of essential unsaturated fatty acids in the body of the rat. He fed a group on casein, a salt mixture, yeast and seventy per cent of the total calories in the form of elaidin, supplemented with cod liver oil. After three to four weeks growth ceased and remained constant for some weeks, when a gradual decline in weight set in. At that point he replaced the elaidin with sucrose in the diet of some of the rats. Growth was resumed immediately. He thought that the high intake of elaidin and presumably of other fats free from the essential fatty acids, prevented the "limited" or partial synthesis of these from the carbohydrates. The source of these acids is still unknown.

Butterfat as a source of the essential fatty acids

Eckstein(19) analyzed samples of butterfat from different parts of the state of Michigan and failed to find a large amount of linoleic and linolenic acids in them. The averages were 0.21 per cent of linolic and 0.12 per cent of linolenic. He admitted, however, that these values were too low, since Hilditch and coworkers(20,21) claimed that butterfat contained as much as 4.5 per cent of linolic acid.

Eckstein also showed that the essential fatty acid content of butter can be increased by feeding feeds rich in them, such as linseed oil meal.

Eckstein's values appear rather low since Burr and Burr (8) showed that butter can cure fat deficiency in rats. Moreover, Evans and associates(12) proved that butter increases the weight at weaning of rats from fat deficient females, thus showing that it produces favourable effects on lactation.

The conclusion that can be derived from these investigations is that rats need linolic and linolenic acids for normal life, but the amount they require is so small, that even butter which contains them in limited amounts, can supply the amount they need.

The Vitamin B_1 sparing action of fats

Besides the functions of energy production and the essentiality of some of its constituents for normal life, fats have been found to possess a vitamin B_1 sparing action.

In 1928, Evans and Lepkovski(22) noticed that fats in some unknown way are related to the body needs of vitamin B_1 as some investigators had previously reported. In 1929(23) they observed that the addition of fifty per cent of lard to the ration in the absence of vitamin B_1 prevented the abnormal condition characteristic of the avitaminosis in rats. However, on a ten per cent level of fat, growth was very poor. Yeast added to the ten per cent fat diet produced normal growth. There had been no chances of the fat being contaminated with this vitamin, since previous analyses had given negative results. In 1931(7) Evans and Lepkovski confirmed their earlier findings.

Three years later(24) since Gregory, Drummond and Steenbock failed to show a vitamin B_1 sparing action by fats, Evans and Lepkovski demonstrated that the levels of protein and vitamin G in the diet play important roles in this function. Moreover, different fats vary in their B_1 sparing ability(25).

Coconut oil was the most efficient, lard was second, followed by cottonseed oil, butterfat, synthetic lard, hydrogenated sesame oil and sesame oil, respectively.

Boyd and associates(26) showed also that the presence of moderate amounts of fat in the diet may have a beneficial effect on the absorption of calcium and phosphorus by the body by maintaining a favorable acidity of the intestinal contents.

PURPOSE

The principal object of this study is to determine the difference that may exist between butterfats produced by cows when fed a ration free from fat and when allowed an optimum amount of fat, respectively.

Minor objects are the determination of the effect that a diet devoid of fat will have on the animal organism, and to obtain the thechnique of experimentation with rats.

PLAN OF RAT EXPERIMENT

Selection of the rats- Particular importance will be placed on the selection of the rats, since it is known that factors such as individuality, sex, age and heredity may affect the experimental results.

Albino rats from the stock reared in the rat colony of the Dairy section and Chemistry Department of the Michigan State College will be used. Care will be taken to group according to and weight. The male parent of most of the animals will be the same to reduce hereditary variations to a minimum.

The maximum weaning age will be three weeks. This will shorten the depleting stage. Rats weighing thirty to forty grams will be used. Later the rats will be grouped according to sex and parentage. At least one rat from each litter will be put in each group.

Number of rats and grouping- Thirty males and females will be divided into ten groups of three rats each. One group will be a Negative control and another Positive control. The other eight groups will be divided into two lots. One lot will receive butterfat produced by Cow 267 when fed the alfalfa hay-velvet bean ration. Half of the other group will receive butterfat produced by Cow 267 when fed the alfalfa-soybean oil meal ration and the rest butterfat produced by Cow 78 of the controls, fed an alfalfa-corn ration.

