

UNIVERSITY OF MISSOURI
COLLEGE OF AGRICULTURE
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RESEARCH BULLETIN 27

**Effects of Feeding Cottonseed
Products on the Composition
and Properties of Butter**

Influence of the Character of the Ration
and Quantity of Cottonseed
Products



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¹In the service of the U. S. Department of Agriculture

Effects of Feeding Cottonseed Products on the Composition and Prop- erties of Butter*

Influence of the Character of the Ration and Quantity of Cottonseed Products

C. H. Eckles and L. S. Palmer¹

INTRODUCTION

Cottonseed cake, the principal by-product in the manufacture of cottonseed oil, has a recognized place among the valuable feeds in the dairy industry, where it is utilized chiefly in the pulverized form, namely, as cottonseed meal. Thousands of tons of meal are consumed by dairy cattle each year in this country, and great quantities are normally exported for similiar use. In some localities in the Southern States the whole seed is fed to dairy cows and cottonseed hulls, another by-product of the cottonseed oil industry, are used extensively as roughage.

The great growth in the use of cottonseed meal in animal feeding and its wide-spread use at present are to be attributed chiefly to economic causes. For the last ten years, at least, cottonseed meal has been the cheapest source of protein for the farmer in all sections of this country where large quantities of concentrates are purchased. In recent years, with the exception of the last year, the average cost of cottonseed meal has been about \$30.00 a ton. Since its digestible protein content is about 35 per cent, the cost of a pound of protein in this form has been about 4.3 cents. The economic advantages of cottonseed meal for dairy cows have been accentuated by the palatability of the feed as shown by the fact that many cows in the Southern States are fed at times solely on cottonseed meal and cottonseed hulls.

Altho the economic importance of cottonseed meal and other cottonseed by-products has been generally recognized, there has been a wide-spread belief that cottonseed products fed to dairy cows have a detrimental effect on the butter. This opinion is unquestionably not

*References in this bulletin are to the bibliography on page 43.

without foundation, and the butter industry of the South has no doubt suffered from the excessive use of cottonseed products.

The importance of studying the influence of various foods upon the normal composition of milk and butter as well as upon the market qualities of the latter was recognized by the Missouri Agricultural Experiment Station in connection with a general project concerning the factors influencing the composition of milk which it has carried on for a number of years. Cottonseed products were early selected for study because of their economic importance, as already indicated. It was also believed that the results of feeding this class of feed stuffs could be readily determined because of the prevailing opinion concerning the pronounced effects upon the butter which accompany the feeding of cottonseed products.

A survey of the experimental literature on this subject gave the impression, however, that the question was far from settled, since results secured by other investigators are varied and frequently inconsistent. The results secured during the early years of our own study were of a similar nature, and on the whole were far less pronounced than other investigators had reported. It was felt that the inconsistencies of our results as well as those of other investigators were to be attributed to some underlying factor which would eventually be revealed. Our studies have shown that this factor is the character of the roughage fed with the cottonseed products. The amount of cottonseed products fed, particularly the quantity of cottonseed oil which they contain, is also important.

Concerning the character of the roughage, data will be presented pointing convincingly to the fact that with certain roughages, such as timothy hay and corn stover, or timothy hay alone, or alfalfa hay alone, or cottonseed hulls, very marked effects on the composition and properties of butter accompany the feeding of cottonseed products, in some cases even in moderate amount. On the other hand it will be shown that certain roughages, particularly corn silage, so counteract the effects of cottonseed products that moderate quantities, e. g., three to four pounds of meal (in some cases as high as six pounds) may be fed daily without lowering the quality of the butter or changing appreciably the composition of the fat. In fact, the effects of the cottonseed meal in these experiments were beneficial in several directions, rather than detrimental. Again, experiments will be presented showing the beneficial effects of feeding moderate quantities of cottonseed products with other succulent feeds, especially fresh pasture grass.

Our studies have not yet been extended to include roughages other than corn silage which have this counteracting effect. Experiments

are being conducted to ascertain the cause of the counteracting influence of silage. It is believed that such studies, if successful, will be more beneficial in extending our knowledge of this subject than any cut and try method of studying other feeds with this point in view. The question is an important one to the butter industry, as can readily be appreciated, particularly in those sections of the country where the industry has suffered because of the excessive feeding of cottonseed products and also, as it now appears, because of an improper roughage fed with them.

It is the purpose of this bulletin to present our results from these standpoints and to show, as well, that most, if not all, of the inconsistencies in the results of other investigators disappear when viewed in the light of the factors mentioned.

Our early investigations showed that the feeding of cottonseed products exerted little if any effect on the percentage composition of the milk. For this reason our attention has been confined chiefly to a study of the effects on the butter, in which the changes in the physical and chemical constants of the butter fat were determined, and, in addition, certain, other qualities of the butter were examined. These were (1) the standing up quality, i. e., the maximum temperature which the butter will withstand without losing its body or shape; (2) the keeping qualities of the butter; and (3) its market qualities. Studies in regard to the cause of the effects secured will also be presented as well as several minor studies, such as the persistence of the effects, and the typical characteristics of butter produced where cottonseed products are fed according to the ordinary practice in the South.

HISTORICAL

The references to previous investigations concerning the effects of feeding cottonseed products on the composition and properties of butter or butter fat are given in chronological order in the bibliography which may be found at the close of the bulletin. Several other investigations, dealing only with the passage of certain reducing substances present in cottonseed oil (substances giving the well-known Halphen's or Bechi's color reactions) into the butter fat after feeding cottonseed products, have been omitted from the bibliography as having no bearing upon the subject in hand. These investigations have recently been summarized by Smith, Wells, and Ewing.¹⁸

On examination of the investigations of other workers in this field one is struck with the great variety of methods used for the solution of the problem of the effects of cottonseed products. The

amount of products fed have varied from as low as two pounds⁹ to as high as eleven pounds of cottonseed meal² a day. In some cases^{3, 4} raw seed was fed ad libitum. The cottonseed products have been fed in some cases without additional grain, and in some cases with practically no roughage. The basal ration with which the cottonseed products have been compared has in some cases been widely different from that used when the cottonseed products were fed. In other cases it has been similar with the exception of the substitution of the cottonseed product for a portion of the grain. The subject has been attacked in some cases by feeding one or more cows a basal and experimental ration in successive or alternate periods. Again an experimental group has been compared with a basal group of animals. The length of the experimental feeding periods has varied from a few days to several weeks. The samples taken for analysis have represented from one to several days' milkings. A great variety of roughages has been fed with the cottonseed products.

It is little wonder that the effects in these experiments have varied from very slight to very great, or that contradictory results seem to have been secured in some cases. On the other hand it is remarkable how consistent these varied results become when tabulated with respect to the two most important factors which control the effects on the butter and butter fat, namely, the character of the roughage and the amount of products fed.

In studying the results with these factors in view the experiments have been divided into three groups; (1) those involving cottonseed meal; (2) those involving the whole seed; and (3) those in which the question has been studied by the addition of cottonseed oil to the ration. These results have been tabulated in Tables 1, 2, and 3, respectively. In these tables are shown the effects of like quantities of meal, seed, or oil on the physical and chemical constants of the butter fat. Where no result is given the fat constant in question was not determined by the investigator. The character of the roughage fed during the experimental period, as well as during the period with which the results were compared, is given in the tables.

In the preparation of these tables it seemed advisable to exclude certain of the results of other investigators. The experiments by Wiley² were not considered because the butter fat was clearly abnormal in composition on the basal ration (pasture). A like reason applies to the exclusion of several experiments with cottonseed meal and cottonseed by Clark¹⁵ in which the basal ration of pasture, only, with one pound of bran, produced butter with abnormally low Reichert-Meissl value and abnormally high melting point. One experiment by Curtis³

in which three pounds of meal were fed with scant pasture and a little hay was excluded because it was compared with a ration of silage, hay, and grain; the change in the roughage in this experiment probably was as much responsible for the change in composition as the introduction of the cottonseed meal into the ration.

Several of the investigations summarized in the tables reported Reichert instead of Reichert-Meissl numbers and melting point in terms of degrees Fahrenheit. These have been converted into Reichert-Meissl numbers and Centigrade degrees in the previously mentioned tables. The former conversion was made by multiplying the Reichert numbers by the customary value of 2.2.

