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A STUDY OF THE EFFECTS OF COTTON SEED PRODUCTS UPON THE COMPOSITION OF BUTTER FAT AND THE CHURNABILITY OF CREAM

by

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INTRODUCTION

Among the various problems which confront the dairyman of this country, there is perhaps no single one of more general importance than that of providing sufficient protein in the ration at a reasonable cost. A cow weighing 1150 pounds and producing 40 pounds of milk requires, approximately, 2.5 pounds of protein. Approximately 15 pounds of cowpea hay, and 24 pounds of alfalfa hay are necessary to supply this amount of nitrogenous matter. It is, therefore, evident that even in dairy sections where these two high protein roughages are grown, it is still impossible to satisfy the protein requirements for a high producing dairy cow because of the inability of the animal to consume a sufficient amount of these bulky feeds. Moreover, the maximum and therefore the most economic production of milk demands that rations contain a liberal allowance of protein in the form of a concentrate. Obviously the problem of supplying protein economically in districts where no nitrogenous roughage is grown differs only in intensity from sections having an abundance of legume protein - in both instances a certain definite amount of the nutrient in the form of a concentrate is needed for profitable dairy feeding.

The following is a statement of the cost of protein when purchased in various feeds:

	Price per cwt.	Cost of protein per lb.	Energy value in terms per cwt.
Wheat bran	$1.35	13.2¢	48.23
Oil meal	2.00	6.8	74.67
Cotton seed meal	1.50	4.2	84.20
Corn	1.00	14.7	88.84

It is clearly shown, by the above table, that cotton seed meal furnishes one of the cheapest sources of protein. Nevertheless, statistics show that in the year 1911, 402,298 tons of cotton seed meal and cake were exported from the United States. In other words, 151,264 tons of digestible protein or an amount sufficient to feed 504250 cows 2 pounds each for a period of 300 days were exported from the United States in the year 1911. This large exportation of cotton seed meal must either indicate that America has more protein than feeders can use or that many cattle are underfed in this nutrient. The opinion of authorities on feeds and feeding connected with extension work in agricultural colleges and experiment stations, as expressed in publications and the press, seems almost unanimous in support of the fact that, in general, high producing dairy cows do not receive sufficient protein. It is, therefore, very probable that many feeders are failing to provide protein from one of the cheapest sources, viz., cotton seed meal.

Practical feeders, however, raise many objections to the feeding of cotton seed meal. In addition to various alleged evil effects on the health of animals to which no consideration will be given in this thesis, cotton seed meal has been held to have certain definite and undesirable effects on the composition of butter fat. For instance, many, though not all, investigators have found that butter made from the milk of cows fed on cotton seed meal has a high per cent of olein and a low per cent of volatile fats. Furthermore, other experimenters have shown that when cotton seed meal is fed with cer-

tain roughages, a very inferior quality of butter is produced. The Purpose of this investigation is to make a further study of the changes produced on the composition of butter fat and the market qualities of the butter when cotton seed meal is included in the ration.

REVIEW OF THE LITERATURE

Hunziker[1] found that corn oil, linseed oil, and cotton seed oil, respectively, increased the olein and decreased the volatile acids, while the melting point remained practically the same. Linseed oil ration gave the highest per cent of olein. In spite of the wide variations in volatile acids and per cent of olein, the melting point increased only slightly. Hunziker also found that the addition of 1 1/4#* of either corn oil, cotton seed oil, and linseed oil to the ration respectively, made the butter soft. He found that the melting point remained practically constant when one and one-fourth pounds of cotton seed oil were fed. The rations consisted of alfalfa hay, corn silage, and a grain mixture of three parts cornmeal, two parts oat, two parts wheat bran and one part oil meal.

Lindsey[2] found that the addition of cotton seed oil (5# per head daily) to a normal ration or to one containing 3# of cotton seed meal low in oil, produced a softer more yielding butter than that produced with the oil omitted. He also found that the addition of one-half to three-fourths of a pound of cotton seed oil to a ration of cotton seed meal (I think that the ration was 3#) appeared to increase the fat percentage of the milk about 0.4 of 1 per cent (5-5.4) and this increase was maintained during the six weeks of the feeding period. Three pounds of cotton seed meal with minimum oil content (8%) had no noticeable effect on the butter. Cotton seed oil (0.5# daily per head) increased the melting point and olein

[1]Hunziker - Purdue Exp. Sta. Bulletin 159.
[2]Lindsey - Mass. Agr. Exp. Sta. Annual Report, 1908, p.112.
*This character (#) is used to indicate "pounds" in this thesis.

percentage of butter fat. Cotton seed meal with a relatively high oil percentage (12.6) produced butter fat that was crumbly when hard and slightly salvy to the taste. Cotton seed meal with a minimum percentage of oil (8%) likewise produced a hard firm butter.

Jordan[1] found that cotton seed meal raised the melting point but did not affect the volatile acids especially. It also increased the iodine number. In bringing about these effects, Jordan changed from a ration of hay, cotton seed meal cornmeal and wheat to one of hay, peas and barley.

Hunt[2] reports that the average score of eight samples of butter produced by cows fed a ration of cornmeal 4# and wheat bran 6# was 80, in contrast to a score of 68 where the only change in the conditions was the substitution of 4# of cotton seed meal for the cornmeal. Corn stover and ensilage composed the roughage. There was also a raise from 93 to 99° F in the melting point when the cotton seed meal was fed.

Graves[3] found that the influence of cotton seed meal on the constants of butter fat was only slightly noticeable, probably due to the character of the roughness fed with the ration. The melting point was raised 1.64 degrees centigrade; the Reichert Meissel number was not affected; the saponification number was lowered slightly and the iodine number raised 2.72. The color was apparently not affected. The

[1]Jordan - Maine Agr. Exp. Sta., Annual Report, 1891, p. 67
[2]Hunt - Pennsylvania Sta., Bulletin 17, pp. 17-19.
[3]Graves - Thesis for A. M. Degree, U. of Mo., 1912.

hardness varied to a slight extent with the iodine number. The firmest butter did not have the highest melting point. Graves showed that the addition of cotton seed meal to a basal ration of silage, alfalfa and corn chop, linseed meal and wheat bran gave a harder butter. He reports a firmer butter from 2# than from either 4# or 6# of cotton seed meal. Cotton seed meal made the butter harder to churn. Four pounds made the butter as hard to churn as did 6#. A distinct flavor was given to the butter but this was not objectionable enough to detract from the market qualities of the butter. The body of the butter was firm, sticky, and brittle, with an overworked appearance. The body of the butter produced from a ration containing cotton seed meal and timothy hay was poorer in flavor and in body than butter produced from a ration containing cotton seed meal, alfalfa hay, and corn silage. Two pounds of cotton seed meal when fed with corn silage and alfalfa hay proved beneficial rather than harmful to butter. Cotton seed meal butter had much better keeping qualities and stood up at a much higher temperature than butter produced from a ration containing no cotton seed meal.

Harrington[1] found that the melting point of butter was raised several degrees by a feed of cotton seed or cotton seed meal. The iodine absorption number was also increased. The volatile acids are greatly lowered. The effects become apparent on a one-fourth ration of meal or seed, but is not sufficient to materially affect the quality of the butter.

[1]Harrington - Texas Agr. Exp. Sta., Bulletin 29, p. 349.

These facts are of economic importance to a farmer who makes butter to sell in a warm climate where cotton seed meal is the most economic feed at his command.

J. Hansen[1] reports as follows: "The percentage of fat in milk is increased by palm nut cake, cocoa nut cake, and cotton seed meal and decreased by poppy seed cake. Sesame cake and rape seed cake have the same influence as peanut cake. Rice meal exerts a favorable influence on the fat content of milk. As compared with peanut cake the daily yield of fat was, therefore, increased by cocoa nut cake, palm nut cake, linseed cake, cotton seed meal and rape seed cake and decreased by sesame cake, poppy seed cake and rice meal."

A. J. Swaving[2] drew the following conclusions: "Cotton seed meal exerted no influence on the yield of butter nor the refractometer and Reichert Meissl number."

Curtis[3] found it impossible to churn butter at 60-64 degrees when only cotton seed and cotton seed meal were fed. The best temperatures with these feeds was 73-80 F. The average time required at these temperatures was 33 minutes. At 68-76 degrees F, the average time was one hour and fifty-six minutes. When they were fed largely but not exclusively on cotton seed or cotton seed meal, the best temperature seemed to be 68-75 degrees F and the average time required 38 minutes. In discussing the subject, Curtis says: "Practical experience has demonstrated, to my judgment at least, that if a considerable amount of green stuff, whether of soiling crops, grass

[1]Hansen - Landw. Jahrb., 35 (1906) Sup. 4, pp. 327-369, According to E. S. R., Vol. 18, pp. 765-766.

[2]Swaving - Zt. Schr. Untersuch. Nahr. 7, Genussmtl. 6 (1903) 3, pp. 97-115, als in Cent. Agr. Chem. 32 (1903) No. 11, pp. 759-761,

[3]Texas Exp. Sta. Bul. 11, p. 11 According to Vol. 15, E. S. R. P. 716

or ensilage, form part of the daily ration, we may add cotton seed or cotton seed meal in a larger proportion without destroying quality than is possible when the cows are on dry feed." Curtis reports the following scores from the rations indicated:

Rations	Score
Pea vine hay 5# Bran 5# Cornmeal 6# Cotton seed meal 4# Millet and pasture	85.79
Oats 11# Cotton seed meal 4# Free access to dry scant pasture about equal to hay	75.80
Ration of nothing but cotton seed meal raw and cooked	70.68

E. W. Allen[1] fed a ration of 10# cowpea vine hay, 20# of corn silage, 4# of wheat bran and 5# of cotton seed meal per head. In the following two weeks, 6# of whole cotton seed was substituted for the 5# of cotton seed meal. In the third period 6# of corn and cob meal was substituted for the cotton seed. The butter was sent to St. Louis and scored. On the scale of 100 points, the butter from the cotton seed meal scored 95 1/2 points, that from the cotton seed 96 points and that from the corn cob meal 96. He concludes that the quality of the butter was not injured by feeding 5# of cotton seed meal or 6# of cotton seed. The average melting point for cows fed 5# cotton seed meal was 100.1° F while that from

[1]Allen - Miss. Exp. Sta. Farmers' Bul. 119, U.S.Dept. of Agr.
[2]Clark - Ala. Agr. Exp. Sta. Bul. 121, p. 203.

the corn meal and wheat bran ration had a melting point of 96.8° F.

Clark[1] found that a ration consisting of 9# cotton seed, 3# wheat bran and 10# sorghum hay gave a butter practically equal in firmness and volatile acids to a butter from a ration consisting of 5 1/4# cotton seed meal, 3# wheat bran and 10# cotton seed hulls. Feeding cotton seed and cotton seed meal to cows on pasture increased the melting point of the butter 1-3 degrees centigrade. Three pounds of cotton seed meal and one pound of wheat bran gave as hard a butter as eight pounds of cotton seed meal and one pound of bran. The volatile acids in the butter were not materially affected by the different rations.

Wood and Parsons[2] found that cotton seed meal produced a hard butter and that gluten meal produced a soft butter. Ensilage also gave a softer butter than did timothy hay. He also found that there was no relation between the hardness and the melting point of butter. However, Wood and Parsons state that the iodine number follows the hardness very closely. Ensilage hay, corn meal and middling were fed with the cotton seed meal.

Morse[3] found that cotton seed meal lowered both the iodine and Reichert Meissel numbers appreciably.

Hills[4] found that the volatile acids were uniformly lowered and the iodine number markedly increased in every case

[1]See note [2] on page 8
[2]Wood and Parsons - New Hamp. Exp. Sta.,Bulletin 13.
[3]Morse - New Hamp. Agr. Exp. Sta., Bulletin 16.
[4]Hills - Vermont Agr. Exp. Sta. 12th Annual Report, 1899,p.297

when oil was fed. Also that corn and linseed oil gave these results even more conspicuously than did cotton seed oil. Cotton seed oil raised the melting point. Hills stated that when the softer fats as olein and linolein are in excess as in linseed and corn oil we get a high iodine number and a softer butter. When, as in cotton seed oil, a harder fat, stearin, is fed we get a low iodine number and a harder butter. All butter made on this ration was said to be of a good quality. Silage and hay made up the roughage of the ration.

The work of Eckles[1], pages 12,13 shows that cotton seed meal had a tendency to raise both the iodine number and the melting point. Also that there was no consistent variation in the Reichert Meissel number. In general, the saponification number was lower. His work also shows that the effects of cotton seed meal were much less when pasture was a part of the ration.

Wiley[2] lowered both the iodine and the Reichert Meissel numbers, and raised the melting point by feeding cotton seed meal.

[1]Eckles, Mo. Exp. Sta., unpublished data.
[2]Wiley - Pros. Soc. Prom. Agr. Science - 1889, p. 88.

The following is a statement of the results of investigators up to date.

Rations	Number of cows	Days on feed before sampling	Melting point Centigrade	Reichert Meissl Number	Iodine Number	Saponification Number
Hunziker[1] corn silage, alfalfa hay, oats 2 parts, oil meal 1 part, wheat bran 2 parts	2	13	Lot 2 33.0°	30.1	36.3	231
			Lot 3 33.7°	31.0	31.3	232
			Lot 4 33.8°	31.0	30.6	231
Same as above plus 1 1/4# cotton seed oil	2	6	Lot 2 34.2°	23.2	46.4	223
			Lot 3 35.0°	30.3	40.3	230
			Lot 4 34.0°	30.0	39.2	229
(Graves Exp.1)[2] Alfalfa hay, corn chop, 4 parts, wheat bran 2 parts linseed meal 1 part	8	8	31.86	29.66	30.78	232.3
Same as above with 2# of cotton seed meal substituted for 2# grain mixture	8	12	32.81	30.01	30.06	231.9
4# of cotton seed meal substituted for grain mixture	8	12	33.50	30.92	33.50	231.3

[1]Hunziker - Purdue Exp. Sta., Bul. 159
[2]Graves - Thesis A. M. degree, Univ. of Mo., 1912.