Management of the rats- The conditions under which the study will be made will be as uniform as possible. The rats will be housed singly in the standard experimental cages with feed and water supplied freely. Each cage will have a tag specifying the lot, group and number of the rat. The room where they will be housed is warm, with uniform temperature, well ventilated and well lighted.

Basal ration to be used- The first stage of the experiment will consist in depleting all the animals of their storage of the essential fatty acids which is indicated by scaliness on the toes and of the end of the tail. For this purpose the following ration will be used:

Edible casein-	18%
Sucrose-	68%
Salt Mixture (McCollum's 185)-	4%
Brewer's Yeast-	4%
Irradiated Yeast-	1%
Alfalfa-leaf Meal-	5%

Sampling of the butterfat- As previously stated, the butterfat used will be obtained from two cows: Cow number 267 and Control Cow 73 of Part I. The milk produced during two consecutive days will be collected from Cow 267 after she has been at least twelve days on alfalfa hay-soybean oil meal and then twelve days after she has been changed to alfalfa hay-velvet bean feeding. Milk will be collected but once from Cow 73, since she will receive alfalfa and corn through the experiment.

The milk will be separated and churned. The butter will be melted and the fat separated from the non-fatty material, packed in a paper container and stored in a refrigerator until used.

Feeding of the butterfat- The time at which the rats will be fed the butterfat will be determined by the development of scaliness on the toes and the tip of the tail. Each group of rats will receive a certain level of fat weekly per one-hundred grams of body weight. The general plan is shown in Table I of the Appendix.

The object of feeding different levels of butterfat to the different groups is to determine the amount of butterfat most favorable to cure scaliness, when compared with the results obtained in the Positive Control group. This group will receive Wesson oil, a very rich source of unsaturated fatty acids. Every week a larger allowance of fat will be fed to each rat to meet their increasing demand with advance in age.

The butterfat feeding period will last for four weeks and the rats will be examined every three days for any change in their condition.

Collection of Data

Weekly weights- Each animal will be weighed weekly beginning from the day of weaning. The unit used will be the gram to determine the smallest possible change in weight. Care will be taken to do this operation at the same time of the day each time they are weighed. The weekly weights of each group will be averaged and the result considered as the figure for that group.

Condition of the animals- Particular care will be exercised to observe the alterations in the health and constitution of the rats during the course of the experiment. Alterations will be based mainly on the development of scaliness on the extremities. The time required to cure scaliness during the fat-feeding stage will be used to measure the value of the butterfats tested.

PROCEDURE

The experiment was carried out as planned. The rats obtained from the Chemistry Laboratory were grouped as controls only, since they differed from the rest of the stock used. The average weight of the rats used was between 35 and 40 grams.

Scaliness on the toes and the tail appeared at about the fourth week from weaning. Development of scaliness was very uniform so that fat feeding began at the same time. Butterfat was fed for four weeks as had been planned, and the rats examined every three or four days for signs of improvement. The observations made are discussed in the following pages.

RESULTS

The early symptoms noticed in the group studied confirmed the necessity of lipids at least for preserving the health of the skin. The rats developed an abnormal condition by the end of the third to the fourth week on the fat-free diet. This condition consisted of irritation of the tip of the tail. The abnormality advanced towards the base with the formation of large scales and ridges, covering at least one third of the tail. Fat deficiency was also indicated by a similar scaliness on the toes, which usually developed earlier than on the tail, and heavier on the hind feet than on the front ones. Considerable variation between animals was noticed, however.

The weight figures obtained during the first half of the experiment showed that a fat deficiency does not affect growth during early age. The weights were used to calculate the amount of butterfat fed weekly to each rat. The average weights for each lot are presented in Table II of the Appendix.

Feeding of butterfat was begun as soon as all the animals showed the scaly condition. The return to the normal condition was used to measure the essential fatty acid content of the butterfat studied.

The results obtained during the experiment are presented in the following paragraphs. A detailed description of the results of each lot is given.