TABLE 1.—INFLUENCE OF ROUGHAGE ON EFFECTS OF COTTONSEED MEAL ON COMPOSITION OF BUTTER FAT

Meal Fed per Day	Saponification Value		Reichert-Meissl No.		Iodin Value		Melting Point		Roughage Fed With Meal	Basal Ration
	Basal	Exp.	Basal	Exp.	Basal	Exp.	Basal	Exp.		
Lbs. 2 ⁹	-----	-----	26.90	26.32	30.20	31.56	33.30	36.35	Pasture plus 10—16 lbs. silage	Pasture; silage; bran; and corn
3 ¹⁴	228.7	230.3	29.10	30.30	28.00	29.60	33.80	34.10	1st cut hay and rowen	1st cut hay; rowen; and grain
3 ⁴	-----	-----	29.80	30.50	-----	-----	35.60	36.30	11 lbs. silage	5 lbs. each corn; oats; bran
4 ⁴	-----	-----	29.80	27.00	-----	-----	35.60	37.90	4.5 lbs. silage; 9 lbs. cottonseed hulls	5 lbs. each corn; oats; bran
4 ¹⁸	229.6	227.9	30.60	31.00	26.40	29.40	34.10	35.60	20 lbs. silage; 10—15 lbs. hay	Silage; hay; bran; oats
4 ⁹	-----	-----	26.90	21.23	30.20	33.46	33.30	38.78	Pasture; 10—16 lbs. silage	Pasture; silage; bran; corn
5 ¹⁵	-----	-----	-----	29.60	-----	-----	-----	40.70	10 lbs. cottonseed hulls	Not stated
5 ¹¹	-----	-----	-----	-----	-----	-----	36.00	37.85	20 lbs. silage; 10 lbs. cowpea hay	Silage; hay; bran
6 ⁹	-----	-----	24.90	12.20	33.50	42.30	33.10	41.40	Cottonseed hulls ad. lib.	Pasture; silage; grain
6 ⁵	-----	-----	-----	-----	-----	-----	34.90	37.20	24 lbs. green rye; 7 lbs. hay; 3 lbs. corn stover	Green rye; hay; stover; corn
6 ⁹	-----	-----	26.90	17.91	30.20	35.24	33.30	40.15	Pasture; 10—16 lbs. silage	Pasture; silage; bran; corn
7.25 ⁸	-----	-----	30.10	24.30	38.50	34.20	-----	-----	40 lbs. silage; 5.5 lbs. hay	Silage; hay; middlings
9 ⁶	-----	-----	-----	-----	30.90	35.00	32.00	36.50	30 lbs. hay	Hay; grain
ad. lib. ⁸	-----	-----	31.70	23.30	-----	-----	35.20	40.80	Cottonseed hulls ad. lib.	Silage; hay; grain

Note.—Superior figures following the quantity of meal fed refer to a like number in the bibliography

Discussion of tables.—The following points especially attract attention in connection with Table 1:

1. In the experiments involving two to three pounds of meal, the effects were very slight with the exception of a marked increase in the melting point when two pounds were fed with pasture and some silage.
2. Six pounds of meal fed with green rye as the major part of the roughage had no greater effect on the melting point (2.3° increase)

than four pounds of meal fed with cottonseed hulls and a small amount of silage as roughage (2.3° increase).

3. Six pounds of meal with hulls alone as roughage reduced the Reichert-Meissl number from 24.9 to 12.2 while 7.25 pounds with a large amount of silage as roughage reduced the Reichert-Meissl number from 30.1 to 24.3 only.

4. Five pounds of meal fed with 20 pounds of silage and 10 pounds of hay had little more effect on the melting point than three pounds of meal with 11 pounds of silage. The increases were 1.85 and 0.7 degrees, respectively.

5. Nine pounds of meal fed with hay as roughage produced fat with a melting point of 36.5° C., while 5.25 pounds with cottonseed hulls as roughage caused a melting point of 40.7° C.

6. The effect of increasing amounts of meal with the same roughage is shown by the experiments of Harrington and Adriance⁹, who fed 2, 4, and 6 pounds in successive periods with pasture and silage as roughage. The results are shown in the following tabular statement:

Reichert-Meissl numbers....26.32, 21.23, 17.91;
 Iodin values.....31.56, 33.46, 35.24;
 Melting point.....36.35, 38.78, 40.15° C.

Each of these values is the average of at least four samples from four cows, two fresh and two advanced in lactation. Considering the character of the roughage fed the results were more pronounced than in the experiments reported by other investigators.

TABLE 2.—INFLUENCE OF ROUGHAGE ON EFFECTS OF COTTONSEED ON COMPOSITION OF BUTTER FAT

Seed Fed per Day	Reichert-Meissl No.		Iodin Value		Melting Point		Roughage Fed With Cottonseed	Basal Ration
	Basal	Exp.	Basal	Exp.	Basal	Exp.		
Lbs.					°C	°C		
3 ⁸	31.70	29.45	-----	-----	34.20	36.50	Scant pasture, only 44 lbs. silage; 6 lbs. hay 40 lbs. silage; 5.5 lbs. hay No roughage Cottonseed hulls ad. lib.	Silage; hay; grain Silage; hay; gluten feed Silage; hay; grain Silage; hay; grain 5 lbs. each, corn; bran; oats
5 ⁷	31.00	28.80	38.45	31.65	34.75	38.05		
6.25 ⁸	29.90	19.50	38.30	32.40	-----	-----		
ad. lib. ³	31.70	17.30	-----	-----	35.20	40.50		
ad. lib. ⁴	29.80	22.30	-----	-----	35.60	43.20		

Note.—Superior figures refer to a like number in the bibliography.

Table 2 shows the summary of the experiments in which the whole seed was fed. These experiments can not be compared with each other because the amount of seed fed differed in each experiment. The data are of interest, however, when compared with those

in Table 1. For example, five pounds of whole seed with considerable silage as roughage raised the melting point 3.3 degrees, while six pounds of meal fed with green rye raised it 2.3 degrees. The marked decrease in the iodine value obtained by Morse⁷ shown in this table is contrary to results secured by any other investigator or by this Experiment Station. It seems doubtful whether Morse's results were correct with regard to this fat constant.

TABLE 3.—INFLUENCE OF ROUGHAGE ON EFFECTS OF COTTONSEED OIL ON COMPOSITION OF BUTTER FAT

Oil Fed per Day	Saponification Value		Reichert-Meisssl No.		Iodine Value		Melting Point		Roughage Fed With Cottonseed Oil	Basal Ration
	Basal	Exp.	Basal	Exp.	Basal	Exp.	Basal	Exp.		
Oz. 8 ¹⁴	231.8	225.3	30.54	28.82	29.29	33.78	32.46	36.46	8—12 lbs. hay; 10 lbs. rowen	Hay; rowen; grain
8 ¹⁸	230.4	224.2	27.97	26.71	29.27	34.65	37.00	38.70	30 lbs. silage; 5 lbs. alfalfa hay	Silage; hay; corn meal
11 ⁸	-----	-----	31.30	25.20	33.50	41.90	-----	-----	23.5 lbs. silage; 11.25 lbs. clover and vetch hay (2:1)	Silage; hay; grain
13.5 ⁸	-----	-----	25.10	19.60	40.70	40.20	-----	-----	40 lbs. silage; 5.5 lbs. hay	Silage; hay; grain
16 ¹⁸	230.4	214.9	27.97	20.12	29.27	41.00	37.00	40.20	30 lbs. silage; 5 lbs. alfalfa hay	Silage; hay; grain
20 ¹⁷	229.0	227.0	29.40	27.80	33.20	42.00	33.90	34.40	35 lbs. silage, plus alfalfa hay	Silage; hay; corn; bran
21.6 ¹⁰	-----	-----	30.00	26.40	31.00	35.80	33.90	37.50	23 lbs. silage; 16 lbs. hay	Silage; hay; bran
24 ¹²	-----	-----	25.30	23.20	34.50	39.80	35.20	36.40	18 lbs. silage; 13 lbs. hay	Silage; hay; corn; bran

Note.—Superior figures refer to a like number in the bibliography.

Table 3 shows the summary of the data in regard to feeding cottonseed oil. Where comparisons are possible the data are of interest in showing the influence of the roughage on the extent of the effects, e. g., the much greater effect on the melting point when 8 ounces of oil were fed with hay than when a like amount was fed with silage, and the greater effects thruout when 21.6 ounces were fed with 35 pounds of silage.

The experiments from which the data in Table 3 are drawn were undertaken for the most part in connection with studies of the effects of vegetable oil feeding. Their connection with the problem of the effects of cottonseed products on butter arises by virtue of the fact that our own data point convincingly to the fact that the effects of cottonseed products on the composition and properties of butter are due largely, if not entirely, to the amount of oil they contain. These

data will be presented later. Viewed from this standpoint at least half of the experiments in Table 3 are of little interest, for they represent equivalent quantities of cottonseed meal or cottonseed far out of proportion to safe feeding practice. This statement is based upon the assumption that the crude fat content of cottonseed meal is 9 to 10 per cent and of the whole seed is 19 to 20 per cent. It has been found possible, however, to prepare a table in which other factors are nearly equal and which bear out the conclusion drawn from our own studies in regard to the importance of oil in producing the effects caused by feeding cottonseed products. The data bearing on this point are shown in Table 4. Considering the method of compiling this table the results are astonishingly consistent.