6# of cotton seed meal substituted for 6# grain mixture	8	12	33.34	30.80	32.71	231.1
Same as in Period 1 (Basal Ration)	8	14	31.70	29.47	30.80	232.0
Graves - Exp.2(2) Timothy hay, corn chop, 4 parts, wheat bran 2 parts, linseed 1 part. 11# of the above in the ration	3	16	33.00	26.56	36.13	226.5
Timothy hay, grain mixture 8 1/3# 4# cotton seed meal	3	18	38.30	26.03	38.53	222.3
Eckles[1] alfalfa hay 17# Grain 5#[2]	1 No (216)	8	33.93	22.74	38.28	223.9
Alfalfa hay 17# Grain 3# Cotton seed meal 2#	1 No (216)	16	34.40	22.60	39.24	222.8
Alfalfa hay, grain 2#, cotton seed meal 3#	1 No (216)	16	35.63	22.90	38.49	222.2
Alfalfa hay 13# cotton seed meal 4#	1 No (216)	16	35.43	23.89	37.21	221.1
Alfalfa hay, 13# grain mixture 4#	1 No (216	17	34.27	25.98	36.18	224.9

[1] Eckles, Mo. Exp. Sta. Unpublished data.
[2] Grain mixture of 4 parts corn chop, 2 of wheat bran and 1 of linseed meal

(Eckles)[1] Pasture grain mixture 4#	1 No (10)	12	33.83	33.16	31.45	232.9
Pasture cotton seed meal 4#	1 No (10)	12	33.20	30.02	34.37	233.2
Pasture grain mixture 4#	1 No (10)	12	33.17	29.85	33.51	233.5
Alfalfa hay 15 # Grain mixture 7# 1-corn 2-bran 3-linseed meal	1 No (301)	13	33.23	28.33	31.44	229.7
Alfalfa hay 14# grain mixture 4# cotton seed meal 3.6#	1 No (301)	16	33.73	27.29	36.96	225.3
Alfalfa hay 15# cotton seed meal 7.5#	1 No (301)	13	36.47	28.06	37.54	223.4
Alfalfa hay 16# Grain mixture 8#	1 No (301)	13	33.63	28.33	31.68	229.5
Wiley[2] (Jersey cow No.6467) Pasture	1	10	34.9	22.8	37.7	
(cow 6467) Cotton seed meal ad. lib.	1	7	38.4	21.4	34.9	
(Aryshire cow 6468) On pasture	1	10	36.3	22.5	41.1	
(No.6468) cotton seed meal ad lib.	1	7	49.00	20.8	36.8	
(cow no. 6469) Pasture	1	10	35.2	22.1	38.0	

[1]Eckles - Mo. Exp. Sta., Unpublished data.
[2]Wiley - Proc.Soc.Prom. Agr. Science, 1889, p. 88

(Cow 6469) On cotton seed meal ad lib.	1	7	38.30	21.10	35.20	
Harrington[1] Cornmeal bran and silage	2	20	33.10	24.85	33.45	247.60
1/4 ration cotton seed meal	2	20	35.4	24.05	32.39	262.61
1/2 ration cotton seed meal	2	17	38.0	21.3	32.60	258.86
3/4 ration cotton seed meal	2	17	39.5	15.45	35.78	264.54
all cotton seed meal and hulls	2	17	41.4	12.15	42.34	272.0
Lupton[2] ground oats 5# corn 5# bran 5# ensilage	10	7	35.6	29.8		
Cotton seed meal 4#,ground oats 4# bran 6# ensilage 6#	10	7	36.1	30.5		
Cotton seed meal 4#,c. s. hulls 9# ensilage 4 1/2#	10	7	37.4	27.5		
Raw cotton seed cotton seed hulls ad lib.	10	7	43.6	22.1		
Cooked cotton seed cotton seed hulls ad lib.	10	7	42.1	22.5		

[1]Harrington - Texas Exp. Station, Bul. 29, p. 35.
[2]Lupton - Ala. Exp. Sta., Bul. 25.

Morse[1] Ensilage 40# Hay 5.5# middlings 2.05, corn meal 2.05# cotton seed meal 2.05# gluten meal 2.05#	2	12		29.00	39.00	
Ensilage 40#, hay 5.5#, middlings 2.4#, cotton seed meal 7.25#	2	14		25.40	33.40	
Ensilage 40#, hay 5.5#, midlings 2.05# cornmeal 2.05#, cotton seed meal 2.05# gluten meal 2.05# pasture	2	12		30.80	38.70	
Ensilage 40#, midlings 2.4# hay 5.5# Cotton seed meal 7.25 pasture	2	28		24.4	34.70	
Ensilage[2] 40#, hay 5.5#, middlings 2.35#, gluten meal 5.3# pasture	1	12		31.00	36.40	
Ensilage 40# hay 5.5# middlings 2.25#, gluten meal 3.5, cotton seed oil 13.5 oz. pasture	1	12		19.70	37.80	

1Morse - N. Hamp. Exp. Sta. Bulletin 16 - p. 5.
2Average of 3 readings given in N.H. Bul. 16, p. 14.

Morse[1]

Ensilage 23 1/2 clover hay 7 1/2 vetch hay 3 3/4, oat meal 3 3/4 middlings 3 3/4				33.10	33.00	
Ensilage 23 1/2 clover hay 11 1/4 oat meal 3 3/4, middlings 3 3/4 stearic (oil) 11 oz	1	14		28.00	35.60	
Ensilage 23 1/2 clover hay 11 1/4, oat meal 3 3/4 middlings 3 3/4, cotton seed oil 11 oz.	1	13		29.60	37.6	
Ensilage 23 1/2 clover hay 7 1/2, vetch hay 3 3/4, oat meal 3 3/4 middlings 3 3/4	1			31.30	33.5	
Ensilage 23 1/2 clover hay 7 1/2 vetch hay 3 3/4, oat meal 3 3/4 middlings 3 3/4 cotton seed oil 11 oz.	1	14		26.20	42.7	

[1]Morse - N. Hamp. Exp. Sta., Bulletin 16, p. 17.

PRESENT STATUS OF THE PROBLEM

The Melting Point:-

The preceding data shows that there is complete agreement among scientists as to the capacity of either cotton seed meal or cotton seed oil to cause a rise in the melting point of butter. However, there are wide variations in the results of different investigators and even of the same investigator when nutrients from different sources make up the ration. Graves, when feeding 4# of cotton seed meal with silage, alfalfa and grain mixture found a rise of 1.64° C, but when 4# of cotton seed meal was fed with timothy hay and grain mixture there was an increase of 5.3 degrees in the melting point. Morse raised the melting point 8.1° C by changing from a ration of corn meal, bran and silage to one of cotton seed meal and hulls. Clark raised the melting point but 1.8° by changing from a ration of ground oats, corn and bran to one of cotton seed meal, 4#, cotton seed hulls, 9#, ensilage 4 1/2#. However, when the ration was changed to cotton seed and cotton seed hulls, the melting point was raised 8 degrees. Hunziker, feeding alfalfa hay, corn silage, oats, wheat bran, and oil meal as a basal ration, raised the melting point as follows by the addition of 1 1/4# cotton seed oil; Lot 1, 1.2° C, Lot 2, 1.3° C, Lot 3, 2° C. These results are less marked than are those of other investigators feeding cotton seed meal. In general, however, both oil and meal seem to have a tendency to cause a raise in the melting point of butter. It is to

be noted, however, that rations containing a succulent feed as silage and pasture, invariably gave a much less increase in the melting point than did rations lacking this kind of roughage. Hunziker[1] concludes that blue grass pasture lowers and that corn silage has no effect on the melting point.

Iodine Number:-

In general the studies up to date indicate a lack of uniformity in regard to the fluctuations of the iodine number. Hunziker, page 11, by adding 1 1/4# cotton seed oil to a basal ration, increased the iodine number as follows: Lot 1, 12.1, Lot 2, 9.3, Lot 3, 8.6. Similarly, Morse, page 16, showed that oil gave in general a much higher iodine number. Graves, page 12, with 4# of cotton seed meal increased the iodine number 2.72, and 2.40 when alfalfa and silage, and timothy hay respectively made up the roughage of the ration. Morse and Wiley, pages 16 and 13 respectively, found that cotton seed meal actually lowered the iodine number and Harrington, page 14, obtained similar results when 1/4 and 1/2 of the ration was cotton seed meal, but raised the iodine number when 3/4 or when all of the ration was cotton seed meal or cotton seed meal and hulls. Silage also was included in this ration. It is obvious from this discussion that whereas cotton seed oil invariably raises the iodine number, cotton seed meal may have an opposite effect. Data, published by Hunziker[1] since the planning of this experiment shows that oil increases but that cotton seed meal decreases the per cent of olein. Less than 5# has no effect.

[1]Hunziker - Purdue Bulletin 159 - p. 317.

Reichert Meissl Number:-

A study of the work done on the variations in the Reichert Meissel number indicates that cotton seed meal may have either a positive or a negative influence. The results secured by Lupton, Wiley and Harrington all show a lowering of this constant. On the other hand, Graves found that 6# of cotton seed meal with a ration of alfalfa and silage, as roughages, had a tendency to slightly raise the Reichert Meissl number. Upon changing to timothy hay as roughage, there was a slight decline in the per cent volatile acids. The work of Graves, therefore, suggests that cotton seed meal has little if any effect on the volatile acid content of butter. From the standpoint of a direct study of the cotton seed meal problem, the work of Graves is especially significant in that all factors other than the introduction of cotton seed meal and the amount of cotton seed meal fed remained constant. In lowering the Reichert Meissl number 7.3, Lupton changed, gradually, from a ration composed of ground oats, corn, and bran to one of raw cotton seed and cotton seed hulls. Obviously this was a radical change. Unfortunately, this data does not include any record of the iodine number. If such could be obtained, it would probably show a high increase in the per cent of olein. Further it is obvious, that if there is a marked increase in oleic fatty acids, there must also be a decrease in other fatty acids, among which are numbered the volatile acids. In the first three periods of Lupton's experiment, when silage was a part of the ration, there was little decrease in the volatile acids, and up to that stage the results agree with

those of Graves. But in the last two periods of Lupton's experiment when no silage was fed, we note the very conspicuous rise in the Reichert Meissl number. The work of Harriman, also, agrees with that of Lupton in suggesting that if silage be included in the ration, there will be little if any variation in the per cent of volatile acids. According to Hunziker[1] corn silage tends to raise the volatile acids and to lower the per cent of olein, i. e., its effects are exactly contrary to those of cotton seed meal and cotton seed oil.[2] Blue grass pasture, however, like cotton seed meal and cotton seed oil, tends to raise the iodine number and to lower the Reichert Meissel number.[3] This capacity of blue grass pasture to cause butter fat constants to vary in the same way as cotton seed oil, and to a less extent in the same way as cotton seed meal may be responsible for the very slight decrease in Reichert Meissl number, obtained by Wiley when, as in three different cases, he secured only a slight decrease by changing from pasture, entirely, to one where the cows received cotton seed meal, "ad libitum". It is obvious that the basal ration, pasture, would in itself give an abnormal iodine and Reichert Meissl reading, and that it would accordingly be impossible to obtain any appreciable variation. Furthermore, Hunziker's results with corn silage help to account for the tendency of all rations containing this roughage to produce very slight effects on butter fat when fed with cotton seed meal or cotton seed oil. This property of silage and pasture grass to pro-

[1]Purdue Bulletin 159 - p. 307.
[2]Purdue Bulletin 159 - p. 317.
[3]Purdue Bulletin 159 - p. 315.

duce opposite effects on the per cent volatile acids and olein, has not, to the writer's knowledge, been substantiated by other scientific investigations. It, therefore, may or may not be the full explanation of the small fluctuation in the iodine and Reichert Meissl numbers when either silage or blue grass pasture is included in the ration.

Saponification Value:-

By far the larger portion of the work done on this subject has omitted the saponification value from consideration. Graves obtained a very slight but gradual decrease when feeding cotton seed meal with corn silage and alfalfa hay. More marked results were obtained when timothy hay was fed as roughage. In contrast to Graves, it may be seen, page 14, that Harrington raised the saponification value, very appreciably, by feeding cotton seed meal. Hunziker, however, lowered the saponification value by feeding 1 1/4# of cotton seed oil. While these results do not warrant any definite conclusions, the tendency seems to be toward a lowering of the saponification value when either cotton seed meal or cotton seed oil are a part of the ration. This is the result that might be expected from the feeding of fats and oils.

Significance of the Work up to Date:-

In view of the fact that there has been a decided lack of control of various factors other than cotton seed meal or oil in many of the experiments thus far performed, no very definite conclusions can be drawn from them. It is now known that various feeds have the capacity to cause a fluctuation in the

constants of butter fat. It is, therefore, obvious that the different feeds fed with a ration of cotton seed meal may accentuate or retard the action of this particular concentrate, and that any conclusion which does not take this fact into account must therefore be invalid. The failure of many of the earlier investigators to recognize the variations possible from feeds other than cotton seed meal and oil, doubtless accounts for much of the diversity of results. If, as Hunziker has concluded, corn silage tends to lower the iodine number and to raise the Reichert Meissel number, it is clear that the property of cotton seed meal and oil to raise the iodine number and to lower the Reichert Meissel number will be much less marked when corn silage is a part of the ration.

Many of the phenomena connected with the changes produced on butter fat by the feeding of cotton seed meal are explained from the standpoint of the oil content of the meal. For instance, the high iodine number produced by feeding cotton seed meal is held to be due to the presence of the oil. Cotton seed oil has a high iodine number and is, therefore, held to be responsible for the corresponding change in the iodine number of the butter. And, since the iodine number is in reality a measure of the amount of oleic acid, which of itself has a low melting point, it is held that the result of a high iodine number should be a soft butter. However, many complications arise when we attempt to explain the changes produced by cotton seed meal from this point of view. Graves, feeding a ration of 2# of cotton seed meal produced a hard butter but when he fed 4# he produced a soft butter. Hunziker, feeding 1 1/4# of oil produced a much softer bodied butter.

Thus we find 6# of cotton seed meal and 1 1/4# of oil producing similar effects. However, 4# of cotton seed tended to harden the butter. Lindsey found that the addition of oil to a ration of cotton seed meal gave a softer butter. No two of the above rations were exactly alike, however, and this fact together with the other contradictions mentioned above makes it impossible to state anything definite regarding the influence of cotton seed meal on the hardness of butter.

Furthermore, we note from the work of Graves and Hunziker that cotton seed meal and cotton seed oil produced very different results even though the other ingredients of the ration were very much the same. Graves found comparatively little variation in either Reichert Meissel or iodine numbers, whereas Hunziker secured very marked fluctuations. Harrington, however, with a ration high in cotton seed meal content produced results very similar to those of Hunziker when feeding oil.