The Negative control lot of rats was kept on the fat-free diet. The weekly average weights for the three animals during the experiment are presented in Table II. Their rate of growth was very similar to that of the other groups. The feeding of butterfat to the experimental animals did not show any favorable increase in the rate of growth when compared to that of the Negative controls. Heavy water consumption was observed in this group, thus confirming the reports of other authors(6,27). The degree of scaliness varied in this lot. One rat showed very marked scaliness on the toes and the tail. The other two, however, were only slightly affected.

Lot I of the group receiving butterfat produced by Cow 267 while being fed the alfalfa-velvet bean ration, developed scaliness on the toes and the tail by the end of the third week after weaning. The degree of scaliness varied in this lot also. Butterfat was fed one week after scaliness was first noticed. Each rat received two grams of butterfat for every one hundred grams of body weight during the first week of the fat feeding stage. The amount fed was increased by 0.5 gram each week until 3.5 grams were fed during the fourth week.

Fat feeding caused an earlier improvement on the condition of the toes than on the tails. First signs of improvement were noticed at the end of the second week. At the end of the four weeks recovery was complete on the toes, but slight scaliness still remained on the tails.

The animals in Lot II showed varying degrees of scaliness on the tail. The first signs of the abnormality were noticed at the same time as in Lot I. The levels of butterfat fed to this lot were 2.5, 3.0, 3.5, and 4.0 grams weekly per 100 grams of body weight, for each of the four weeks that the fat feeding lasted.

The response of this lot to fat feeding was more marked than in Lot I. Improvement was uniform by the end of the second week. At the end of the fourth week recovery was complete on the toes. The tails were not completely cured, however.

Fat deficiency was more marked in Lot III than in the other groups previously mentioned. The butterfat used in this lot was the same as for Lots I and II. The amount fed was 3.0, 3.5, 4.0 and 4.5 grams per 100 grams of body weight for the four weeks, respectively. The signs of improvement were also noticed by the end of the second week. Recovery was complete on the toes by the end of the fourth week of fat feeding. Improvement of the tails was slower and still showed scaliness at the end of the experiment.

In Lot IV similar results were obtained. Each rat in lot was fed 3.5, 4.0, 4.5 and 5.0 grams of the same butterfat per 100 grams of body weight during the four weeks, or 0.5 gram more each week than to Lot III. Improvement in the condition of the toes was observed one week after the first feeding. Recovery was complete at the end of the third week. Improvement of the tails was gradual and scaliness was observed at the end of the fourth week.

Fat-deficiency symptoms appeared in Lot IA three weeks after weaning. Butterfat feeding was begun at the fourth week when each rat received two grams of butterfat per 100 grams of body weight. The butterfat studied in this lot was produced by Cow 267 during the alfalfa-soybean oil meal feeding period. The allowance was increased by half a gram each week until each rat received 3.5 grams of butterfat per 100 grams of body weight during the fourth week.

Improvement from the fat deficiency was slower than in case of Lot I. The toes showed a very slight recovery by the end of the fourth week. No improvement was noticed in the condition of the tails.

The animals in Lot IIA received one half-gram more each week per hundred grams of weight than the rats in Lot IA. The butterfat used was the same.

All the rats in Lot IIA showed a slight scaliness on the toes and the tail when changed to butterfat feeding. Recovery from it was more marked, however, than in Lot IA. Signs of improvement were noticed on the toes at the end of the second week of fat feeding. The tails were only slightly cured by fat feeding, however. Recovery was incomplete in both toes and tails by the end of the fourth week.

Symptoms of fat deficiency were more irregular in Lot IIIA than in other lots of this group. At the fourth week after weaning the rats in this lot were fed butterfat produced by Cow 78 of the Control group of Part I, which had been fed alfalfa hay and corn throughout the experiment. The levels fed were 3.0, 3.5, 4.0 and 4.5 grams per 100 grams of body weight during the four weeks of the fat-feeding period.

Improvement of the condition of the toes and the tails was noticed two weeks after the fat feeding had started. In two rats scaliness was completely cured in both toes and tails by the end of the fourth week. In the other rat, which had been affected by marked scaliness, recovery was incomplete.