TABLE 4.—INFLUENCE OF COTTONSEED MEAL, AND EQUIVALENT QUANTITIES OF COTTONSEED OIL ON THE COMPOSITION OF BUTTER FAT¹

Feed	Amt.	Oil Content	Reichert-Meissl No.		Melting Point		Roughage Fed
			Basal	Exp.	Basal	Exp.	
Meal ¹¹	Lbs. 5	Oz. 7.3	-----	-----	36.00	32.85	20 lbs. silage; 10 lbs. cowpea hay
Oil ¹⁸	-----	8.0	-----	-----	37.00	38.70	
Meal ⁸	7.25	10.6	30.10	24.30	-----	-----	30 lbs. silage; 5 lbs. alfalfa hay
Oil ⁸	-----	11.0	31.30	25.20	-----	-----	40 lbs. silage; 5.5 lbs. hay
Meal ⁶	9	13.0	-----	-----	32.00	36.50	23.5 lbs. silage; 11.25 lbs. hay
Oil ⁸	-----	13.5	-----	-----	34.75	38.05	44 lbs. silage; 6 lbs. hay
							40 lbs. silage; 5.5 lbs. hay

¹Based on average oil content of cottonseed meal of 9.1 per cent.

Note.—Superior figures refer to references in bibliography.

When the literature is surveyed as a whole, as presented in the preceding paragraphs, one is impressed by two features, namely, the more or less consistent trend of the effects of feeding cottonseed products, and the great influence of the character of the roughage upon the extent of these effects. The trend of the effects as far as the constitution of the butter fat is concerned, is toward a decrease in the saponification and Reichert-Meissl numbers, and an increase in the iodine value and melting point, the latter change bearing out the opinion, now well-established, that cottonseed meal causes a firmer butter.

The influence of the roughage on the extent of these changes, as disclosed by the literature, bears out the statement made in advance of the presentation of the results. This influence appears to have been overlooked by most, if not all, of the investigators in this field. Curtis,³ however, stated in connection with his investigations, that, "Practical experience has demonstrated, to my own satisfaction at least, that if

considerable amount of green stuff, whether soiling crops, grass, or silage, forms part of the daily ration, we may add cottonseed or cottonseed meal in larger proportion without destroying quality, than when the cows are on dry feed entire." The experimental data on this point which this investigator presented were very meager. Similar opinions are held by others, as we have learned recently thru correspondence with various scientific dairymen in different localities in the South. Replying to a question sent out in regard to the character of the roughage usually fed with cottonseed products one correspondent stated that, "It has been my observation that a better grade of butter can be made where silage is used in connection with cottonseed meal than when dry feed is used altogether."

The data presented in this bulletin in regard to the influence of the roughage on the effects of feeding cottonseed products are of great practical importance, as well as of scientific interest. The experiments which will be reported are believed to be the first to demonstrate experimentally the relation of the roughage to the character of the milk fat produced when cottonseed meal forms a portion of the ration fed dairy cows.

EXPERIMENTAL

The investigations conducted by the Missouri Agricultural Experiment Station which form the basis for this bulletin were too extensive to warrant the report of each experiment in detail. A statement of the extent of the studies here reported, therefore, may not be out of place in this connection. Twenty-three experiments were conducted in which 56 cows, comprising 43 individual animals, were used. There were 177 periods in which samples were taken in these experiments, and 2,033 chemical determinations and experimental observations were made, each in duplicate, frequently in triplicate.

It is obvious that it will be impossible to report all these data. Many of the determinations represent analyses of the percentage composition of the milk constituents, made in the earlier studies. Reference has already been made to the fact that negative results characterized these analyses in so far as the influence of feeding cottonseed products is concerned. These data will be omitted entirely from the present bulletin. Only those data will be reported which have a bearing on the influence of feeding cottonseed products on the composition and properties of butter.

Thruout certain of the experiments samples were taken frequently, and sometimes composites of each day's milking were analyzed.

In these cases only the typical effects of the experimental conditions will be reported.

Others of the experiments were duplicates in every respect. In these cases the results have been averaged. The data which are of this character will be indicated in connection with the experiments concerned.

Some of the experiments conducted, particularly those with reference to the effects of feeding cottonseed products with pasture, were more or less preliminary in nature or were experiments which later data indicated had been vitiated by other factors. These experiments have not been included in the present bulletin. Reference to them will be made later.

One or two experiments with individual cows in which the results were contradictory to those obtained in similar studies with a group of animals have been omitted as probably vitiated by factors related to individuality, animal idiosyncrasy, or other unknown factors.

The data which have been collected will be presented, in general, strictly from the standpoint of the two factors which a careful study of our entire data indicates are those which influence the effects of feeding cottonseed products, namely, the character of the ration and the amount of cottonseed products fed.

All experimental animals were chosen with care and given the best of treatment. Purebred dairy animals from the University of Missouri herd were used. In no case did they receive any food other than the experimental ration. None of the rations were deficient with respect to the requirements of Armsby's standard for energy and protein. Exercise was confined in all cases to a dry lot. Changes to experimental rations were always made gradually; three to eight days, depending upon the extent and character of the change, were allowed in all cases. Experimental periods proper, exclusive of preliminary periods during which the changes in ration were made, were usually about two weeks long. Preliminary experiments showed that this period was more than sufficient to bring about the maximum effect of such changes in ration. All samples represented at least two successive days at the end of the experimental period. The sampling and preparation of samples for analysis, as well as the methods of analysis for the physical and chemical constants of the fat were identical with those described in detail in previous publications.¹⁹ The methods for determining the standing up and keeping qualities of the butter will be described later.

CHARACTER AND CAUSE OF EFFECTS PRODUCED BY COTTONSEED PRODUCTS

Before presenting the data with reference to the influence of the character of the roughage and quantity of cottonseed products, the experiments will be presented showing the typical effects that accompany the feeding of cottonseed products, which form the basis for our conclusion, already stated, that these effects are due largely, if not entirely, to the quantity of oil in the products fed.²⁰ Our attention was directed toward this probability by observing that cottonseed exerts a more pronounced effect upon the composition of butter fat than cottonseed meal.

The data which we wish to present in this connection were secured from eight animals, comprising four Jersey, two Holstein, and two Ayrshire, cows. Each animal was fed a basal ration of timothy hay, 8—12 pounds; corn stover, 8—12 pounds; and a grain mixture of corn, 4 parts; bran, 2 parts; and linseed meal, 1 part. The animals were divided into three groups. In the first and fifth periods of the experiment, exclusive of a preliminary period when the animals were changed from the herd ration to the basal ration, 10 pounds of the grain mixture was fed each animal in addition to the roughage indicated. In the intervening periods one group of cows had the grain mixture replaced pound for pound by 4, 6, and 8 pounds of cottonseed meal, respectively, containing 0.4, 0.6, and 0.8 pounds of oil. Another group had the grain mixture replaced pound for pound by 1.1, 1.7, and 2.1 pounds of cottonseed meats, respectively, containing 0.4, 0.6, and 0.8 pounds of oil. (The cottonseed meats were the kernel of the seed, from which the oil had not been pressed. They were secured by running the whole seed thru a feed grinder and sifting the broken hulls from the meaty part of the seed. The meats contained approximately 36.5 per cent oil, calculated from the ether extract.) The third group of animals had the grain mixture replaced pound for pound by 0.4, 0.6, and 0.8 pounds of cottonseed oil, respectively. The oil fed was the unrefined oil direct from the press, secured from the Fidelity Cotton Oil and Fertilizer Co., Houston, Texas.

It is seen from the foregoing that each group of cows received the same amount of oil in corresponding periods, the difference being that one group received it in cottonseed meal, another in the cottonseed meats, and the third received the oil directly. It was believed that this method would answer the question of the cause of the effects

of feeding cottonseed products. Timothy hay and corn stover constituted the roughage in this experiment because it was desired to secure as pronounced results as possible. The studies which we had made previous to this time had shown the importance of the roughage in connection with cottonseed meal feeding, and the timothy-stover roughage was one which our previous studies had indicated would lead to very pronounced results.

In the experiment proper two cows were used in each group. Two additional cows were later carried thru an experiment identical with the cottonseed meal group, and the results secured have been averaged with those obtained in the larger experiment. The data from the cottonseed meal feeding are thus the average from four cows.

Effects on constitution of butter fat.—The data showing the effects on the physical and chemical constants of the butter fat are given in Table 5.

TABLE 5.—CHARACTER AND CAUSE OF EFFECTS PRODUCED BY COTTONSEED PRODUCTS

Date of Feeding	Cottonseed Products Feed			Saponification Value			Reichert-Meissl No.			Iodin Value			Melting Point		
	Meal Group	Meats Group	Oil Group	Meal Group	Meats Group	Oil Group	Meal Group	Meats Group	Oil Group	Meal Group	Meats Group	Oil Group	Meal Group	Meats Group	Oil Group
1912-13 Dec. 8-26	Lbs. 0	Lbs. 0	Lbs. 0	225.1	228.0	225.4	26.89	25.38	24.06	33.32	34.77	33.58	°C 33.85	°C 32.45	°C 33.17
Dec. 27- Jan. 13	4	1.1	0.4	222.2	220.0	220.2	26.27	23.53	22.21	35.00	36.05	35.60	35.63	37.60	37.35
Jan. 14- 31	6	1.7	0.6	221.5	219.2	218.0	24.72	22.06	20.74	35.80	37.04	36.21	39.48	37.85	38.90
Feb. 1- 18	8	2.1	0.8	218.2	217.8	216.8	21.91	21.13	19.67	36.04	37.07	37.57	39.30	40.10	39.75
Feb. 19- March 8	0	0	0	226.8	223.8	222.8	25.97	23.52	23.77	34.23	37.02	36.38	33.50	33.55	33.05

¹ The fat constants of the meal group are the true averages of data taken at this time with similar data from two additional cows taken on the following days during 1915: Feb. 16-17; March 6-7; March 22-23; April 24-25; the cows were fed 0, 4, 6, and 8 lbs. of cottonseed meal, respectively, during the periods intervening between and including the samples.