If, therefore, investigations will not warrant the conclusion that the changes produced by cotton seed meal are due to the oil contained in the meal, then it would seem as though the protein or nitrogenous content must be responsible for the fluctuations observed. In fact, Morse did conclude that cotton seed oil and cotton seed meal produced opposite variations on the iodine number. In commenting on his investigations, Morse writes as follows: "It was found that the oil and the meal or nitrogenous part affected the volatile acids alike; but the iodine number was raised by the oil and lowered by the meal. When fed all together in the original grain, cotton seed produced the effect of the meal or nitrogenous

matter; while corn produced the effect of the starch."

In the preceding paragraphs I have explained an observation of the data of Morse, which shows that his conclusions are correctly stated. Still the work of Harrington shows that cotton seed meal lowered the volatile acids and raised the iodine number - in other words, that meal produced the same effects as oil. Again, the most marked variation secured by Graves when feeding cotton seed meal was the increase in the iodine number. Moreover, his data show that while the Reichert Meissel number did not fluctuate much, it did tend to increase rather than to decrease. Clark, too, failed to influence the Reichert Meissel number by feeding cotton seed meal.

Market Qualities of Butter:-

Graves failed to produce any appreciable change in the quality of butter by feeding 6# of cotton seed meal with alfalfa hay and corn silage. Hunt, however, found that 4# of cotton seed meal when fed with ensilage and corn stover and wheat bran lowered the quality of the butter very greatly. When feeding 4# cotton seed meal with millet and dry pasture, Curtis produced a low grade of butter. Allen fed 6# of cotton seed meal, cowpea vine hay, corn silage, and wheat bran, without producing any change in the quality of the butter.

The work thus far performed, does not warrant any definite statement relative to the effect of cotton seed meal on the market quality of butter. In general the effect of the cotton seed meal seems to be greatly influenced by the kind of

roughage fed.

Hardness of Butter:-

The work of all investigators studied by the writer shows that invariably cotton seed meal produced a harder butter. Lindsey, however, found that cotton seed oil gave a softer butter. Hunziker, too, concluded that cotton seed oil tended to produce a softer butter. This investigator also states that the effects of cotton seed oil may be variable. Both of these findings, however, tend to show that cotton seed oil has an effect exactly opposite to that of cotton seed meal on the hardness of the butter. This relationship between cotton seed oil and cotton seed meal is inconsistent with the theory that the oil contained in the meal is responsible for the changes observed in butter fat.

Churnability of Cream:-

Curtis[1] found that when cows were fed only cotton seed meal and cotton seed hulls, it was practically impossible to churn the butter. Graves[2] found that cotton seed meal made butter harder to churn. However, he did not have any serious trouble in churning. Other investigators have failed to publish anything relative to "Churnability."

The facts thus far presented indicate that there is a need for further investigations on the changes produced on butter fat by feeding cotton seed meal.

1 & 2 (Previously given)

EXPERIMENTAL WORK

The Objects of This Investigation are as follows:

1. To determine whether or not the changes produced on butter fat by feeding cotton seed meal are due to the oil or to the nitrogenous part of the meal.
2. To secure further data in regard to the influence of the roughage fed upon the results of feeding cotton seed meal.

General Plan:- Lot 1[2] was fed cotton seed meal, Lot 2, cotton seed meats and Lot 3, raw cotton seed oil. The cotton seed meats was the fleshy part of the raw cotton seed, obtained by removing the hulls. This was accomplished by running the cotton seed through a feed grinder and then sifting the broken hulls from the meaty part of the seed. In order to determine to what extent, if any, the oil was responsibe for the changes observed in butter fat when cotton seed meal is fed, this experiment was so planned that all lots received the same amount of oil at corresponding periods. Calculations based upon the oil content of cotton seed meal[1], 10%, and cotton seed meats, 37%, made possible this equality of oil in the different lots. Table 1 shows the amount of oil fed to each lot. It should be noted from the discussion, however, that each lot received its oil allowance in a different form from each of the other two lots. Lot 3 received the raw cotton seed oil; Lot 2 received its oil in the form of cotton seed meats. Cotton seed meal provided the oil fed to Lot 1. By this method of feeding, it was considered possible to study the effects of the oil, the meal, and a combination of the two, viz., the

[1]Analysis by L. S. Palmer, Sta.Chem., Mo. Agr. Exp. Sta.
[2]See Table 2, p. 27.

cotton seed meats, upon the composition of butter fat.

TABLE I

SHOWING GENERAL PLAN OF EXPERIMENT

PERIODS	LOTS	POUNDS OF COTTON SEED OIL IN RATIONS
No. 1 - Basal	1, 2 and 3	None
No. 2	1, 2 and 3	0.4
No. 3	1, 2 and 3	0.6
No. 4	1, 2 and 3	0.8
No. 5 - Basal	1, 2 and 3	None

Cows used in this Experiment:- Three lots of two cows each were chosen for this experiment. Lots 1 and 3 consisted of one Jersey and one Holstein; Lot 2 consisted of one Ayrshire and one Jersey. In Table 2 is given detailed information concerning the individuals selected.

TABLE 2

LOT	NO. OF COW	BREED	AGE YEARS	DAYS IN MILK or DAYS ADVANCED IN LACTATION	LBS MILK PER DAY PRODUCED	AVER-% FAT	AVER-WT. Pounds
1	16	Jersey	13	34	27	3.8	850
	220	Holstein	4	100	20	3.2	1100
2	57	Jersey	6	131	12.5	5.4	830
	303	Ayrshire	6	148	21	3.4	1040
3	64	Jersey	2 1/2	102	13.5	5.8	850
	213	Holstein	6	61	17	3.2	1200

Plan of Feeding:- Table 3 shows the concentrates fed to the individual cows. In addition the cows were fed from 8-10# of both corn stover and timothy hay. This amounted to 16-18# of hay and stover or practically to feeding these roughages "ad libitum". Individual consumption of hay and corn stover varied slightly according to size and appetite, but such variations came within the limits of 8-10# for each roughage.

TABLE 3

SHOWING AVERAGE DAILY RATION FOR INDIVIDUAL COWS

LOT	COW	FEED	PERIOD 1: BASAL #	PERIOD 2 #	PERIOD 3 #	PERIOD 4 #	PERIOD 5 #
1	16	Grain Mixture	9	6.0	6.0	3.0	11
		Cotton Seed Meal		4.0	6.0	8.0	
	220	Grain Mixture	10	6.0	4.0	2.0	10
		Cotton Seed Meal		4.0	6.0	8.0	
2	57	Grain Mixture	9	8.9	8.3	7.9	10
		Cotton Seed Meats		1.1	1.7	2.1	
	303	Grain Mixture	10	8.9	8.3	7.9	10
		Cotton Seed Meats		1.1	1.7	2.1	
3	64	Grain Mixture	10	9.6	9.4	9.2	10
		Cotton Seed Oil		0.4	0.6	0.8	
	213	Grain Mixture	10	9.6	9.4	9.2	10
		Cotton Seed Oil		0.4	0.6	0.8	

Armsby's standards were used to calculate the energy value needed for each cow. Throughout the entire experiment a slight excess of nutrients was maintained. In Periods 2, 3 and 4, when the cotton seed meal, cotton seed meats and cotton seed oil, substituted, had a higher therm value than did the grain mixture, this excess was unavoidable. Inves-

tigations at the Missouri Experiment Station[1], however, show that underfeeding - not overfeeding - tends to change the per cent of fat in the milk and the composition of the fat as well. Calculations on the energy needed, were based upon the fat content of the milk, as well as the number of pounds of milk produced by each cow. (Armsby's tables do not take the fat test of the milk into account.) Eckles[2] has made the following determinations of the therms needed for milk of the various fat tests.

Fat Tests of Milk	Therms Required Per Pound of Milk
4-4-5%	0.3
4.5-5-0%	0.35
5.0-5.5%	0.4
5.5-5.0%	0.45
6.0-6.5%	0.50

The slight increase (2#) in the grain mixture of cow No. 16, Period 2, was necessitated from the fact that in Period 1 this cow suffered a slight inflammation of the udder and a decrease in the concentrates was necessary until the trouble was improved. An improvement was accompanied by an increase in milk yield; accordingly more nutrients were then needed. With the exception of cows 57 and 16, no change was made in the grain mixture. In general, therefore, the

[1] Eckles - Mo. Exp. Sta., Bulletin 100.
[2] Eckles - Unpublished Data.

only change that was made in the rations was to substitute the meal, meats and oil in the respective lots.

Samples For Churning:- Two samples for churning were taken during the last three days of each period. The first sample was composed of the first three milkings--two mornings' and one night's milk--and the second sample was composed of the last three milkings--two nights' and one morning's milk.

In preparing these samples, the milk of each lot was separated as soon as the milking was completed, and the cream was cooled to a temperature of 45° F. After the third milking was separated, the cream was added to that of the two preceding milkings. This composite constituted a single sample for churning. Exactly 600 cc of each composite cream sample was used as a sample for churning in the experimental churn.[1] The remainder of both composite samples was combined and constituted a single sample used for churning in the large barrel churn.

Methods of Handling Composite Cream Samples:- After standardizing to twenty-five per cent cream and adding a five per cent starter the sample was kept at a temperature of 70°F until 0.6 per cent acidity had developed. It was then cooled to the churning temperature used, 64° F. Churning was completed after the sample had stood 10-12 hours or within 48 hours after the first milking. No salt or coloring was added to this butter. In the case of the sample churned in the large barrel churn, 96 hours intervened between the first milking and the time of churning. This comparatively long

[1]See Chapter on Churnability, p. 93, for description of churn.

period intervening, however, was unavoidable in that the butter made in this churn was derived from the cream of the whole period, viz., three days. The temperature used in the large churn was 56° F.

Observations as to the Variations in the Composition of the Butter Fat:- Samples made in the experimental churn were used for chemical analyses. This included a determination of the Reichert-Meissl number, iodine number, saponification number, color readings and the melting point.[1]

Definition of Terms:- Saponification value is the amount of alkali required to neutralize the fatty acids in a given weight of oil or fat.

The iodine number is a measure of the amount of unsaturated fatty acids present. Since the most common unsaturated acid of butter is held to be oleic acid, it follows that the iodine number is usually defined as being a measure of the amount of oleic acid present.

The Reichert-Meissl number is a measure of the amount of volatile acids present in fats or oils.

Tests on Market Qualities of the Butter:- Each sample of butter was scored by Professor Eckles, Assistant Professor L. G. Rinkle and the writer. Further tests on the keeping qualities, hardness, and standing up qualities were made and the method used in each case is described in the chapters in advance, pages 45, 36 and 44 respectively, where the results are also discussed.

Variations in the Fat Constant of the Milk:- A study of the effects of the various rations upon the fat content

[1]Chemical analyses were made by L. C. Palmer, Sta. Chemist, University of Mo.

of the milk was also made. Samples from each cow were collected every second day of the last four periods. As a check, a composite sample was taken the last five days of the first period. The regular tests made every second day of the last period constituted a control sample for this period.

Length of Periods:- Each period covered 18 days. Three days at the beginning of each period were used in getting the cows on full feed. Twelve days intervened between the date when the cows went on full feed and the date when the first churning samples were taken. The milk of the subsequent three days was used for samples. The following are the dates of each of the five Periods.

Period 1 - December 8 - December 26 - 1912
Period 2 - December 26, 1912, - January 13 - 1913
Period 3 - January 13 - January 31 - 1913
Period 4 - January 31 - February 18- 1913
Period 5 - February 18 - March 8 - 1913

CHURNABILITY OF CREAM

In order to maintain a constant temperature for churning, a specially devised experimental churn was used. This churn is described in detail by L. G. Rinkle[1]. In brief, it consisted of an ordinary metallic churn on the inside of which, near the center, and oppositely, there projected two iron frames. A two liter jar was supported and held in each frame. Duplicate samples of 300 cc of 25 % cream were churned each time. The churn was filled with H_2O at a temperature of 64^{o}. In view of the fact that the temperature of the churning room was from $60-65^{o}$ F, it was possible to keep the temperature of the cream in the jars at a practically constant temperature.

The churn was revolved by means of a belt from a small motor. This arrangement gave a uniform rate of sixty revolutions per minute. All future references to the rate of churning will, therefore, be made in terms of "Number of Revolutions". In Table 4 is given the number of revolutions required to churn butter to granules about the size of quail shot. Each reading is the average of two samples, A and B.

The figures of the first three periods indicate a gradual increase in the hardness of churning for all lots. The maximum effect, however, came in Period 3 when the cows of Lot 1 were receiving six pounds of cotton seed meal, and those of Lots 2 and 3 an amount of oil (0. 6#) equivalent to that contained in the six pounds of cotton seed meal. No explanation, aside from the possibility of the animal adapt-

[1] Rinkle - Thesis, University of Missouri, 1910.

ing itself to the continued feeding of cotton seed meal, can be offered for the marked decline in hardness of churning in Period 4 when 8# of cotton seed meal were being fed.

TABLE 4

SHOWING REVOLUTIONS REQUIRED FOR CHURNING

	Period 1	Period 2	Period 3	Period 4	Period 5
Lot 1	1528	2438	3024	2463	1414
Lot 2	1625	2372	3492	3022	1828
Lot 3	1755	3120	3685	2760	1690

A further comparison of the data shows that four pounds of cotton seed meal produced a butter nearly as hard to churn as did eight pounds.

It is interesting in this connection to study Graves' observations on the effect of cotton seed meal upon the churnability of cream. This experimentor, with conditions similar to those of the writer as to temperature, methods of churning, acidity, per cent of fat in cream and age of cream, but with a ration of alfalfa, corn silage, grain mixture (4# corn chop, 2# bran, 1# linseed meal) and two, four and six pounds cotton seed meal in Periods 2, 3 and 4 respectively, obtained the results indicated in Table 3. Each period consisted of thirteen days.

TABLE V

SHOWING REVOLUTIONS REQUIRED FOR CHURNING

GRAVES' EXPERIMENTS

PERIODS	REVOLUTIONS FOR CHURNING
No. 1 - Basal Ration	1855
No. 2 - 2# C. S. Meal	2701
No. 3 - 4# C. S. Meal	3085.2
No. 4 - 6# C. S. Meal	2549
No. 5 - Basal Ration	1868.5

The fact that Graves fed alfalfa and silage as roughage as well as the fact that individual cows may produce butter differing greatly in ease of churning, makesa comparison of the total number of revolutions required for churning in these two experiments of no value, even though the conditions as to method of churning, fat content of cream, temperature, and acidity were the same in both cases. However, a comparative study of the results of each investigation is of immediate interest in this connection.