Lot IVA exhibited a medium degree of scaliness on both toes and tails by the fourth week after weaning. The allowance of butterfat was 3.5, 4.0, 4.5 and 5.0 grams per 100 grams of body weight during the four weeks of butterfat feeding, respectively. The butterfat studied was the same used for Lot IIIA.

Recovery from the abnormal condition on the toes and tails was rapid. In one rat an improved condition of the toes was noticed one week after the first feeding of fat. Recovery was complete by the fourth week in both toes andtails. In one rat, however, a slight scaliness still remained on the tail.

The Positive control group was used to check the results obtained from the study of the butterfats mentioned, with a fat having a high content of unsaturated fatty acids. Due to the larger quantity of these acids in Wesson oil(purified cottonseed oil), the amount fed was only one-tenth of the weight of butterfat received by Lot I.

The rats in the Positive control lot were depleted from their essential fatty acid storage just the same as with the other groups. At the end of four weeks, when the signs of fat deficiency were exhibited, each rat was fed 200 milligrams of Wesson oil weekly per 100 grams of body weight. The amount was increased by 50 milligrams each week until 350 milligrams per 100 grams of liveweight were fed during the fourth week.

The results obtained with this group showed that even these amounts of Wesson oil are capable of curing fat deficiency in rats. In one rat improvement was noticed on both toes and tail by the end of one week after the first feeding of fat. Scaliness in this rat, however, was slight. The other rats showed improvement by the second week after fat feeding began. The toes were completely cured by the end of the third week in one rat and by the end of the four weeks in the other two. The tails of two of the rats, however, still showed slight scaliness at that time.

DISCUSSION

The main object of this report is to determine the difference between butterfats from cows fed rations with varying levels of fat. Thirty rats weaned at twenty-one days of age were grouped into ten lots, one of which served as a Negative control, another as Positive control and the other eight were fed the butterfat samples.

The study was divided into two stages. During the first stage all the lots were fed on a fat-free diet to deplete their storage of essential fatty acids. The absence of these fatty acids in the body was indicated by scaliness of the extremities between the third and fourth week after weaning. This abnormal condition demonstrated that certain fatty acids are needed for preserving the health of the skin. These results are in agreement with those of many investigators. Growth, however, was not affected at this early stage of the deficiency.

The value of fats studied was measured by their ability to cure the scaly condition of the rats. The procedure used in this work, therefore, varied from that used in the investigations discussed in the review of the literature, where the response of rats to fat feeding was measured by the increase in rate of growth. The effect on the rate of growth requires a much longer time.

The results obtained, as outlined previously, demonstrate that a difference exists in the butterfat produced by the same cow when fed rations containing varying levels of fat. This can be explained by the decrease of the storage of essential fatty acids in the body of the cow, and subsequently, a decrease of these acids in milk fat during low-fat feeding. The addition of a feed, such as velvet beans containing 5.41 per cent ether extract, increased the essential fatty acids in the milk. Eckstein(19) reported similar observations by feeding linseed oil meal to dairy cows.

The data obtained in the present experiment also indicate a marked individual variation on the extent or the seriousness of the fat deficiency induced in the rats. Two of the rats of the Negative control showed a slight scaliness on the tail even after fed the fat-free ration for eight weeks. Considerable variation was also noticed between the response of the toes and the tail to butterfat feeding. In all cases in which fat improved the condition of the rats, the toes showed an earlier and more uniform response. The tail, however, was slow to recover and even in the lots that received the heaviest allowance of butterfat, scaliness was still present at the end of the experiment. This suggests, therefore, the possibility of using the feet rather than the tail, for measuring the response obtained from feeding fats.

The results obtained with the Positive control lot indicated that the amount of essential fatty acids needed by the rat is very low, since one-fifth of a gram per week per 100 grams of body weight induced a favourable reaction. Comparing the results from butterfat feeding with those from Wesson oil the assumption can be made that this oil is at least ten times as potent in curing fat-deficiency as butterfat produced by a cow receiving a normal amount of fat in the ration.