An examination of these data shows that the character of the effects secured were identical for each group of cows. This was manifested by a marked drop in the saponification value and Reichert-Meissl number and a marked increase in the iodine value and melting point. These effects on the physical and chemical constants of the butter fat are identical in their general trend with those secured by other investigators, which were pointed out in a preceding paragraph. Our data seem to us to point convincingly to the fact that the effects on the constitution of butter fat which accompany the feeding of cottonseed meal are due to the oil in the meal. At the same time, how-

ever, there is some indication that somewhat less pronounced effects are secured when the oil is fed in the cottonseed meal than when added directly to a grain mixture containing no cottonseed meal. This appeared to be particularly true in our experiments in connection with the saponification value, Reichert-Meissl number, and melting point, but applied almost entirely to the period when four pounds of meal were fed. Above this quantity of meal the extent of the effects as shown in Table 5 was practically identical. Whether cottonseed meal contains a material which counteracts to some extent the effects of the oil, as our results would indicate, could only be ascertained by determining the effects of feeding oil-free meal. Such a method of attack would have been the ideal one in connection with the question of the cause of the effects usually resulting from cottonseed meal feeding. We were forced to abandon such a scheme, however, owing to the nonfeasibility of securing fat-free cottonseed meal.

Effect on other properties of butter.—In connection with the data already presented studies were made with regard to the standing up quality and flavor and body of the butter secured from each group of animals in each period. For this purpose butter was made in a semi-commercial way and judged by members of the station staff for its flavor and body. To determine the standing up quality, small cakes of butter 3 cm. square and 1 cm. thick were placed in a water-jacketed oven and the temperature gradually raised a degree or two at a time until the cake of butter lost its shape. Temperatures were maintained at each point for one-half to three-quarters of an hour.

The effects on the market qualities of the butter (flavor and body) were marked. The butter secured from the basal rations was fair in quality and that secured when the animals were receiving four pounds of meal or its oil equivalent would not have been judged objectionable from the consumer's standpoint. The butter made in the other experimental periods was of a very undesirable quality, which was the most marked when the largest quantity of meal, meats, and oil was fed.

In regard to the standing up quality, in general, the basal ration samples lost their shape at 32—35° C., while all the samples during feeding of meal, meats, and oil withstood a temperature of 40—43° C. The maximum effects in this regard were secured in almost every case in Period 3, when six pounds of meal or its oil equivalent were fed.

Cause of effects accompanying cottonseed meal feeding.—From a physiological standpoint it is at present impossible to state the reason why the oil contained in cottonseed meal causes such a marked depression in the volatile fatty acids of the butter fat and an equally marked

increase in the iodine value and melting point. The authors believe that any explanation based on the supposition that the cottonseed oil passes into the milk fat is wholly unsound both from the standpoint of the physiological chemistry of fat metabolism and from the standpoint of the composition of cottonseed oil. To assume even that the oil passes from the food to the milk fat with a preliminary hydrolysis in the digestive tract and subsequent resynthesis in the intestinal wall is inadequate. Cottonseed oil is composed of about 25 per cent palmitic and arachidic acids, largely the former; 65 percent of the remainder of the fatty acids is linolic acid, and the rest is oleic acid. With such a high proportion of linolic acid in cottonseed oil, one would expect to find considerable quantities of this unsaturated acid in the butter fat if the oil passes from the food directly to the milk. We have made numerous attempts to isolate linolic acid as linolic tetrabromide from butter fat when cows were receiving large quantities of cottonseed meal and the butter showed the usual characteristics of cottonseed meal feeding. The result has been failure in each case.

The increase in the iodine value of the butter fat which accompanies cottonseed meal feeding must, of course, be due to the high content of unsaturated acids which cottonseed oil contains. Apparently the mammary gland in its fat synthesis makes use of some of the excess oleic acid which the blood stream acquires as the result of the cottonseed oil feeding.

The marked rise in the melting point accompanying cottonseed meal feeding is due, for the most part, to the great influence the volatile fatty acids of the butter fat possess in controlling this physical constant. Experience has shown that a marked decrease in the Reichert-Meissl number, such as occurs in cottonseed meal feeding, is almost invariably accompanied by a high melting point, notwithstanding an increase in the iodine value which may occur at the same time. The presence of arachidic acid, which melts at 77° C., in cottonseed oil may also be a factor in causing the high melting point.

One is forced to admit, however, that explanations such as the foregoing are largely superficial. The real changes in the constitution of the butter fat are no doubt much more deep-seated. It is possible to obtain butter in many other ways which will show the same physical and chemical constants that accompany cottonseed meal feeding, but which does not possess the peculiar oily flavor or gummy consistency which characterizes cottonseed meal butter. The butter fat which accompanies advanced lactation¹⁹ as well as that which accompanies underfeeding²¹ has a low Reichert-Meissl number and a high iodine

value and melting point. One is constantly confronted with the fact that the usual chemical and physical constants of fat in reality reveal but little of the true constitution. Methods of fat analysis are lacking which would reveal what the actual changes are in the constitution of the fat. We seem at present to be facing an insurmountable wall in this field of study.

INFLUENCE OF ROUGHAGE AND AMOUNT OF COTTONSEED PRODUCTS FED

In presenting our data with regard to the influence which the character of the roughage and the quantity of cottonseed products (particularly with reference to their oil content) exert on the effects of cottonseed feeding, the plan of stating the results secured with each roughage with varying amounts of cottonseed products will be followed. These experiments will be reported briefly. A more extensive experiment will then be reported which was carried out for the purpose of showing the influence which the character of the roughage exerts.

Cottonseed products with timothy hay as roughage.—Two experiments were conducted in which timothy hay was the sole roughage fed. Experiment 1²² involved three cows and Experiment 2, two cows. Each animal consumed 12 to 15 pounds of timothy hay a day in addition to the grain. The same grain mixture, consisting of 4 parts corn, 2 parts bran, and 1 part linseed oil meal, was used in each experiment. Each experiment was begun with a basal period of two to three weeks, following a preliminary period in which the ration was changed from the usual herd ration to the basal ration. This basal ration consisted of the timothy hay in the amounts mentioned and 8 to 12 pounds of the grain mixture. The amount fed was regulated by the weight of the animal and the milk flow. The entire ration of each animal conformed to Armsby's standard for protein and energy. In each experiment the basal period was followed by a period of three weeks in which four pounds of the grain of each animal was replaced by four pounds of cottonseed meal. The effects of the basal and experimental rations on the physical and chemical constants of the milk fat are shown in Table 6. These data are the average results of the two experiments.

Butter was made in a semi-commercial way, under carefully controlled conditions, in each of the two experiments. Several pounds of butter were made in each experiment and the butter judged for its

market value, particularly with regard to body and flavor. Standing up qualities were also determined. The chemical analyses reported in Table 6 were made on a portion of the rendered fat.

With regard to the standing up quality it was found in Experiment 2 that the basal butter lost its shape at approximately 34° C., while the butter from the cottonseed meal ration withstood a temperature of 40-41° C. Similar results were secured in Experiment 1.

The market qualities of both the basal and experimental butter in Experiment 1 were inferior. This was particularly true of the cottonseed meal butter which was found to have an oily, flat taste, gummy consistency and overworked appearance. In Experiment 2 the basal butter was of fair quality and the cottonseed meal butter was not so decidedly inferior as in Experiment 1. It would have passed for a fairly good table butter, altho it possessed to a slight extent the oily flavor which was so pronounced in the other experiment.

TABLE 6.—INFLUENCE OF COTTONSEED MEAL WITH TIMOTHY ON FAT CONSTANTS

	Basal Period	Cottonseed Meal Period
Saponification value.....	226.6	222.4
Reichert-Meißl Number.....	27.03	25.02
Iodin value..... Hübl	35.19	36.29
Melting point.....°C	33.29	38.45

The butter made in Experiment 2 was kept for a while to determine its keeping quality. Portions of the butter in each period were packed tightly in one-pound glass jars, which were then covered with a tight-fitting fiber cover and sealed over with paraffin. Several jars from each period were placed in the refrigerator at about 8° C. Jars were removed at intervals and their quality judged. In six months the basal butter had become very rancid with a strong butyric acid odor. The cottonseed meal butter, on the other hand, after five and one-half months was apparently in the same condition as when it was put away. Other portions of the same butter were still in good condition after seven and one-half months altho a slightly old taste had developed.

Cottonseed products with timothy hay and corn stover.—Two experiments were conducted in which increasing quantities of cottonseed meal replaced a like amount of grain mixture (corn 4, bran 2, oil meal 1) in a ration of which the roughage was timothy hay and corn stover. These experiments, however, have already been summarized in Table

5 in connection with the studies concerning the cause of the effects of feeding cottonseed products. The reader is referred to this table and the accompanying paragraphs for the details of the results obtained. It is of considerable interest to point out the striking similarity between the fat constants resulting from feeding four pounds of cottonseed meal with timothy and corn stover with those resulting from feeding a like amount of meal with timothy hay. Inspection of Tables 5 and 6 shows this similarity.