No definite conclusions can be drawn from Table 4 with regard to the comparative effects of cotton seed meal, meats, and oil. Lot 3, receiving oil, shows the most marked effects by reaching a maximum, in Period 3 of 3685 revolutions. The marked decline in revolutions of Periods 4 and 5, however, robs this data of any significance as might be suggested from the data of the first three periods.

In so far as this work shows a tendency of cotton seed meal, in any amount, to cause an increase in the revolutions

necessary for churning, it agrees with that of Curtis[1] of the Texas Station. Unlike this investigator, however, no butter was found that could not be churned even at a temperature of 56° - that used in the large churn. Since Curtis churned at various temperatures none of which were as low as that used by the writer in the barrel churn (56°F) and since his ration, both roughage and concentrates, was secured very largely if not entirely from cotton seed meal, it is impossible to make comparisons of any significance.

HARDNESS OF BUTTER

The apparatus used for testing the hardness of the butter was that devised by Perkins.[2] It consisted essentially of a plunger to which any desired weight could be attached and which was allowed to fall 10 cm before striking the butter. Duplicate readings were taken on samples of butter from the three lots. A pound print was used as a sample for the hardness tests. The results are given in Table 6.

Single readings taken on samples of rendered butter fat, i. e., butter from which water, curd and salt had been removed, are given in Table 7.

TABLE 6

SHOWING MILLIMETERS PENETRATION IN SAMPLES OF BUTTER

	Period 1	Period 2	Period 3	Period 4	Period 5	Averages Basal Ration	Averages cotton Seed
	(mm)	(mm)	(mm)	(mm)	(mm)		
Lot 1	28	21	17.5	22.5	37.5	32.75	20.3
Lot 2	41	19.5	23.0	23.5	43.0	42.00	21.6
Lot 3	25	22.0	17.0	21.5	27.5	26.50	20.1

1Curtis - Texas Agr. Exp. Sta., Bulletin 11
2Perkins - Thesis B.S.degree, U. of Mo., 1911.

The readings on hardness given in Table 4 show that the least penetration for Lots 1 and 3 was obtained in Period 3 when Lot 1 was receiving four pounds of cotton seed meal. There is little difference between the readings of Periods 2 and 4, when the cows were receiving four and eight pounds of cotton seed meal, respectively. A marked difference in the hardness of the butter of the three lots when as in Periods 1 and 5 no cotton seed meal, meats or oil was fed, is shown in Table 6. In both of these periods the butter of Lot 2 was much the softest. The final reading of 43 M. M. for Lot 2 does not represent the exact condition of this sample, for after the plumger had been dropped it continued to slowly sink through the butter. (There was a slight pause after striking the butter and it was then that the reading was taken.) Lot 2 also had the greatest increase in hardness when changed from the basal to the cotton seed meats ration. The data of Table 4 show that Lot 2, the softest of the three samples on the basal ration was made the hardest by the addition of 0.55 pounds of meats (containing0.2 pounds oil) in changing from Period 1 to Period 2. In Period 3, however, Lot 2 again produced the softest butter and continued to do so until the end of the experiment. This tendency of Lot 2 to produce a soft butter might have been due to the fact that one Ayrshire and one Jersey made up the lot. Hunziker[1] found that the penetration was 16.83, 4.88 and 1.83 mm for butter made from Ayrshires, Holsteins and Jerseys respectively. This investigation is unable to account for the extreme softness of the butter from the Ayrshire breed.

[1]Hunziker, Purdue Agr.Exp. Sta., Bulletin 159, p. 346.

TABLE 7

SHOWING PENETRATION ON RENDERED SAMPLES OF BUTTER FAT

	Period 1	Period 2	Period 3	Period 4	Period 5	Average of Periods 1 & 5	Average of Periods 2, 3 & 4
	m.m.	m.m.	m.m.	m.m.	m.m.	m.m.	m.m.
Lot 1	18	17	18	17	20	19.0	17 1/3
Lot 2	28	17	17	18	33	30.5	17 1/3
Lot 3	18	22	15	16	21	19.5	17 2/3

In so far as the data of Table 7 shows that the butter produced by either, the cotton seed meal, meats or oil rations was, in general, harder than was that produced on the basal ration, and in so far as it indicates the extreme softness of the butter of Lot 2, it agrees with that of Table 6. The data on the rendered butter samples fails, however, to show any marked difference in hardness in Periods 2, 3, or 4. The writer believes, however, that it was impossible to work with the same degree of accuracy on the rendered samples of raw butter. This opinion is founded on the fact that the rendered samples were smaller; besides they were contained in metallic cans the sides of which undoubtedly resisted the outward pressure of the butter when the plunger was dropped and thereby influenced the reading to some extent. However, since all readings are relative, it is not theoretically impossible for the readings of the rendered samples to be as nearly correct as were those on the raw butter. To what extent the factors mentioned above influenced the readings cannot even be approximated. It is not improbable, however, that the slight inconsistencies of the data of these two tables were

due to these factors. On the other hand, the small penetration registered by Lots 1 and 3, in Period 3, Table 6, might have been due to some difference in the amount or method of working the raw butter. In working a small sample by hand there is, always, a possibility of varying the conditions to a small degree at least. It should be noted, however, that in both tables the data shows that the butter of Periods 2, 3 and 4 was uniformly harder than was that of the basal rations. Moreover, this data suggests that the hardness was due to the oil since all lots had very similar decreases in penetration. As shown by Table 8, the data secured by Graves suggest that there is no relation between the amount of cotton seed meal fed and the hardness of the butter, for whereas two pounds of cotton seed meal gave a decrease of 4 M. M., four pounds of cotton seed meal gave an increase of 2 M. M. in depth of penetration over that obtained in Period 1.

TABLE 8

SHOWING THE PENETRATION OBSERVED BY GRAVES

Amount of Cotton Seed Meal in the Ration	m. m. Penetration
None	23.00
2#	19.00
4#	25.00
6#	23.00
None	20.50

The very striking difference in the results secured by Graves and those of the writer is that in all periods,

excepting Period 2, when 2# of cotton seed meal was fed, Graves secured a butter as soft or softer than that produced on the basal rations, whereas, as is shown by Table 6, the writer secured a harder butter in every period that cotton seed meal, meats or oil were fed. It is clearly shown, Table 6, that the hardness did not increase with the increased amount of cotton seed meal fed; still, all lots produced a harder butter in the periods when either cotton seed meal, meats and oil was included in the ration. The sharp decline in the penetration of samples from all lots in Period 5, is strong evidence of the fact that the hardness of the butter had been produced by the oil incorporated in the different rations. This is exactly contrary to the findings of Hunziker[1] as is shown by Table 9.

TABLE 9

SHOWING EFFECT OF CORN OIL, LINSEED OIL AND COTTON OIL ON THE MECHANICAL FIRMNESS OF BUTTER[1]

	Depression in M. M.			
	Group 2	Group 3	Group 4	Average
Basal	29.2	10.4	14.6	18.1
Corn Oil	40.6	33.3	55.0	43.0
Basal	37.5	20.3	31.3	29.7
Linseed Oil	62.5	23.5	41.7	42.6
Basal	40.6	18.8	18.8	26.1
Cotton Seed Oil	37.5	70.8	21.9	43.4
Basal	42.4	3.1	18.8	21.4

[1]Hunziker - Purdue Exp. Sta., Bulletin 15, p. 348.

The above lots, according to Hunziker, were fed corn silage, alfalfa and grain mixture compounded of corn meal 3 parts, oats 2 parts, wheat bran 2 parts and oil meal 1 part as a basal ration. Five days were consumed in getting the cows on a full feed of oil, viz., 1 1/4#. On the 6th and 7th days, samples of milk were taken. Each Basal period lasted 13 days. In commenting on this data, Hunziker writes as follows[1]: "These figures can leave no doubt that rations rich in vegetable oils cause the resulting butter to be soft; but while the corn oil and linseed oil made a uniformly soft butter, the effect of the cotton seed meal was very variable. In the case of Group 3, it made an exceedingly soft butter and in the case of Group 4 the butter from the cotton seed oil ration was pracically as firm as that from the average basal ration. This fact clearly indicates that all oils do not produce the same effect and that the effect of the same oil on different cows may vary widely."

"The variability in the hardness of the butter is made more obvious by noting that Group 5 actually produced a harder butter on cotton seed meal, whereas Lots 2 and 3 produced softer butter on a similar ration."

There is obviously a lack of uniformity of results on the subject under discussion. Hunziker feeding cotton seed oil and Graves feeding cotton seed meal, each produced a softer butter, whereas the writer obtained a much harder butter with both cotton seed meal and cotton seed oil. In attempting to account for the fact that 2# of cotton seed meal gave an increase and 4# a decrease in hardness, Graves makes the follow-

[1]Hunziker - Purdue Exp. Sta., Bulletin 15, p. 348.

ing statement: "An explanation may be found for this in the observation of Morse and Lindsey on the effect of cotton seed oil on butter. They found that butter from a cotton seed meal ration was firm but the addition of half a pound of cotton seed oil to the ration caused the butter produced on this ration to be soft. Thus when 4-6 pounds of cotton seed meal is fed the amount of oil contained may be sufficient to cause the butter to be soft."

Upon further consideration of the above interpretation made by Graves it would seem as though his conclusion could hardly be drawn. It is a perfectly obvious fact that when 4# of cotton seed meal were fed the proportion of oil to meal was the same as when 2# of meal was fed. If, as assumed by Graves, cotton seed meal tends to harden and cotton seed oil to soften, then the balance must have been in favor of the meal in Period 2 when a harder butter was obtained. If, as appears from the table, the effect of 2# was to harden the butter, it is only logical to assume that 4# should at least keep up the increase in hardness. At any rate the increase in softness could not be attributed to the same cause as the increase in hardness, namely, cotton seed meal. Morse and Lindsey, however, added the oil to a ration containing cotton seed meal; they were justified, therefore, in concluding that the oil was responsible for the softer butter produced when the oil was added to the ration, since by such addition of oil the proportion of meal to oil was lowered. There is, however, no analogy between the results of Morse and Lindsey and those of Graves.

The relation of the per cent of moisture in butter to the amount of penetration is shown in the following Table - No. 10.

TABLE 10

SHOWING THE PER CENT OF MOISTURE AND THE M. M. OF PENETRATION

Periods	Lot 1 m. m. Penetration	Lot 1 % Moisture	Lot 2 m. M. Penetration	Lot 2 % Moisture	Lot 3 m. m. Penetration	Lot 3 % Moisture
1	28.0	12.0	41.0	13.0	25.0	13.2
2	21.0	9.0	19.5	9.4	22.0	9.2
3	17.5	9.3	23.0	10.4	17.0	10.0
4	22.5	10.4	23.5	10.6	21.5	10.2
5	37.5	11.3	43.0	11.4	27.5	10.0

All samples show a comparatively low water content. The samples produced when cotton seed meal, meats and oil were fed and when the hardest butter was obtained, also had the lowest per cent of moisture. In Period 3, when the penetration was the least, the per cent of moisture was likewise the least; still, there is little difference between the moisture content of Periods 3 and 4, when the butter of Lot 4 was decidedly softer. Graves found no relation between hardness and moisture content whereas Hunziker reports a direct relation between moisture content and depth of penetration. In view of the fact that all of the samples tested in this experiment were low in water and that there was no appreciable variation, it seems reasonable to believe that the hardness found in periods when cotton seed meal, meats and oil were fed, was due, very largely at least, to some factor other than to the per cent of moisture.

STANDING UP QUALITIES OF BUTTER

In order to obtain some idea regarding the effects of this ration on butter when placed under ordinary conditions as when put on the table at meal time the following tests were carried out: Samples about 1 centimeter thick, and 3 centimeters square were placed on watch glasses and heated at gradually increasing temperatures until the butter lost its shape and spread out on the dish. In making these tests the samples were placed in double walled metallic boxes. Water was placed between the walls and the outer walls of the boxes were covered with asbestos paper. This construction made it possible to hold the temperatures very nearly constant. All samples were heated one hour at the desired temperatures.

In general the results of these tests showed that butter produced by all lots in Periods 2, 3, and 4 withstood approximately 10 degrees F, higher temperature before losing its shape. The butter produced on the basal ration, Periods 1 and 5, spread out over the bottom of the dish at 90-95 degrees F. The addition of the cotton seed meal, cotton seed meats and cotton seed oil to their respective lots gave a butter that held its shape fairly well at 105 degrees F. At 110 degrees, however, the sample spread out on the dish. In all tests, the butter produced by Lot 1 was the least resistant to heat. This fact would seem to indicate that the oil of Lot 3, and the meats of Lot 2 had the most effect on the "standing up qualities" of the butter. Lot 2 produced the softest butter when on the basal rations but when placed on the oil rations this sample became the hardest. Here, as in the tests on churn-

ability, the maximum effects came when, in Period 3, all lots were receiving 75% of the full allowance of cotton seed meal, meats and oil. The maximum for tests made on standing up qualities was maintained in Period 4, however, and in this respect differs from the tests on churnability. In Period 2, about one half the maximum effects were secured; Lot 1 and Lot 2 lost their shapes at 100° F, whereas Lot 3 seemed somewhat more resistant. At 102° F, however, samples from Lot 3 also assumed a very thin consistency.

Throughout this experiment, there seems to be, in general, at least a marked correlation between the results on hardness and those on standing up qualities. Perhaps the strongest single illustration of this fact is found in Period 5, when a basal ration was fed, for as shown by Table 4, Lot 2 then had a much greater penetration than either Lots 1 or 3. Similarly, in period 5, the work on standing up qualities, it was found that the butter of Lot 2 began to loose its shape at 90° F, whereas Lot 1 resisted until 95°, and Lot 1 until 98 degrees before spreading out on the dish. In these tests as well as in the tests on hardness there seems to be no relation between the moisture content and the standing up qualities.

MARKET QUALITIES OF BUTTER

The quality and flavor of this butter was tested by Professor C. H. Eckles, Assistant Professor L. G. Rinkle and the writer. No numerical score was made. The samples were, however, carefully examined as to flavor, body, etc.