Butterfat from the cow fed alfalfa and corn produced practically the same response as equal levels of the butterfat from the cow on velvet beans. The lowest level that cured the fat deficient rats was not determined, however, due to the restricted number of animals available.

SUMMARY AND CONCLUSIONS

Fat-deficient diets cause an early abnormality in the rat consisting of an irritation of the tail, which advances towards the base as the deficiency is prolonged. This irritation is accompanied by the formation of large scales and ridges around the tail. Scaliness also occurs on the toes, more markedly in the hind than on the front ones.

The time usually required to produce these symptoms in rats on a fat deficient diet, is between three and four weeks after weaning.

Growth is not affected during this period, however. The weight figures presented in the Appendix show that the rate of growth was the same during depletion of fatty acid storage as during butterfat feeding. A decrease in the growth rate occurred towards the end of the experiment, but it must have been due to advancing age.

Rats differ in the degree of scaliness induced by fat-deficient diets. In some animals the abnormality was marked by the third week after weaning. In two of the Negative control lot, however, it was slight at the end of the eighth week.

The addition of butterfat to the fat-deficient diet cured scaliness in rats. There was observed, however, a difference between the butterfats studied. Fat produced by a cow when fed an alfalfa-soybean oil meal ration was inferior to the fat produced by the same cow when fed alfalfa and velvet beans.

Wesson oil was at least ten times as efficient as butterfat as a cure for fat-deficient symptoms.

At least two weeks are needed to obtain a response from butterfat feeding. Only with the highest levels of fat was an earlier improvement observed.

The results obtained in this experiment indicate that scaliness on the toes is a better indication of an essential fatty acid deficiency than scaliness on the tail. Response to fat feeding was more definite on the toes, improvement could be better appreciated and recovery was more rapid than on the tails. The toes of the rats that responded to butterfat feeding were cured by the end of the experiment, while most of the animals still had scaly tails at that time. Even the rats fed the highest amounts of fat still showed an abnormal tail by the end of the experiment.

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APPENDIX

TABLE I

Scheme followed in feeding the butterfat to the experimental rats

Number of lot	Butterfat fed from	Butterfat fed weekly/100 grams body weight***			
		First week	Second wk.	Third wk.	Fourth wk.
		grams	grams	grams	grams
I	Cow 207 (Alfalfa-and Velvet bean	2.00	2.50	3.00	3.50
II	" "	2.50	3.00	3.50	4.00
III	" "	3.00	3.50	4.00	4.50
IV	" "	3.50	4.00	4.50	5.00
IA	Cow 207 (Alfalfa-Soybean oil meal	2.00	2.50	3.00	3.50
IIA	" "	2.50	3.00	3.50	4.00
IIIA	Cow 78 (Alfalfa hay and Corn	3.00	3.50	4.00	4.50
IVA	" "	3.50	4.00	4.50	5.00

***- Week of butterfat feeding after following the depletion period.

TABLE II

Weekly average weights of the experimental rats

Age in days	NUMBER OF LOT									
	Negative Control gr.	I gr.	II gr.	III gr.	IV gr.	IA gr.	IIA gr.	IIIA gr.	IVA gr.	Positive Control gr.
DEPLETING STAGE:										
21	38.2	36.0	35.0	36.0	36.5	37.1	35.5	36.6	35.6	40.0
28	60.5	43.0	48.6	55.0	46.5	40.3	45.0	46.8	46.5	59.8
35	88.5	65.3	72.5	79.0	67.5	54.2	62.5	68.3	65.6	87.0
42	121.5	88.3	104.0	115.0	91.5	82.5	92.5	93.0	95.8	124.5
49	148.0	115.5	124.0	140.0	116.0	100.6	[illegible]	115.6	117.0	155.6
FAT FEEDING STAGE:										
56	168.5	135.0	146.0	168.0	138.0	126.5	130.6	178.6	171.0	174.0
63	186.5	143.0	162.0	193.0	150.6	146.6	148.0	150.0	145.0	204.0
70	210.0	160.0	176.6	211.0	177.8	150.6	167.0	164.0	155.0	[illegible]
77	225.0	173.0	191.3	228.0	198.0	173.6	178.3	179.0	175.0	241.0