Cottonseed meal with alfalfa hay.—Three experiments with individual cows were conducted in which cottonseed meal was fed with alfalfa hay as roughage. In each experiment the meal replaced an equal amount by weight of the grain mixture used in all our experiments, namely, corn, 4 parts; bran, 2 parts; oil meal, 1 part. The data secured in these experiments with regard to the physical and chemical constants of the milk fat are summarized in Table 7. The data are reported separately for each experiment.

TABLE 7.—EFFECT ON FAT CONSTANTS OF COTTONSEED MEAL WITH ALFALFA HAY

Experiment	Amount of Meal in Ration	Saponification Value	Reichert-Meisel Number	Iodin Value	Hehner Number	Melting Point
1	Lbs.			Hübl		°C
	0	227.0	27.90	32.25	-----	33.60
	2	227.7	27.02	32.40	-----	34.50
	2.5	228.3	25.12	33.74	-----	34.33
	3	227.6	25.99	34.43	-----	34.10
	4	225.9	24.54	35.50	-----	34.77
2	0	228.9	27.68	33.33	-----	32.73
	0	229.4	28.64	33.78	-----	33.63
	4	223.7	28.94	35.31	-----	35.00
	5	219.8	27.13	36.65	-----	36.43
	0	221.2	27.30	35.14	-----	34.20
3	0	229.7	28.33	31.44	84.50	33.23
	3.6	225.3	27.29	36.96	76.70	33.73
	7.5	223.4	28.06	37.54	86.64	35.47
	0	229.5	28.33	31.68	86.29	33.63

It is noticeable that the fat constants are very similar with like amounts of meal. They are also very similar to the fat constants obtained when the same amount of cottonseed meal was fed with timothy hay or timothy hay and corn stover. A comparison of data from the three roughages with four pounds of cottonseed meal in the ration is shown in Table 8. The basal ration constants in this table are the average of the basal ration constants of the experiments compared.

Cottonseed meal with alfalfa hay and corn silage.—The experiment²² which we wish to report in this connection was conducted with two groups of cows, containing seven and eight cows respectively. One

group was fed a basal ration of corn silage, 30—45 pounds; alfalfa hay, 7—11 pounds; and the usual grain mixture 6—11 pounds of corn, bran, and oil meal. The varying amounts were due to the requirements of the different animals. This group of cows received the foregoing ration 62 days without variation. The other group of cows received the same ration in a first and fifth period. During the three intervening periods the grain was replaced pound for pound with two, four, and six pounds of cottonseed meal, respectively. Dur-

TABLE 8.—COMPARISON OF FAT CONSTANTS WITH DIFFERENT ROUGHAGES AND COTTONSEED MEAL

	Basal Ration Without Cot- tonseed Meal	Four Lbs. Meal With Timothy Hay	Four Lbs. Meal With Timothy Hay and Corn Stover	Four Lbs. Meal With Alfalfa Hay
Saponification value.....	227.0	222.4	222.2	224.7
Reichert-Meißl number.....	27.61	26.02	26.27	26.74
Iodin value..... Hübl	33.62	36.29	35.00	35.41
Melting point..... °C	33.59	38.45	35.63	34.89

ing the last three days of each period, which was about two weeks long, a composite sample was taken from each group. Analyses were made of the butter fat secured. Butter was also made on a semi-commercial scale and judged for its market qualities, and for its standing up and keeping qualities.

The results in regard to the physical and chemical constants of the milk fat are given in Table 9. The striking feature of the results of this experiment was the *lack* of effect on the physical and chemical constants of the milk fat. Absolutely the only effect was an increase in the melting point of 1.6° C. from the basal to the six pounds of

TABLE 9.—EFFECT ON FAT CONSTANTS WHEN COTTONSEED MEAL IS FED WITH ALFALFA HAY AND CORN SILAGE

Group	Period	Amount of Meal in Ration	Saponification Value	Reichert- Meißl Number	Iodin Value	Melting Point
		Lbs.			Hübl	°C
I	1	0	233.6	30.94	30.40	32.7
I	2	0	232.3	31.07	29.68	32.4
I	3	0	232.2	32.10	32.13	31.0
I	4	0	231.9	30.20	32.20	32.2
I	5	0	233.0	30.95	30.73	31.7
II	1	0	232.3	29.66	30.77	31.9
II	2	2	231.9	30.00	30.06	32.8
II	3	4	231.3	30.90	31.75	33.5
II	4	6	231.0	30.80	32.72	33.5
II	5	0	232.0	29.48	31.24	32.2

meal. These results are in marked contrast to those reported when timothy hay, timothy hay and corn stover, and alfalfa hay comprised the roughages. The marked results upon the other qualities of the butter which were manifested in the experiments with the other roughages were also lacking in this experiment. Whereas the cottonseed meal when fed with the other roughages caused the production of butter of very poor quality, the results in this regard when corn silage and alfalfa hay constituted the roughage were not nearly so pronounced. The butter from the periods when four and six pounds of cottonseed meal were fed had the oily flavor characteristic of cottonseed meal feeding when compared with the butter from the animals receiving no meal, but the effects were not sufficiently pronounced in this respect to detract from the market value of the butter. The opinion of several persons, among whom was Professor Mortensen of the Iowa State Agricultural College who judged the butter without any knowledge of the conditions under which it was made, concurred in regard to this.

As in the other experiments, the butter showed a decidedly higher standing up quality during the periods of cottonseed meal feeding, particularly during the four- and six-pound periods. The basal butter lost its shape in most cases between 29 and 30° C., while this was increased to 33° C. during the four-pound period and 34.5° C. during the six-pound period. It is readily seen that the effects of the meal in this respect were decidedly beneficial inasmuch as the basal butter lost its shape at a temperature which was lower than would be demanded for a high grade table butter.

A decided difference in keeping quality between the basal and experimental butters was noticed, each time in favor of the cottonseed meal butter, which retained its original flavor for a considerably longer period than the basal butter. The samples were kept at 25° C. and 5—10° C., respectively. Those kept at the lower temperature naturally retained their flavor longer. Four pounds of meal seemed to defer the time of going off flavor over two pounds of meal; the same relation held true for the six pounds of meal.

Experiment showing relation of roughage to effects of cottonseed products.—The marked difference in the effects of cottonseed meal feeding upon the composition and properties of butter in the experiments reported in the foregoing pages, particularly when the results of feeding cottonseed meal with hay alone, or hay and corn stover are compared with the results of feeding the meal with hay and silage

led us to investigate further the relation of the roughage to the effects of cottonseed meal feeding.

For this purpose two groups of cows were chosen, each group comprising one Jersey, one Holstein, and one Ayrshire. Each group was fed a grain mixture of corn, 4 parts; bran, 2 parts; and oil meal, 1 part; in each of six successive periods. Periods 1 and 6 were basal periods and the remainder experimental periods. One group received 0.6 pounds of crude cottonseed oil in addition to the grain in each of the experimental periods. The roughage fed was the same for each group in the same period, but varied for the different periods. The character of the ration fed in each period to each group is shown in Table 10.

TABLE 10.—RATIONS FED IN COTTONSEED OIL VERSUS ROUGHAGE EXPERIMENTS

Period	Group I	Group II
1	Alfalfa hay and grain	Alfalfa hay and grain
2	Alfalfa hay; grain; 0.6 lbs. cottonseed oil	Alfalfa hay and grain
3	Timothy hay; corn stover; grain; 0.6 lbs. cottonseed oil	Timothy hay; corn stover; grain
4	Alfalfa hay; corn silage, 30—40 lbs.; grain; 0.6 lbs. cottonseed oil	Alfalfa hay; corn silage, 30—40 lbs.; grain
5	Alfalfa hay; corn silage, 20—25 lbs.; grain; 0.6 lbs. cottonseed oil	Alfalfa hay; corn silage, 20—25 lbs.; grain
6	Alfalfa hay and grain	Alfalfa hay and grain

The plan of the experiment shown in Table 10 made it possible to determine the influence of certain roughages on the composition of the milk fat and, at the same time, the influence of these roughages on the effects of cottonseed meal feeding. The roughages chosen were those used in our previous studies of the effects of cottonseed meal feeding, the results of which were so widely divergent. Cottonseed oil was fed in this experiment because it was desired to secure as pronounced results as possible. Experiments already reported indicated that cottonseed oil produces slightly more pronounced results than cottonseed meal. The amount of oil chosen for the experimental feeding, namely, 0.6 lbs., was equivalent to a liberal feeding of cottonseed meal on the basis of 8 to 10 per cent oil in cottonseed meal of average grade. Previous experiments having indicated that corn silage has a marked counteracting influence upon the effects of cottonseed meal feeding, Periods 4 and 5 were planned to determine what influence is exerted by the amount of silage in the ration. Thirty to 40 pounds of silage was fed in Period 4, but this was reduced to 20 to 25 pounds in Period 5.