It was found that the butter produced by all lots, when on basal rations was very much the same. It was not a highly

flavored butter; still, it had no undesirable flavors. The body was somewhat crumbly. Even rough estimations of the firmness made by pressing the blade of a knife against the sample indicated that the butter of Lot 2 was much the softest of the three samples, but that there was little difference between Lots 1 and 3.

All changes from the basal to the rations of cotton seed meal, meats, and oil, resulted in a butter with a flat, tallowy, salvy taste, and a body that tended to resist melting when placed in the mouth. Upon melting, the samples tended to remain in the palate of the mouth as an oily product. This quality was much less marked in Period 2 than in Periods 3 and 4. In fact, it was the unanimous opinion of the judges that the butter produced in Period 2, when 4# of cotton seed meal, 1.1# of meats, and 4# of oil respectively were fed, would not meet any serious objection from the consumer. In the succeeding Period, (3) however, the flat tallowy taste was so very much in evidence that it was hardly possible to believe that consumers would not consider the butter unpalatable. In order of high oil flavor, the samples ranked, Lot 3, Lot 2, and Lot 1. There was little difference in the quality of the butter of Lots 1 and 2; Lot 3 was considered the poorest flavored of the three samples. None, however, was of a grade high enough to permit the sample to be classed as good market butter. The butter produced in Period 4 was of a somewhat poorer quality than that of the preceding periods. The difference was one of degree only, however. As a practical test of this butter a

sample of Lot 1 was served, unknown to the eaters, to a table of six graduate students in the Dairy Department of the University of Missouri. With one exception every boarder objected seriously to the flavor of the butter after tasting it for the first time. This trial was not made with the butter of Period 3; it is the opinion of the writer that if it had, similar objections would have been raised.

Graves, feeding a ration of 2, 4, and 6# cotton seed meal and grain mixture (corn chops, bran, and linseed meal) as concentrates and with corn silage and alfalfa as roughages obtained a good quality of butter. In fact, one churning made from cows receiving 2# of cotton seed meal actually scored more than did the butter of a check lot receiving no cotton seed meal. Even with 4-6# of cotton seed meal, a fairly good quality of butter was secured. Graves makes the following statement in regard to this butter "while the cotton seed meal did have a peculiar effect on the flavor and body of butter as described previously yet this effect is not probably such as to hurt the market qualities of the butter when cotton seed meal is fed with alfalfa hay and corn silage for roughness. This is readily shown from the fact that an expert judge like Professor Mortenson (Iowa State College) scored the butter produced on the cotton seed meal higher than that produced on a ration without this seed though he was entirely ignorant of the kind of feed fed to the cows that produced this butter".

Graves states further that "four pounds of cotton seed meal in the ration gave almost as marked effects on the flavor and body of the butter as six pounds."

The preceding disucssion indicates that the quality of the butter produced by the writer and that produced by Graves differed greatly. In view of the fact that the scoring of both was done by the same men (Professor Eckles and Assistant Professor Rinkle) and that a marked difference was observed, it seems logical to conclude that the butter produced by the writer with an exactly similar ration (for Lot 1 at least) except that corn stover and timothy hay made up the roughage instead of alfalfa and corn silage, was distinctly inferior to that made by Graves. The possibility of the difference in quality being due to the roughage fed is further supported by the results of a short experiment of two periods in length, performed by Graves (Experiment No. 2) in which timothy hay made up the roughage. The quality of this butter was very much inferior to that produced when alfalfa and silage made up the roughage.

EFFECT UPON THE PER CENT OF FAT IN THE MILK

Table 11 gives the individual fat tests made on each cow throughout the experiment. At the close of Period 1, a five days' composite sample was taken and this test was used as the control for the first period. In order to observe the immediate effects of the cotton seed meal, cotton seed meats, and cotton seed oil on the per cent of fat, daily tests were made the first five days of Period 2. All subsequent tests were made every second day.

TABLE 11

SHOWING PER CENT OF FAT IN MILK IN

INDIVIDUAL COW' MILK

Lot	Cow	5 day com- pos- ite	Dec. 28	Dec. 29	Dec. 30	Dec. 31	Jan. 1	Jan. 4	Jan. 6	Jan. 8	Jan. 10
1	16	4.1	4.9	4.3	4.3	3.6	4.3	4.4	3.8	3.6	4.5
	220	2.9	3.0	3.0	3.0	3.0	3.2	3.0	3.5	3.4	3.3
2	57	5.0	5.0	5.5	5.3	5.5	5.9	6.1	4.8	5.7	5.9
	303	3.5	3.6	4.0	4.0	4.2	4.2	4.3	4.4	4.4	4.7
3	64	5.7	5.9	6.3	5.8	6.4	6.3	4.9	5.1	6.9	6.1
	213	3.1	3.1	4.3	3.0	3.0	3.0	3.0	3.0	3.0	3.3
		Jan. 12	Jan. 14	Jan. 16	Jan. 18	Jan. 20	Jan. 22	Jan. 24	Jan. 26	Jan. 28	Jan. 30
1	16	4.8	4.0	4.5	4.2	4.4	4.3	4.2	4.7	4.5	4.4
	220	3.2	3.4	3.2	2.9	3.1	2.9	3.3	3.0	2.9	2.9
2	57	5.6	5.9	5.6	5.3	6.2	5.2	5.5	5.5	5.4	5.2
	303	4.2	4.3	4.0	4.0	4.3	4.1	4.1	4.4	4.1	4.1
3	64	6.0	6.3	6.8	6.1	5.9	6.3	6.5	6.4	5.8	6.0
	213	3.0	2.7	3.0	3.0	3.1	2.6	3.0	3.0	2.6	2.6
		Feb. 1	Feb. 3	Feb. 5	Feb. 7	Feb. 9	Feb. 11	Feb. 13	Feb. 15	Feb. 17	Feb. 19
1	16	5.2	4.5	4.4	4.5	4.4	4.5	4.4	4.4	4.2	4.2
	220	3.3	3.1	3.0	2.9	3.0	3.1	3.2	2.8	3.0	3.3
2	57	5.5	6.1	5.1	5.6	6.1	6.3	5.5	5.6	5.6	5.8
	303	4.4	4.5	4.3	4.4	4.2	4.6	4.3	4.4	4.2	4.4
3	64	6.1	6.2	6.0	5.6	5.7	5.8	6.0	5.5	5.5	5.4
	213	3.1	2.6	2.6	2.7	2.6	2.7	2.3	2.7	2.5	2.8
		Feb. 21	Feb. 23	Feb. 25	Feb. 27	Mar. 1	Mar. 3	Mar. 5	Mar. 7	Mar. 9	Mar. 11
1	16	4.3	4.2	4.3	4.2	4.2	3.8	3.9	3.9		
	220	3.2	3.4	3.0	3.0	3.1	2.1	2.8	2.8		
2	57	6.0	5.5	5.0	5.2	4.9	4.5	5.0	5.0		
	303	4.5	4.2	3.8	4.0	3.5	3.3	3.6	3.5		
3	64	5.9	5.8	5.1	5.9	5.3	5.4	5.3	5.6		
	213	3.0	2.8	2.6	3.1	2.6	2.6	2.4	2.5		

PER CENT AND YIELD OF FAT IN MILK

In Table 11, it is shown that the first effect of either meat, meats or oil was to raise the per cent of fat in the milk. Cow No. 213 rose from 3.1 to 4.3% in 48 hours after the addition of cotton seed oil to her ration. In 72 hours, however, the test of this same cow had receded to 3%, from which level it varied but little during the remainder of the experiment. With Cow No. 220, however, there was scarcely any rise in per cent of fat until the cotton seed meal had been fed several days; this cow, nevertheless, maintained her increase in per

cent of fat in milk at a higher level and much more uniformly than did No. 213, though the latter seemed much more responsive to the oil in the first part of the period.

It may be observed, Table 11, that the fat tests were made every second day. The data of Table 12 was obtained by multiplying the three last fat tests of each period by the yield of milk, Table 13, on the corresponding date, and dividing to total fat by the total number of pounds milk. This method was used in order to obtain, as nearly as possible, the correct average fat per cents at the close of each period. This same method was used in calculating the combined average per cents of Periods 1 and 5, and of Periods 2, 3, and 4.

TABLE 12

SHOWING THE AVERAGE FAT PER CENT OF MILK IN VARIOUS PERIODS

Name of Period	Lot 1		Lot 2		Lot 3	
	16	220	57	303	64	213
	%	%	%	%	%	%
Period 1	4.1	2.9	5.0	3.5	5.7	3.1
Period 2	4.4	3.3	5.7	4.4	6.1	3.0
Period 3	4.5	2.9	5.3	4.2	5.8	2.7
Period 4	4.4	3.0	5.5	4.3	5.6	2.5
Period 5	3.8	2.7	4.8	3.4	5.4	2.5
(Basal Periods), (Aver.) 1 and 5	3.95	2.8	4.9	3.45	5.65	2.8
(Cotton Seed Meal Per.) ~~(Aver.)~~ 2, 3, and 4 (Aver.)	4.4	3.1	5.5	4.3	6.0	2.7

TABLE 13

SHOWING YIELD OF MILK AT DATES CORRESPONDING TO DATE WHEN SAMPLES WAS TAKEN FOR TESTING AT THE CLOSE OF EACH PERIOD

Lot	Cows	Period 1 Dec. 1912	Period 2 January-1913 10	12	14	Period 3 January-1913 26	28	30	Period 4 February 13	15	17	Period 5 March 3	5	7
			lbs	lbs	lbs	lbs	lbs	lbs	lbs	lbs	lbs	lbs	lbs	lbs
Lot 1	16	5 day composite	19.3	18.6	20.7	20.1	20.7	17.9	20.5	18.0	19.3	18.6	17.9	15.8
	220	sample	15.2	14.6	15.3	15.0	14.6	14.8	14.1	12.4	13.5	14.4	13.1	11.8
Lot 2	57	5 day composite	10.5	10.0	11.2	9.7	9.3	9.0	9.6	9.1	10.1	9.8	9.9	9.1
	303	sample	13.2	13.4	15.3	14.9	14.5	14.7	13.5	12.5	13.8	12.9	12.3	12.3
Lot 3	64	5 day composite	13.2	10.5	11.0	13.3	11.6	11.8	12.5	13.3	13.2	12.5	11.0	11.1
	213	sample	11.1	10.8	10.8	12.7	11.4	11.0	13.8	11.0	11.6	11.1	10.0	9.6

From Table 12, it may readily be observed that all of the cows, with the exception of 213, had a higher average per cent of fat whether fed on the cotton seed meal, meats or oil rations. In general, the greatest increase in fat content came in Period 2, or in the period immediately following the change from the basal ration. Lot 2 on the meats shows the most marked change in fat content and Lot 3, fed the pure cotton seed oil, shows the least. With none of the cows, however, was there any relation between the amount of cotton seed meal, meats and oil

fed and the increase in per cent of fat. The fact that all cows, with the exception of No. 213, produced milk with an increased fat content is further confirmed by a comparison of the average fat per cent of the basal periods 1 and 5, with those of the periods when cotton seed meal, meats and oil were fed,--Periods 2, 3 and 4.

There are two possible explanations of the failure of No. 213 to respond to this ration high in oil: (1) for unknown reasons the tests made in the basal periods may have been abnormal; (2) all cows are not affected similarly and to the same degree by any concentrate in the ration.

It may be noted, Table 10, that No. 213 had a test of 3.1 for the first period and of 2.5 for the last period. In other words, instead of having the increase normal to an advance in lactation, there was a decrease of 0.6%. The following is a statement of the fat tests of No. 213 as made by the Station in connection with keeping the herd record.

Cow No. 213.

Dec.	1912	2.9%	(2nd month of lactation period)
Jan.	1913	3.4%	
Feb.	1913	3.2%	
March	1913	2.5%	

If, as a basis of comparison, and average of the tests of the months of December 2.9%, and of March 2.5%, is taken from the herd record, the per cent of fat for the basal periods is 2.7%. It, therefore, is evident that when the tests made by the Station men are taken as a basis from which to make comparisons, No. 213 had a slight increase rather than a decrease in fat content. Moreover, the tests as made by the Station show that, while this cow tended to fluctuate widely in fat tests,

the greatest fluctuation or rather decrease came in March, the month subsequent to removing the oil from her ratinn.

If there is a possibility of an excess of protein affecting the per cent of fat in milk, the higher tests of Lots 1 and 2 might be accounted for from this point of view. Still, Lot 1, receiving the highest allowance of protein, did not show as high a rise in fat content as did Lot 2, with a protein content about normal.

Whatever interpretation is placed upon the preceding data, the fact that there is, under normal conditions, an increase in the per cent of fat of milk should also be taken into consideration. Analyses of the milk of fourteen cows throughout an entire lactation are quoted as follows by W. A. Henry:[1]

1st month - 4.02%	7th month - 3.9%
2nd month - 3.74%	8th month - 3.94%
3rd month - 3.71%	9th month - 3.92%
4th month - 3.84%	10th month - 4.19%
5th month - 3.87%	11th month - 4.58%
6th month - 3.9 %	

A comparison of this data with that of Table 12 shows that the increase in fat percentage was very abnormal with at least four of the cows - 16, 57, 64 and 303 - used in the experiment.

These results relative to the tendency of cotton seed meal, meats or oil to influence the fat content of milk are confirmed by at least a few other investigators. As shown on page 7, J. Hansen found that the percentage of fat in milk was increased by palm nut cake, cocoanut cake and cotton seed meal. On the contrary, however, A. J. Swaving, as shown on page 7, found that the yield of butter was not affected by cotton seed meal. Lindsey, too, page 4, found

[1]Henry - Feeds and Feeding - p. 381.

that the addition of one-half to three-fourths of a pound of cotton seed oil increased the fat content 0.4 of 1% for the entire feeding period of six weeks.

EFFECTS OF THE CONSTANTS OF BUTTER FAT

In order that proper conclusions may be drawn as to the variations in the constants of butter fat produced by cotton seed meal, it is necessary that the variations which normally follow the advance in lactation be taken into consideration. In Table 13[1] is given, in 4 week periods, the average variations of 11 cows, including Jerseys, Holsteins, Ayrshires and Shorthorns. It is to be noted that while there are fluctuations, particularly in the iodine number, they are, in general, gradual, and approach either a higher or a lower reading in the later periods of lactation. At the close of the lactation period, however, fluctuations are wider and more irregular.