All the periods in this experiment were fifteen days long. All the milk from each animal was saved during the last three days of each period. Butter was made from the composite from each group under carefully controlled conditions in a semi-commercial way. Portions of the butter were rendered and the fat analyzed for the usual physical and chemical constants. The remainder of the butter was examined for its standing up qualities. The results are shown in Table 11.

TABLE 11.—INFLUENCE OF ROUGHAGE ON COMPOSITION AND PROPERTIES OF BUTTER DURING COTTONSEED OIL FEEDING

Period	Group	Saponification Value	Reichert-Meissl Number	Iodin Value	Melting Point	Standing-up Temperature of Butter
1	I	223.6	24.57	Hübl 35.21	°C 33.10	°C 33—33.5
2	I	218.3	24.51	40.41	34.63	36—37
3	I	216.8	22.00	41.21	34.83	36.5—37.5
4	I	221.5	25.70	39.61	33.88	34.5—35
5	I	220.7	24.84	40.40	33.90	33—34
6	I	224.3	25.28	37.70	33.30	33—33.5
1	II	224.2	27.36	34.06	33.00	33.5—34
2	II	224.8	26.47	35.19	33.25	33—33.5
3	II	224.6	26.71	36.92	32.50	33—33.5
4	II	227.7	30.02	32.75	33.08	32.5—33
5	II	227.1	29.83	34.86	32.70	32—33
6	II	225.3	27.37	37.78	33.35	34

Bearing in mind that Group I received 0.6 pounds of cottonseed oil in Periods 2 to 5, inclusive, the striking feature of the results of this experiment was to confirm the marked influence of silage feeding upon the effects of adding the cottonseed oil to the ration. This was manifested particularly in this experiment by the Reichert-Meissl number and melting point of the butter fat and by the standing up quality of the butter. The influence upon the saponification value and iodine value was less marked. An examination of the data from Group II, which received no cottonseed oil, but had the roughage changed in the various periods, indicates that this result is due to the marked effect which silage itself exerts upon the fat constants. The direction of the change which silage exerts upon the fat constants is, moreover, in the opposite direction to that resulting from cottonseed meal or cottonseed oil feeding. This has led us to conclude that corn silage contains a specific substance, (or substances) which counteracts the effects of feeding cottonseed products upon the composition and properties of butter. We are investigating the nature of this counteracting material at present. Preliminary experiments already conducted give us reason to believe that the investigation will have a successful issue.

The data in Table 11 were less striking in some features than those from some of the previous experiments. For example, the melting point of the butter fat was not as high during the periods when the oil was fed with alfalfa hay or timothy hay and corn stover as our previous studies led us to expect. The effects upon the standing up temperature of the butter were more marked. The lowering of this standing up temperature during the silage periods is striking. In each case the reduction was to that found for the butter from the basal periods. The reduction in the amount of silage in the ration in Period 5 did not bring about as great a change in the fat constants for either group as was expected, altho there was some change in both groups. Apparently nearly as much of the counteracting material was absorbed from the digestive tract when 20—25 pounds of silage was fed as when the amount was 30—40 pounds. Another interesting feature of the results was that there was practically no difference in the composition of the butter fat on the dry feed rations. Apparently just as normal butter, as far as the composition of the fat is concerned, is obtained from feeding timothy hay and corn fodder for roughage as when the roughage is alfalfa hay. The effects of oil feeding were somewhat more pronounced during the timothy hay and stover period than when the roughage was alfalfa hay. This bears out our previous observations in this regard when the ration contains a liberal amount of cottonseed products.

Influence of cottonseed products with pasture.—The influence of cottonseed meal on the melting point of butter fat is undoubtedly of as great practical importance as any of the other effects which the meal exerts on the composition of the fat. The increase in the melting point which accompanies cottonseed meal feeding is directly connected with the increase in the standing up quality of the butter, as manifested by its ability to withstand a higher temperature before losing its shape or body. This is a matter of considerable importance from the standpoint of the consumer. This is particularly true during hot weather when the ease with which the ordinary run of table butter loses its body becomes a source of much annoyance to the housewife who has not refrigeration facilities necessary to cope with this problem. The difficulties encountered in this connection during the summer months, and especially during the first hot weather of the summer are accentuated by the fact that butter produced while cows are on grass is especially characterized by its soft body. This is particularly true when the cows are first turned to grass in the spring when the pastures are the most succulent. The butter made at this time is characterized

further by its poor keeping quality. For this reason storage houses are reluctant to receive butter for storage at this time of the year.

Our investigations with regard to the feeding of cottonseed products which show a marked improvement in the body of the butter and an increase in the keeping quality would seem to be of much practical importance if similar results should accompany the feeding of cottonseed products in connection with pasture, particularly fresh pasture grass. Experiments planned for the purpose of demonstrating whether cottonseed products have such an effect when fed with pasture are, however, much more difficult to control than the experiments in which cottonseed products are fed with dry feed. The difficulty arises because cows frequently suffer from underfeeding when first turned to pasture. The authors have called attention to this in a recent publication,²¹ in which the importance of this factor is discussed fully. It is pointed out there that underfeeding itself causes the production of butter fat of abnormal composition.

Several preliminary experiments were conducted in which cottonseed meal was fed with pasture, but in almost every case the results were vitiated by the fact that the butter fat was clearly affected by underfeeding in the periods when no cottonseed meal was fed. These experiments will not be reported. A typical case is shown, however, in Table 12. In this experiment a group of four cows which had been on fresh pasture for 7 to 10 days were fed two pounds of cottonseed meal and one pound of bran for a period of 12 days, which was followed by a period of the same length in which the meal and bran were removed from the ration. A composite sample was taken the last three days of each period. The butter made was judged for flavor, and standing up quality, and the usual fat constants were determined on a portion of the rendered fat.

TABLE 12.—COTTONSEED MEAL WITH PASTURE VITIATED BY UNDERFEEDING

Period	Saponification Value	Reichert-Meissl Number	Iodin Value	Melting Point	Standing-up Temperature of Butter
1	219.2	23.33	Hübl 43.28	°C 34.95	°C 35—35.5
2	216.4	19.73	44.01	37.40	37—38
3	216.0	20.92	44.56	36.40	37—37.5

The low saponification value and Reichert-Meissl number and very high melting point in Periods 1 and 3, when no cottonseed meal was fed, are characteristic of underfeeding and not of pasture feeding.

It was evident from the preliminary experiments that the question of feeding cottonseed products with pasture could be successfully tested only when the factor of underfeeding incident to changing from dry feed to pasture is carefully controlled. In order, also, that any influences should be manifested which might arise from a change in the composition of the pasture it was considered desirable to study the effects of cottonseed meal feeding when the pasture was at its best. The results would in this way be strictly comparative, and would, at the same time, indicate what may be expected when the pastures are more mature. To satisfy these conditions the group plan was adopted, in which several groups of cows were changed from dry feed to pasture under conditions that would be the least likely to cause underfeeding. Five such groups were used, each containing two cows. Three of the groups received cottonseed products in their pasture period. One group was reserved for a basal group and no cottonseed was added to the ration. Each of the four groups just mentioned received an ample grain ration while on pasture. The cottonseed products formed a part of this grain in the cases in which they were fed. The grain mixture, aside from the cottonseed products, was identical with that fed in all the experiments reported in the preceding pages.

The feeding of an ample grain mixture in the experimental period of this experiment was for the purpose of preventing any underfeeding when the animals were turned to pasture. This raised the question, however, whether this would influence the composition of the butter usually resulting from pasture feeding. In other words, the question involved was whether the same effects on the composition of the butter fat would accompany an experiment in which the pasture was fed simply as a roughage (altho ad libitum) as are usually found to accompany a ration of pasture only. It was for the purpose of testing this question that a fifth group was changed from dry feed to a ration of green alfalfa in which the green feed was fed as a soiling crop in sufficient amount to prevent underfeeding. The amount fed per day was about 110 pounds for each animal.

The cottonseed products fed in the experimental periods consisted of cottonseed meal to which crude cottonseed oil was added in amount equal to the oil content of the meal. This was approximately 10 per cent. In this way Group I received cottonseed oil equivalent to two pounds of meal, Group II received cottonseed oil equivalent to four pounds of cottonseed meal, and Group III cottonseed oil equivalent to six pounds of cottonseed meal. The rations fed the different groups in the basal and experimental periods are shown in detail in Table 13. The

basal ration was the regular ration of the University herd so that a basal period was not necessary. The animals chosen for the experiment were under careful observation, however, for a period of two weeks before the sample was taken, and were treated in every way like experimental animals during this period. After a three-day period for taking samples the cows were turned to pasture with the exception of the fifth group which received the green alfalfa. The basal roughage was gradually withdrawn, and also a portion of the grain, and the cottonseed products substituted for a portion of the grain. At the end of a week of such transition period each group was on the full experimental ration including Group V which was fed the green alfalfa. At the end of two weeks on the full experimental rations, a second

TABLE 13.—BASAL AND EXPERIMENTAL RATIIONS; PASTURE—COTTONSEED MEAL EXPERIMENT

Group	Cow	Daily Basal Ration			Daily Experimental Ration			
		Grain	Alfalfa Hay	Silage	Grain	Cottonseed Meal	Cottonseed Oil	Pasture
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Ad. lib.
I	1	12.0	11.3	38.0	8.0	1.0	0.1
	2	8.0	5.7	30.0	5.0	1.0	0.1
II	1	8.0	9.3	30.0	5.0	2.0	0.2
	2	9.0	8.0	30.0	5.0	3.0	0.2
III	1	8.0	10.0	35.0	4.0	3.0	0.3
	2	9.0	8.7	33.0	5.0	3.0	0.3
IV	1	12.0	10.0	35.0	8.0	0.0	0.0
	2	8.0	8.0	28.0	5.0	0.0	0.0
V	1	8.0	10.0	30.0	Green alfalfa 110 lbs.		
	2	6.0	8.0	30.0	110

three-day composite was taken from each group of cows. The cows were turned to pasture May 4.

Butter was made in a semi-commercial way from each group at the end of the basal and experimental periods, respectively. This butter was judged for market qualities, standing up quality, and samples preserved in the refrigerator for observing the keeping quality of the butter. The method followed was that already described in connection with another experiment. Portions of the butter were also rendered and analyzed for the usual fat constants.

Influence on constants of fat and standing up temperature of the butter.—The physical and chemical constants of the butter fat and the standing up temperature of the butter for each group of cows on the basal and experimental rations are shown in Table 14.

The results obtained in this experiment are a striking demonstration of the advantages of a careful control of all factors in experiments

TABLE 14.—EFFECTS OF COTTONSEED MEAL ON BUTTER DURING PASTURE FEEDING

Group	Period	Cottonseed Meal Equivalent of Oil in Ration	Saponification Value	Reichert-Meissl Number	Iodin Value	Melting Point	Standing-up Temperature of Butter
		Lbs.			Hübl	°C	°C
I	1	0.0	232.8	30.22	30.64	31.5	33.5
I	2	2.0	228.0	30.39	37.46	33.0	34.5
II	1	0.0	230.6	29.18	31.66	31.3	33.0
II	2	4.0	219.6	25.81	41.69	33.7	35.0
III	1	0.0	229.8	29.91	31.11	32.9	33.5
III	2	6.0	221.6	27.97	41.05	35.6	38.0
IV	1	0.0	229.1	27.67	31.48	32.1	33.5
IV	2	0.0 ¹	222.9	27.49	41.59	31.7	32.5
V	1	0.0	227.2	26.14	32.26	32.9	34.0
V	2	0.0 ²	223.7	26.13	41.42	31.8	33.0

¹Pasture and grain without cottonseed products.

²Fed green alfalfa.

of this character. The obvious effect of this control is seen in the consistency of the results.

Groups IV and V in this experiment indicate clearly the normal effects on the composition of the butter resulting from changing the ration from dry feed to pasture. The effects were, moreover, identical with each group showing that the addition of a normal grain ration to pasture feeding in no wise alters the composition of the butter fat from a ration of pasture alone. The data from these two groups show that blue grass pasture and green alfalfa produce butter fat of the same composition. The principal change apparent from these data is a marked rise in the unsaturated fatty acids of the butter fat at the expense of the non-volatile fatty acids only. This results in a material decrease in the saponification value of the fat, and, as would also be expected, in a lowering of the melting point. The latter change manifests itself in a decrease in the maximum temperature which the butter will sustain without losing its shape or body.

With regard to the effects of cottonseed products in the ration during pasture feeding the data in Table 14 are of much importance. No additional change in the iodine value from that caused by the change to pasture was manifested in any of the rations containing cottonseed products. The only change in the composition of the fat indicated by the data which can be attributed to the cottonseed products is a marked decrease in the volatile fatty acids, manifested by a decrease in the Reichert-Meissl number. The extent of this change was more or less proportional to the quantity of cottonseed products in the ration. The principal effect of this change was in causing a material rise in the melting point of the butter fat. This again was manifested very

strikingly in the increase in the maximum temperature which the butter would withstand before losing its body. We have termed this the standing up quality of the butter.

The differences of the standing up quality of the butter in the different periods of each group were, in fact, so striking that we attempted to photograph the results in this particular. The results of this attempt are shown in Figures 1, 2, and 3. Cakes of the butter about 6.5 cm. square and 3 cm. deep from each group and in each period were placed in Petri dishes and brought to a certain temperature very slowly in a water-jacketed oven and maintained at that temperature for one-half hour. The cakes of butter were then chilled in the refrigerator and afterward photographed. The results of three such trials are shown in the three figures. Figure 1 shows the results of holding the butter at 31.5 to 32° C. for one-half hour; Figure 2 shows the results at a temperature of 32.5 to 33° C.; while Figure 3 shows the results at 35 to 35.5° C.

The photographs bear out in every particular the data given in Table 14. In each figure the butter from the basal ration of each group is shown above the butter from the experimental ration. With this fact in mind a comparison of dishes 7 and 8 and dishes 9 and 10, particularly in Figure 1, shows the softening effect on the butter of the change from dry feed to pasture. Each of the figures shows the beneficial effects of the cottonseed products on the standing up quality of the butter. These benefits increase with the amount of products in the ration. A comparison of dish 2 with dishes 8 and 10 in Figure 1 shows that even two pounds of cottonseed meal in the ration caused a marked improvement in the standing up quality over the butter from the pasture rations containing no cottonseed products. Particularly striking, however, is the butter in dish 6 in Figure 3. The butter in this dish was somewhat soft after standing at 35 to 35.5° C. for one-half hour, but it retained its body perfectly while all the other samples, with the possible exception of the butter in dish 4, had completely spread out.

Effect on the market value and keeping quality of butter.—In addition to the studies of the chemical and physical properties, the butter from each group was judged for its market value in each period. Portions of the butter were also packed away in glass jars, tightly sealed with paraffin, and stored in the refrigerator for future observations on the keeping quality.

All the samples of butter were of excellent quality when made, altho that from Group III on the experimental ration had a slightly oily

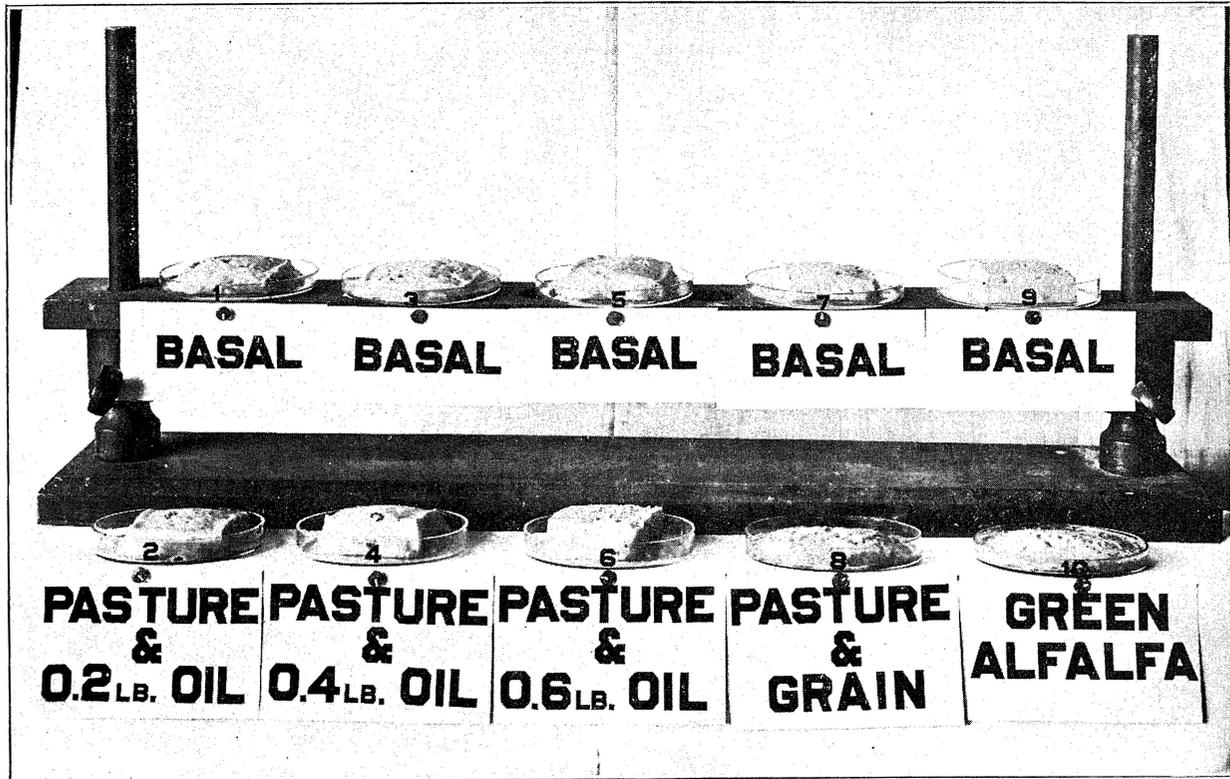


FIG. 1.—INFLUENCE OF COTTONSEED PRODUCTS WHEN FED WITH PASTURE ON THE STANDING UP QUALITY OF BUTTER.