TABLE 13

SHOWING HOW BUTTER FAT CONSTANTS VARY WITH THE ADVANCE IN LACTATION

	PERIODS						
	1	2	3	4	5	6	7
Iodine Number	32.28	31.58	32.22	30.85	31.36	31.72	32.96
Reichert Meissl	29.13	27.49	27.06	26.45	26.58	26.40	25.52
Saponification	233.7	230.0	231.0	229.0	228.9	225.7	226.7
Melting Point	31.73	32.96	32.82	33.08	33.28	33.25	33.32
	8	9	10	11	12	13	
Iodine Number	32.26	34.56	35.41	35.48	35.17	39.22	
Reichert Meissl	25.20	24.23	22.48	22.18	20.29	17.20	
Saponification	225.6	223.4	223.4	220.6	216.6		
Melting Point	33.41	33.51	33.94	34.68	33.85	36.48	

[1]Eckles and Shaw, U.S.Dept.of Agr.Bur. of An. Ind., Bul.155.

TABLE 14

SHOWING VARIATIONS IN THE MELTING POINT, REICHERT MEISSL AND IODINE NUMBERS

Periods	Melting Point			Reichert Meissl Number			Iodine Number		
	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
1	33.80	32.45	33.17	24.56	25.38	24.06	33.60	34.77	33.58
2	36.95	37.60	37.35	26.65	23.53	22.21	33.67	36.05	35.60
3	39.50	37.85	38.90	23.48	22.06	20.74	35.49	37.04	36.21
4	38.35	40.10	39.75	26.83	21.13	19.67	34.88	37.07	37.57
5	32.80	33.55	33.05	25.97	23.52	23.77	34.23	37.02	36.38

TABLE 15

SHOWING VARIATIONS IN THE SAPONIFICATION AND COLOR READINGS

Periods	Saponification			Color					
				Yellow			Red		
	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
1	226.1	228.0	225.4	21.50	17.50	19.50	1.45	1.30	1.30
2	224.1	220.0	220.2	9.50	5.25	6.50	1.25	1.00	1.05
3	221.7	219.2	218.0	6.50	3.50	3.75	1.05	0.70	0.75
4	224.5	217.8	216.8	5.75	3.00	4.50	1.25	1.05	1.25
5	226.8	223.8	222.8	8.50	5.25	5.25	1.4	1.2	1.20

TABLE 16

SHOWING THE AVERAGE READINGS OF THE BASAL PERIODS AND OF THE PERIODS WHEN COTTON SEED MEAL MEATS OR OIL WAS FED

Periods	Melting Point			Reichert Meissl Number			Iodine Number		
Average	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
(Basal)	C	C	C						
1 & 5	33.30	33.00	33.37	25.25	24.45	23.91	33.91	35.89	34.98
2,3 & 4	38.26	38.66	38.66	25.57	22.24	20.87	34.68	36.72	36.46
Fluctuation	*/4.96	/5.66	/5.26	/0.31	-2.21	-3.04	/0.77	/0.83	/1.48

TABLE 17

(CONTINUATION OF TABLE 16)

Periods	Saponification			Color					
				Yellow			Red		
Average	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
1 & 5	226.4	225.9	224.1	15.5	11.37	12.37	1.45	1.25	1.25
2,3 & 4	223.4	219.0	218.3	7.25	3.91	4.91	1.18	0.91	1.01
Fluctuation	-3.0	-6.9	-5.8	-7.25	-7.46	-7.46	-0.24	-0.34	-0.24

Melting Point:- As shown by Table 14, there was a uniform increase in the melting point of all lots. The one exception to this statement is with Lot 1 in Period 4, at which time there was a slight decline.

Table 16 shows the average increases for the periods when cotton seed meal was fed to be as follows: Lot 1, 4.96; Lot 2, 5.66; Lot 3, 5.26. Obviously, there was little difference in the property of the meal, meats or oil to raise the melting

*This character(/) is used to indicate "plus".

point. Hunziker[1], feeding 1 1/4# of oil with a ration of corn silage, alfalfa, oats, wheat bran and oil meal produced only a slight rise in the melting point. Other investigators[1] feeding cotton seed meal have invariably produced a rise in the melting point. With a ration of alfalfa, corn silage, grain mixture and cotton seed meal, Graves raised the melting point 1.64° C. Hunziker[1], with alfalfa and corn silage and grain mixture (oats, wheat bran and oil meal), as a basal ration, raised the melting point but 0.9° C on an average of 3 trials. Harrington[1], however, raised the melting point 8.3°C by feeding a ration of cotton seed meal and hulls. Lupton, too, raised the melting point 6.5° C by feeding cooked cotton seed and cotton seed hulls. Graves[1] raised the melting point 5.3° C by feeding 4# of cotton seed meal with timothy hay as a roughage. In view of the fact that all lots used in this experiment had approximately the same increase in the melting point, the conclusion that such increase was due to the oil contained in the meal is very well established. One other fact equally well demonstrated from a study of this data and of that obtained at the Missouri Experiment Station by Graves[1] is that the increase in melting point is greatly influenced by the character of the roughage. It is to be noted that the only difference in the ration used by Graves (Exp. No. 1) and that used by the writer for Lot 1, was that the former used corn silage and alfalfa, whereas timothy hay composed the roughage for this experiment. Still Graves raised the melting point but 0.95° C when feeding 4#, whereas the writer

[1]See, Review of Literature, pp. 4-10.

raised the melting point 3.15° C when 4# of cotton seed meal were added to Lot 1, Period 2, as shown in Table 14. A comparison of this increase of 0.95° C obtained by Graves with the variations given in Table 14, indicates that it is entirely possible for this relatively small rise to be nothing more than a fluctuation. At any rate it can only be accepted as an indication of a rise in the melting point. On the other hand, the 3.15° C increase, observed by the writer, can hardly be considered a fluctuation. That such was a result of the cotton seed meal is indicated by the rise in melting point for Lot 1, Periods 2, 3 and 4 when more cotton seed meal was fed, (Table 14). Graves (Exp. No. 2) when feeding timothy hay as a roughage and with a grain mixture exactly similar to that of the writer, obtained 5.3° C increase from 4# of cotton seed meal. Moreover, the average increase of 4.96° C in the melting point obtained by the writer in contrast to 1.43° C, by Graves, for periods when cotton seed meal was incorporated in the ration, is additional proof of the tendency of a dry roughage - at least of timothy, hay and corn stover - to produce an abnormally high melting point. A correlation of the works of Hunziker[1] with the results of Lot 3, fed raw cotton seed oil, indicates that the effect of cotton seed oil on the melting point of butter, like that of cotton seed meal, is influenced by the character of the roughage fed in the ration. This is as we should expect if, as this data indicates, the oil contained in the meal is responsible for the rise in the melting point.

[1]Previously given.

Relation of the Melting Point to the Hardness of the Butter Fat:- The data of Table 18, show that, in general, an increase in the melting point was accompanied by an increase in the hardness (decrease in the reading) of the butter.

TABLE 18

SHOWING THE RELATION OF THE MELTING POINT TO HARDNESS OF BUTTER FAT

Periods	Lot 1		Lot 2		Lot 3	
	Melting Point	Penetration	Melting Point	Penetration	Melting Point	Penetration
	°C	M.M.	°C	M.M.	°C	M.M.
1	33.80	28.00	32.45	41.00	33.70	25.00
2	36.95	21.00	37.60	19.50	37.35	22.00
3	39.50	17.50	37.85	23.00	38.90	17.00
4	38.35	22.50	40.10	23.50	39.75	21.50
5	32.80	37.50	33.55	43.00	33.05	27.50

The periods of maximum melting points were not, except in the case of Lot 1, coincident with the periods of least penetration, however. Graves[1] found no relation between the melting point and the hardness of butter when feeding corn silage and alfalfa hay as rougahges. Still, his variations in both of these constants were too slight to warrant any conclusions on the matter.

Reichert Meissl Number:- The data in Table 14 show that Lot 3 had a very marked decrease in the per cent of volatile acids. Both Lot 2 and Lot 3, however, suffered a decisive

[1] Graves- Thesis, A. M. degree, U. of Mo., 1912.

and uniform decline in the Reichert Meissl number. Lot 1, on the contrary, had marked fluctuations in this constant. Moreover, this lot suffered a slight average increase in the Reichert Meissl number (Table 16). It is, therefore, evident that the effect of cotton seed meal upon the Reichert Meissl number of Lot 1 was quite different from that of cotton seed meats and cotton seed oil fed to Lots 2 and 3 respectively. Still, the irregular variations of Lot 1 may have been due to some abnormal conditions of the cows. One individual, No. 16, suffered a slight attack of mamitis in Period 1 and while no milk from the quarter of the udder was used (the teat went blind) there may have resulted physiological disturbances that tended to cause such unusual Reichert Meissl readings. If it were possible to show that this individual was experiencing marked fluctuations, the similarity between such results and those of the group could very readily be understood, for Cow No. 16 produced approximately 65% of all the butter fat churned from Lot 1. Furthermore, a study of the effects of proteins in general, upon the per cent of volatile acids tends to suggest that Lot 1, did not respond normally to the cotton seed meal. Wilson, as quoted by Hunziker[1] found that cowpeas lowered the Reichert Meissl number; also that less than 5 pounds of cotton seed meal had no effect. Lindsey, as quoted by Hunziker[1], further states that soy bean meal free from oil had no effect. Hunziker[1] also states that according to Browne, linseed meal tends to decrease the volatile acids. A further study of the review of the literature on this subject, made by Hunziker[1], reveals

[1]Hunziker - Purdue Exp. Sta. Bul. 159, p. 317.

the fact that ho protein feeds other than those high in fat, cause an increase in the Reichert Meissl number. Furthermore, only those relatively high in oils, linseed oil possibly excepted, cause a decrease. Theoretically, then, the Reichert Meissl number of Lot 1 should either have remained constant or, because of the oil content, have shown a tendency to decline. From this point of view, it seems that the writer is justified in suggesting that little significance be attached to the Reichert Meissl readings of Lot 1. Moreover, repeated experiments at the Missouri Experiment Station[1] have shown that cotton seed meal has little influence on the per cent of volatile acidscontained in butter. Jordan[2], Clark[3], Lindsey[4], Graves[5], and Eckles[6], have all failed to produce any appreciable and consistent variation in the Reichert Meissl number, by feeding cotton seed meal. In fact, Morse[7] is the only investigator whose results show that both cotton seed meal and cotton seed oil produce a marked decline in the per cent of volatile acids. In obtaining a decrease from cotton seed meal, however, Morse, substituted 2.05 pounds of both corn and gluten meal with 5.2 pounds of cotton seed meal. However, Hunziker[8], has shown that corn meal invariably increases the volatile acids; also that gluten meal, rich in fats, increases this constant. Obviously, the question as to whether or not the decrease in the Reichert Meissl number observed by Morse,

[1]2, 3, 4, 5, 6 and 7 all given previously.
[8]Hunziker, Purdue Agr. Exp. Sta., Bul. 159, p. 17.

when feeding cotton seed meal, was due to the complete removal of the corn and gluten meals, or to the addition of the cotton seed meal, may well be raised. Harrington and Lupton, by feeding rations very high in cotton seed meal did observe a marked decline in the Reichert Meissl number. These investigators, however, have failed to produce decisive declines until practically all the ensilage in the ration was substituted by cotton seed meal and hulls. Wiley observed a small but gradual decline in the volatile acids when cows on pasture were fed cotton seed meal "ad libitum." In general, therefore, very slight variations in the Reichert Meissl number have been observed where cotton seed meal was fed with corn silage, ensilage or pasture. In no instance was there an increase of the volatile acids such as was obtained by Lot 1, Period 2 of this experiment, (Table 14). This fact tends to further confirm the idea that the variations of this Lot were abnormal.

In general, the effects of cotton seed oil on the Reichert Meissl number of butter fat were much more uniform and decisive than were those produced by feeding cotton seed meal. Moreover, the effects of the oil seem to be less influenced by the character of the roughage than are the effects of cotton seed meal. Hunziker, Hills, Morse and the writer all lowered the Reichert Meissl number by feeding cotton seed oil, regardless of the great differences in the roughage fed. For instance, Hunziker fed corn silage and alfalfa

as roughages whereas the writer fed timothy hay and corn stover. Hills fed corn silage and Morse fed ensilage as roughages. Still there was a marked decline in the Reichert meissl reading in all of these experiments.

Regardless of the abnormal fluctuations in the Reichert Meissl number of Lot 1, to which little consideration can be given, the marked and uniform decline of this constant with Lots 2 and 3 are facts which warrant the conclusion that any decline in the per cent volatile acids observed by feeding cotton seed may be considered as being caused by the oil contained in the meal.

Iodine Number:- As in the case of the melting point, all lots showed an increase in this constant. With Lot 1, however, this increase was not observed until the 3d period; furthermore, the average rise for Lot 1 in the periods when cotton seed meal was fed, was 0.77° C as compared to 0.83° C and 1.48° C for Lots 2 and 3, respectively. (Table 16.) These comparatively small average increases in the iodine number shown by Table 16 for all Lots are due, in part at least, to the fact that in Period 5 (see Table 14), all of the iodine numbers, particularly those of Lot 2 and 3, tended to remain inflated. Consequently, the average readings of these two periods, on which comparisons are based, are also high and the amount of increase necessarily low. If, however, the maximum increase is measured from Period 1, the results of the rations become more apparent. On this basis Lots 1, 2 and 3 would have maximum increases of 1.89, 2.25 and 2.80 respectively. Even with these values, the ranking in order of increase in the

iodine number remains Lot 1, Lot 2, and Lot 3. If the slight advance in the iodine number of Lot 3, can be considered as an increase due to the oil, as seems altogether reasonable, then the results of the investiagion as compared to the results obtained by Hunziker, show that the latter obtained very much more pronounced results than were observed in this experiment, despite the fact that corn silage and alfalfa were included in his ration. Upon adding 1 1/4# of cotton seed oil to a ration consisting of corn silage, alfalfa, oats, bran and oil meal, this investigator raised the melting point 12.1, 9.3 and 8.6 for Lots 1, 2 and 3 respectively. However, Hunziker fed 0.45 of a pound more oil than the writer. Table 16 shows that Lot 3, invariably responded to an increase in the oil of the ration. Whether or not this response would have continued is impossilbe to state. It is, therefore, useless to attempt to settle definitely the results of the different rations. Nevertheless, when correlated with Hunziker's work, these results seem to suggest that corn silage and alfalfa do not offset the property of cotton seed oil to cause a rise in the iodine number. The work of Morse, wherein the iodine number was greatly lowered by the addition of cotton seed oil (11 oz.), is at variance with the work of both Hunziker and the writer. His results, in the light of present knowledge, can only be regarded as an exception to those of other investigators on the subjects of both cotton seed meal and oil. It is, also, obvious that in obtaining these marked declines in the iodine number, Morse obtained results which seem impossible from a theoretical

standpoint. Cotton seed oil is held to be high in both oleic and linolic acids, both unsaturated acids, and it is, therefore, difficult to account for a decrease in the iodine number when this concentrate is fed. Graves,[1] Harrington[2], Lupton[3], Jordan[4], Hills[5], and Eckles[6] all found that cotton seed meal raised the iodine number of butter fat. Wiley[7] and Morse[8], alone, obtained a decline. Clark[9] did not observe any fluctuatinn of the idoine number from feeding cotton seed meal.

Relation of the Iodine Number to the Hardness of Butter Fat:- Theoretically, a high iodine number should be accompanied by a softer butter. This follows from the fact that oleic acid, of which the iodine number is a measure, is an unsaturated acid liquid at room temperatures. While this theory has been advanced by many, the attention of future investigators should be called to the fact that an increase in oleic acid is not the only change possible from a ration containing cotton seed oil. L. S. Palmer[10], calculating from Lewkowitsch,[11] reports the following composition of cotton seed oil.

Linolic acid..................	48.5%
Oleic acid......................	25.6%
Palmitic acid................	21.9%
(and little archidic acid)	
Glyceral, unsoponifiable matter and volatile acids).	4.0%
Total...........................	100.0%

Linolic acid, having twice the unsaturation of oleic acid, would tend to cause a marked rise in the iodine number. Accordingly, the slight increase in the iodine number observed

[1]1, 2, 3, 4, 5, 6, 7, 8 and 9 all previously given.
[10]Palmer - Station Chemist, Mo. Exp. Sta.
[11]Lewkowitsch - Oils and Fats, Vol. 2, p. 153, 1909 Edition.

in this and many previous experiments might not indicate the increase of any appreciable amount of oleic acid. Moreover, it is not theoretically impossible for the archidic acid, with a melting point of 77° C to more than offset the slight increase in oleic acid, an acid liquid at room temperature. The result would, accordingly, be a hard butter. The palmitic acid of cotton seed meal has a melting point of 62.6° C as compared to 69.3° C for stearic acid. Obviously any substitution of palmitic would, like oleic, tend to produce a softer butter.

The results of this experiment as given in Table 19, show, however, that in general a high iodine number was coincident with a decrease in penetration.

TABLE 19

SHOWING THE IODINE NUMBERS AND HARDNESS READINGS

Periods	Lot 1		Lot 2		Lot 3	
	Iodine number	m.m. Penetration	Iodine Number	m.m. Penetration	Iodine Number	m.m. Penetration
1	33.60	28.00	34.71	41.00	33.58	25.00
2	33.67	21.00	36.05	19.50	35.60	22.00
3	35.49	17.50	37.04	23.00	36.21	17.00
4	34.88	22.50	37.07	23.50	37.51	21.50
5	34.23	37.50	37.02	43.00	36.38	27.50

With Lots 1 and 3, the maximum increase in the iodine number came in Period 3. Lot 2 had the greatest increase in Period 2. It is, therefore, obvious that the relation between the increase in the iodine number and the increase in the hardness is not in direct proportion to the amount of oil fed, and, therefore, that

the oil cannot be held to be instrumental in producing the harder butter, on the sole assumption that acids of a higher melting point, as for example archidic acids are replacing stearic acid in the butter fat. Obviously more oil would, according to this theory, produce a harder butter provided the individual cows did not, upon continued feeding tend to adapt themselves to the oil of the ration. In no case was the period of highest cotton seed meal, meats or oil allowance coincident with the lowest hardness reading. Consequently, the only statement that can be made concerning this relation is that the oil, meats and meal invariably produced a harder butter, and a higher iodine number but that this change in hardness was not dependent upon the amount of these nutrients fed.

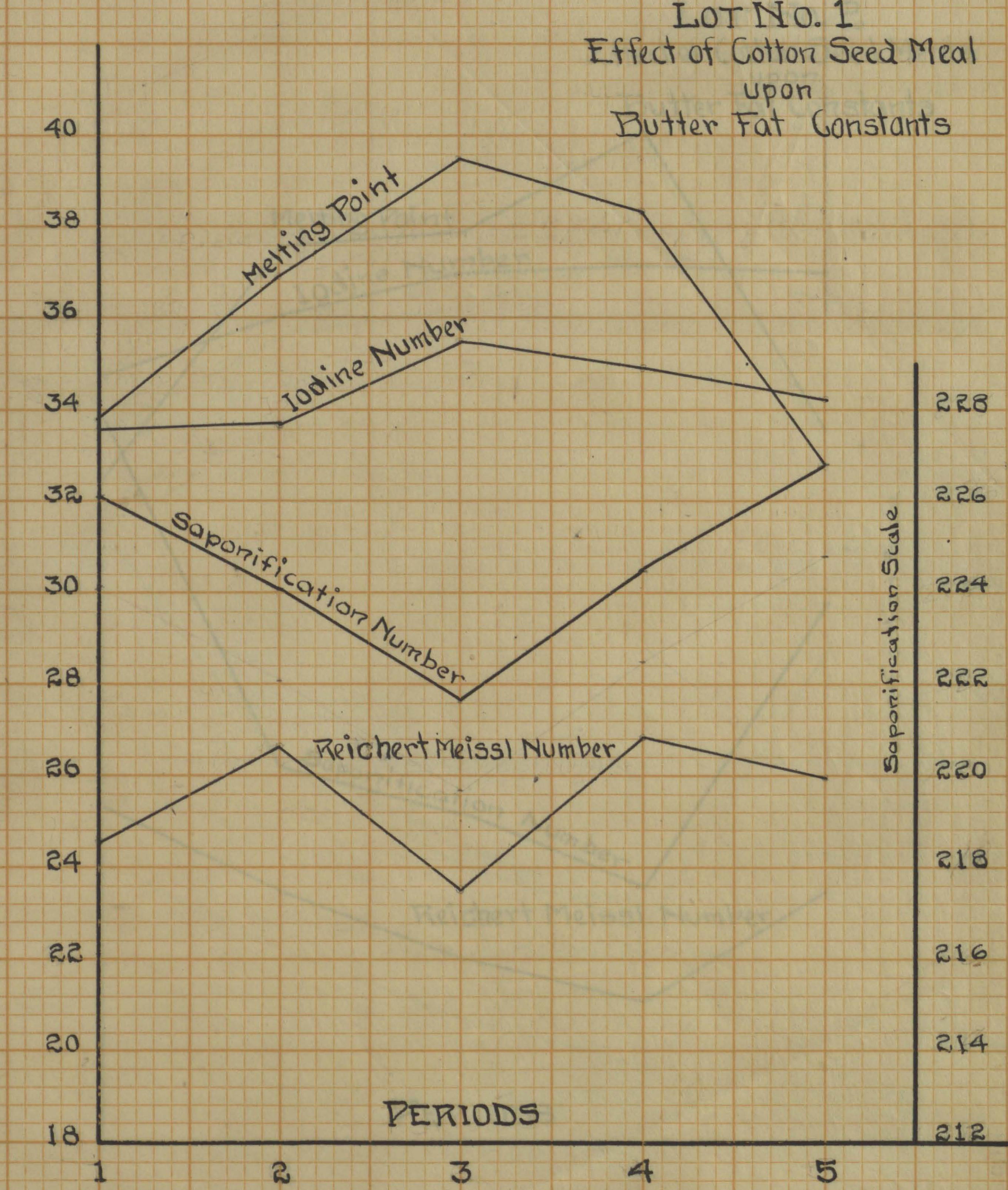
Saponification Number:- The data of Table 14 shows that all lots had a marked decline in the saponification number. The maximum as well as the average decline (Table 17) of Lot 1 was much less marked than were those of Lots 2 and 3. The average decline for Lots 1, 2 and 3 (Table 17) was, 3.0; 6.9; and 5.8 respectively. This data may be presented as strong evidence of the fact that the decline in the saponification number when feeding cotton seed meal is due to the oil contained in the meal. The failure of Lot 1 to respond with as large a decline as did Lots 2 and 3 may have been caused by the tendency of protein to offset the effects of the cotton seed oil contained in the meal. The writer has no information relative to the effects of protein on the saponification number. Moreover, this lot may not have been as responsive as were Lots 2 and 3. Hunziker lowered the saponification number only slightly by feeding 1 1/4 pounds of

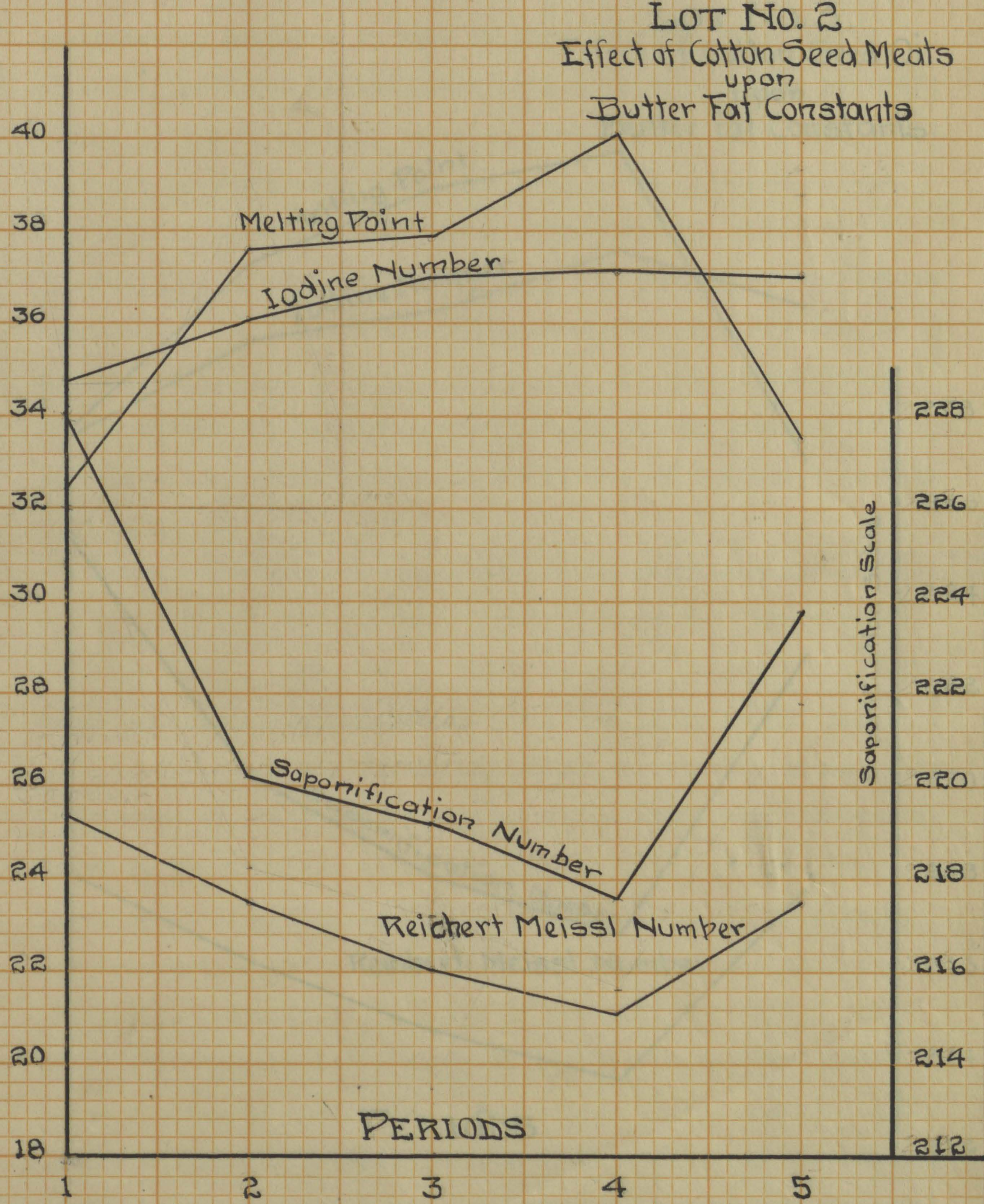
cotton seed oil, with corn silage, alfalfa, oats, wheat bran and linseed meal. Graves, when feeding 6 pounds of cotton seed meal with corn silage, alfalfa, corn chop, bran and linseed meal, failed to produce any appreciable fluctuation in this constant. But when timothy hay was fed in place of the corn silage and alfalfa, Graves obtained a decline of 4.2 by feeding 4 pounds of cotton seed meal. This decline is comparable with these results observed in this experiment when corn stover and timothy hay made up the roughage. A correlation of the work of Hunziker, Graves, and the writer not only suggests that oil is responsible for the changes observed in the saponification number but that such variations, whether observed in rations containing meal or oil, are greatly influenced by the character of the roughage fed.

Study of the Curves:- One fact very obvious from a study of the curves, pages 70, 71 and 72, is that in all lots the highest melting point and the highest iodine number were coincident with the minimum Reichert Meissl readings. With Lot 1, however, this relation developed in Period 3, whereas with Lots 2 and 3 the highest melting point and iodine numbers and the lowest Reichert Meissl readings were not secured until the 4th Period. It is, therefore, obvious that for Lots 2 and 3 the maximum variation in all butter fat constants were produced at the period when the maximum amount of meats and oil, respectively was incorporated in the ration. No satisfactory explanation for the fact that Lot 1 reached a maximum in Period 3, when only 6 pounds of cotten seed meal were being fed, can be offered. It is possible that these cows tended to adapt themselves to the change in the ration more readily than did those of Lots 2 and 3, receiving, respectively

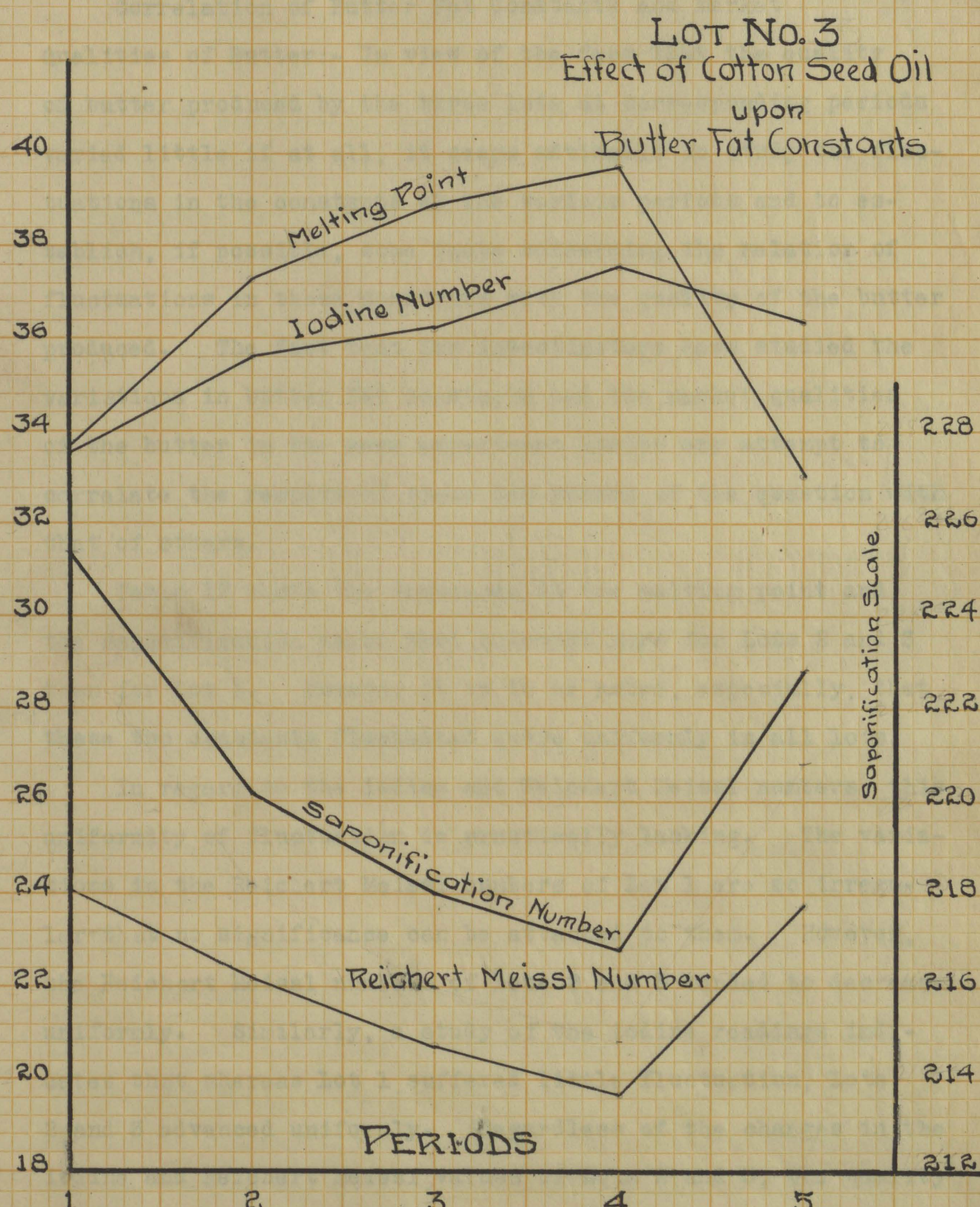
a concentrated form of meal - the meats - and the pure cotton seed oil.

The saponification curves of all lots reach the lowest, when the melting point and iodine curves reach the highest point. This is exactly the relation that exists between the Reichert Meissl number and the melting point and iodine numbers for Lots 1, 2 and 3, pages 70, 71 and 72. Lot 1, however, is again an exception to Lots 2 and 3, in that the saponification number as well as the melting point and iodine numbers, reaches the maximum variation in Period 3. Lots 2 and 3, however, did not suffer maximum effects until the 4th Period. This failure of Lot 1 to respond with a further decline in the saponification number when more than 6 pounds of meal were fed, cannot be fully explained. As previously stated, it is possible, however, that the cows of this group adapted themselves to the addition of the cotton seed meal more readily than did those of Lots 2 and 3 fed the cotton seed meats and cotton seed oil respectively.


LOT NO. 1
Effect of Cotton Seed Meal
upon
Butter Fat Constants
Melting Point
Iodine Number
Saponification Number
Reichert Meissl Number
Saponification Scale
PERIODS
40
38
36
34
32
30
28
26
24
22
20
18
228
226
224
222
220
218
216
214
212
1
2
3
4
5



Lot No. 2
Effect of Cotton Seed Meats
upon
Butter Fat Constants
Melting Point
Iodine Number
Saponification Number
Reichert Meissl Number
Saponification Scale
Periods
40
38
36
34
32
30
28
26
24
22
20
18
228
226
224
222
220
218
216
214
212
1
2
3
4
5



Lot No. 3
Effect of Cotton Seed Oil
upon
Butter Fat Constants
Melting Point
Iodine Number
Saponification Number
Reichert Meissl Number
Saponification Scale
Periods
40
38
36
34
32
30
28
26
24
22
20
18
228
226
224
222
220
218
216
214
212
1
2
3
4
5

Correlation of Butter Fat Constants and Market Qualities of Butter:- In view of the fact that the quality of butter produced by the three lots at corresponding periods varied little if at all, it seems advisable to study the fluctuations in the constants at the various periods and to establish, if possible, some facts concerning the relation of fluctuations in these constants with the quality of the butter produced. The fact that few investigators have studied the variations in butter fat constants and the market qualities of the butter in the same experiment limits any attempt to correlate the results of these two phases of the question with that of others.

Table 17 shows the increases in the melting point and the saponification value were somewhat more for Lots 2 and 3 than for Lot 1. However it is to be noted, especially, that these two constants fluctuated quite uniformly in all lots.

In regard to the iodine and Reichert Meissl numbers, this uniformity of fluctuation is practically lacking. The variations in the Reichert Meissl numbers of Lot 1 are so irregular that no significance can be attached to them. However, the Reichert Meissl numbers of Lots 2 and 3 tended to decrease uniformly. Similarly, a study of the iodine readings indicates that whereas Lot 1 suffered little fluctuation, Lots 2 and 3 advanced uniformly. Regardless of the changes in the iodine and Reichert Meissl values of Lots 2 and 3, the quality of the butter was little if any inferior to that produced by Lot 1 having almost a constant value for these constants. Moreover, the data of Table 15 shows that in Period 2, Lot 1

had a Reichert Meissl number of 26.55 and an iodine number of 33.67. In Period 4 this same lot had a Reichert Meissl number of 26.83 and an iodine number of 34.88. Briefly stated, Lot 1, with practically no variation in either Reichert Meissl or iodine number in Periods 2 and 4, did produce a good butter in the former period and a very inferior one in the latter period. Another instance of the failure of high iodine number to produce an inferior quality of butter may be observed in Lot 2, Table 17. In Period 4, with an iodine number of 37.07, the above Lot, as did all others, produced undesirable butter. When changed to the basal ration, Period 5, Lot 2 produced a very fair grade of butter. The iodine number, however, was then 37.08. Obviously the marked improvement in the quality of the butter was not coincident with any change in the iodine number. And since the butter of Period 5 had lost the characteristic salvy, oily flavor, it may be stated that these investigations fail to show any relation between the increase in the iodine number and the oily flavor so prevalent in butter made from cows fed cotton seed meal.

Further evidence of a lack of relation between the Reichert Meissl number and the quality of butter is found in the work of Graves. This investigator shows that in the production of a very low grade butter from ration containing 4# cotton seed meal, grain mixture (corn chop, bran, and linseed meal) with timothy hay as roughage, the Reichert Meissl number was lowered but 0.53 or practically remained constant. When feeding corn silage, alfalfa hay, and cotton seed meal, Graves produced slight, though inconsistent variations in the

Reichert Meissl and iodine numbers, and a fairly good quality of butter.

On the whole, this work as well as that of Graves suggests that the quality of butter produced by feeding cotton seed meal is much more dependent upon the fluctuations in the melting point and saponification number than upon the variations in the Iodine and Reichert Meissl numbers. Further evidence of the fact that all changes in the composition of butter fat cannot be measured by a high iodine number is found in the work of Browne.[1] This investigator makes the following statement: "It is a well known fact ~~that~~, and one wholly confirmed by the preceding tables that the oleic acid is the constituent of butter fat most susceptible to chemical changes: being an unsaturated compound it absorbs oxygen with great avidity at the points of unsaturation yielding other oxy compounds or decomposing into simpler bodies of lower molecular weight." He further states that one of the chief causes of rancidity in butter is due to oxidization of these unsaturated fats.

The work of Graves as well as the results of this investigation indicates that butter made from cotton seed meal rations and having a high iodine number, tends to keep much better than butter made from rations lacking this concentrate. This apparent inconsistency between the theory of Browne and the results of the writer can only be explained by stating

[1]Browne - Penn. Agr. Exp. Station, Annual Report 1900.

that other changes in the composition of butter fat, other than an increase in the per cent of oleic acid must result from feeding cotton seed meal. As previously stated, some fats of higher melting points, may be substituted for stearine, and therefore an increase in the melting point results. Furthermore, my work has shown that a harder butter was produced when there was an increase in the melting point and the iodine number. In this fact is found additional evidence for a refutation of the popular theory in regard to the direct relation between a high iodine number and the softness of the butter. Obviously there are many inconsistencies as to the significnace of the iodine number.

SUMMARY

The effects of the by products of cotton seed meal upon the composition of the butter fat and the market qualities of the butter may be summed up as follows:

1. The iodine number and melting point of all lots were raised appreciably. There was a lowering of the saponification number of all lots. Cotton seed meats and cotton seed oil both lowered the Reichert Meissl number. The variations in the Reichert Meissl number of the cows fed cotton seed meal was very irregular and therefore can have little if any significance in this experiment. With the exception of the Reichert Meissl number of the lot fed cotton seed meal, similar variations in constants of the butter fat were produced by either cotton seed meal, meats or oil. In general, a high iodine number and a high melting point were coincident with a harder butter. Moisture content seemed to have no effect on the hardness of the butter. The data on the relation of moisture to hardness were not extensive enough, however, to have any great significance.

   The effects of cotton seed meal, cotton seed meats, and cotton seed oil upon the chemical composition of butter fat are practically identical.

2. When more than four pounds of cotton seed meal was fed, a very poor quality of butter was produced. This amount gave the characteristic oily salvy taste but not to the extent of making the butter unpalatable. With six to eight pounds, however, the quality was so very inferior that consumers would doubtless have raised serious objections. The keeping quality as well as the capacity of the butter to retain its form when heated at varying temperatures was greatly inproved. A decided increase in the number of revolutions required for churning was also observed.

In general, these findings correspond with those of previous investigators. However, the unusual observations of some, particularly of Morse, Clark and Wiley, stand as exceptions to these results.

Cotton seed oil produced the greatest and cotton seed meal the smallest variations in the composition of the butter fat and in the quality of the butter. Cotton seed meats produced results that were quite comparable to those of cotton seed oil. If it were possible that the changes observed are dependent upon both the protein and the oil of cotton seed meal, then Lot 1, fed cotton seed meal, should have had the greatest changes in both the butter fat constants and in

and in the quality of the butter. The only possible exception that can be raised to this theoretical relation is that the 0.4 of a pound of oil contained in the meal, produced the maximum variations and that the protein of the meal could not effect a further increase or decrease of any particular constant. As a matter of fact, however, maximum variations did not result until six pounds of cotton seed meal were fed. In the case of Lot 3, the greatest variations come when 0.8 of a pound of oil was in the ration. It, therefore, appears that if the protein had any effect it was to retard rather than to accentuate fluctuations. At any rate, the changes in the composition of the butter fat can not be considered as having been increased by the protein of the meal, for in no period were the variations of Lot 1 more pronounced than were those of Lots 2 and 3 receiving a normal amount of protein.

When correlated with the work of Graves this investigation indicates that the quality of the butter as well as the variations in the butter fat constants are greatly influenced by the character of the roughage fed. According to the results of Hunziker, Hill and Morse, as interpreted by the writer, this property of certain roughages to influence the variations in the constants of butter fat, particularly the iodine and Reichert Meissl numbers, does not obtain when the pure oil is fed. These investigators make no statement relative to the quality of the butter produced, and their results, therefore, can not be held to indicate that roughages do not influence the quality of the butter even when raw cotton seed oil is fed.

This follows from the fact that as yet investigators have failed to establish any relation between the fluctuations of the constants of butter fat and the quality of the butter. My study of the problem suggests a possible relation between a rise in the melting point, and the quality of the butter when cotton seed meal is fed. Hunziker, however, observed only a slight rise in the melting point. It is therefore not improbable that a good quality of butter could have been made from the butter fat produced by Hunziker when feeding cotton seed oil with corn silage and alfalfa hay as roughages. While no concise and satisfactory explanation can be offered for the fact that cotton seed oil when fed in the form of cotton seed meal produced less marked variations than does the raw oil, it should be remembered that when cotton seed meal is fed the oil is intimately associated with the protein and that a much larger amount of protein is necessarily included in the ration. These two conditions may be important factors in lessening the effects of the oil when fed in the form of cotton seed meal. This must be regarded as theory, however. Nevertheless, a failure to account for the extreme variations observed by Hunziker when feeding cotton seed oil with corn silage and alfalfa can not be regarded as evidence on which to base a refutation of the theory that the typical changes produced by feeding cotton seed meal are due to the oil contained in the meal.

The following conclusions may be drawn from the data obtained in this experiment. It can not be stated, however, that similar conclusions will be reached when cotton seed meal or cotton seed oil are fed with roughages and concentrates unlike those used in this experiment.

1. The variations observed in the constants of the butter fat and in the market qualities of the butter were produced by the cotton seed oil contained in the respective rations.
2. A very inferior quality of butter was produced when six to eight pounds of cotton seed meal were fed. However, four pounds did not make the butter unpalatable..
3. With the exception of the variations in the hardness of butter, and in the churnability of the cream, the changes observed were, in general, proportional to the amount of cotton seed by products fed in the ration.
4. The variations observed in the constants of butter fat and the market qualities of butter when rations containing the by products of cotton seed are fed were influenced appreciably by the character of the roughage fed.

The last conclusion, No. 4, is drawn from the combined results of Graves and the writer.

T[redacted]

Nei[redacted]