The above photograph shows the standing up qualities of the different lots of butter after having stood at a temperature of 31.5—32° C. for one-half hour. Notice that the two samples on pasture alone had practically lost their shape in comparison with the basal butters. Notice the improvement of each of the cottonseed product samples in comparison with its basal butter, and the relation of this improvement to the quantity of cottonseed oil in the ration.

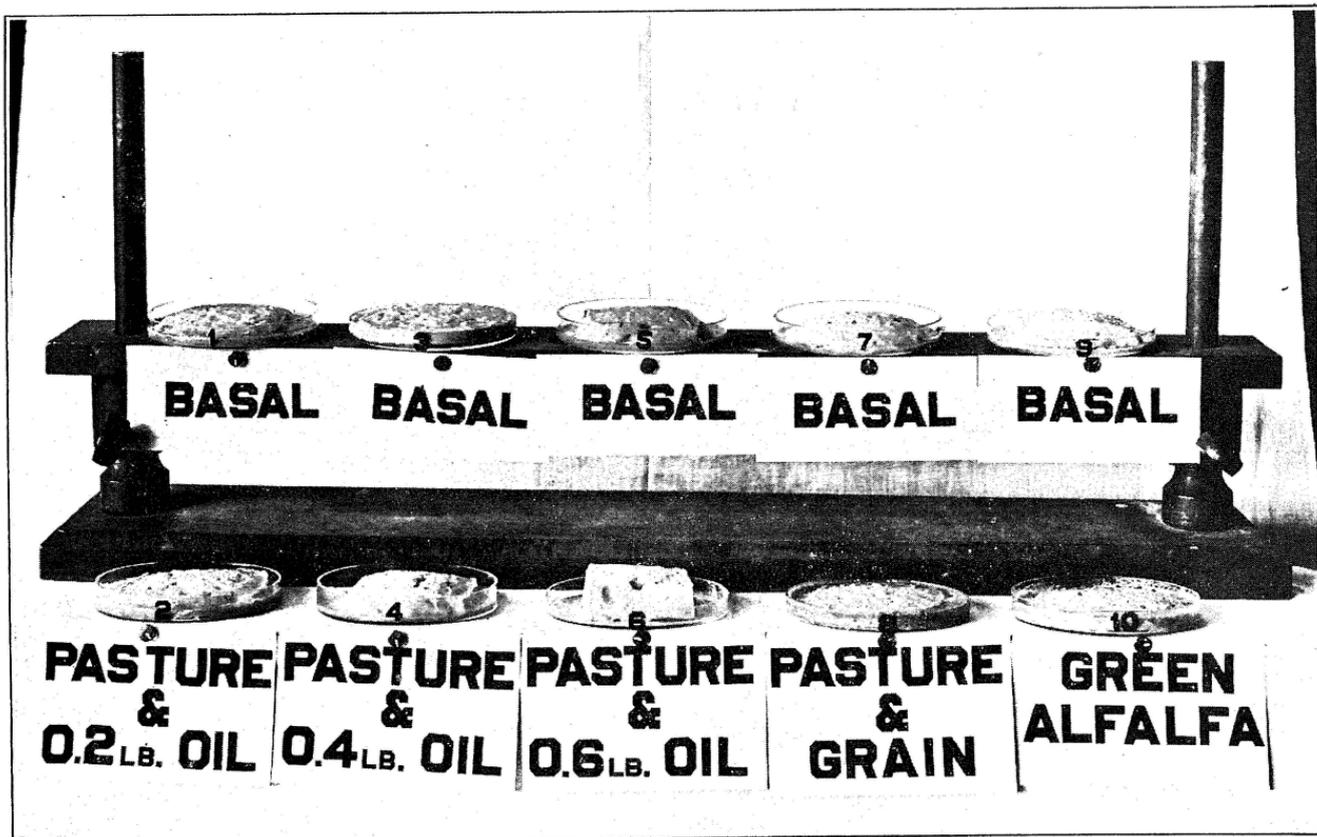


FIG. 2.—INFLUENCE OF COTTONSEED PRODUCTS WHEN FED WITH PASTURE ON THE STANDING UP QUALITY OF BUTTER.

The above photograph shows the standing up quality of the different lots of butter after having stood at 32.5–33° C. for one-half hour. The improvement of each cottonseed product butter over its basal sample is still noticeable.

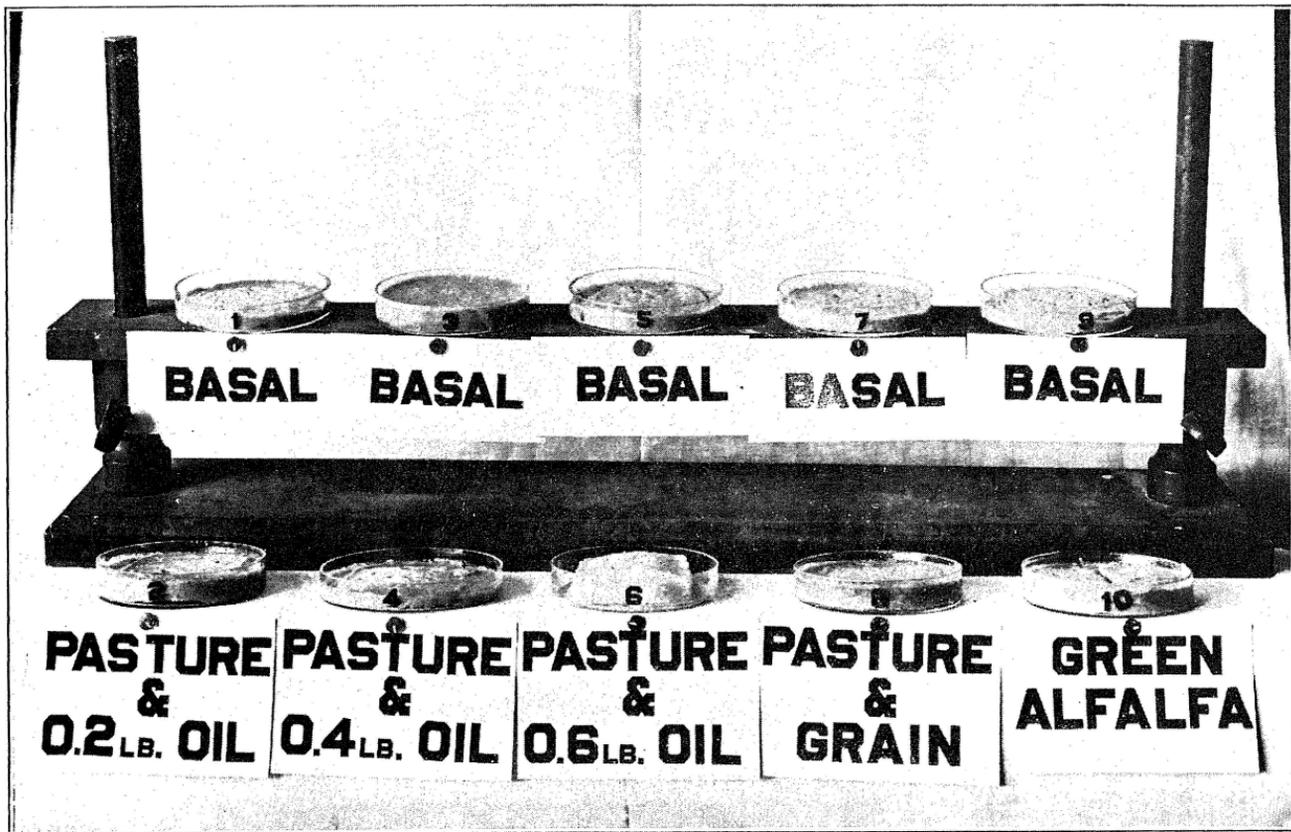


FIG. 3.—INFLUENCE OF COTTONSEED PRODUCTS WHEN FED WITH PASTURE ON THE STANDING UP QUALITY OF BUTTER.

The above photograph shows the standing up quality of the different lots of butter after having stood at 35—35.5°C. for one-half hour. Notice that all the samples have lost their shape except that from the ration containing the largest amount of cottonseed oil.

taste similar to that obtained in previous experiments involving a liberal ration of cottonseed products.

All the samples of butter from the basal rations were of good quality after two months storage. The experimental butters were judged at two periods. Samples were opened after five weeks storage, when the basal samples were judged, and other samples were opened after five months. It is to be understood, of course, that no attempt was made to imitate ideal storage conditions. All samples were kept in the creamery refrigerator which varied in temperature from 8 to 12°C. After five weeks storage the samples of butter from the groups which received cottonseed products were of good quality. There seemed to be little if any difference between these lots in this respect, and as far as could be judged there had been practically no deterioration. The samples from the two groups which received no cottonseed products had, on the other hand, suffered considerable deterioration after the five-weeks storage. After a period of five months storage samples from the latter two groups were unfit for anything but the garbage bucket; they were, in fact, astonishingly bad. The samples from the groups which received the cottonseed products while on pasture were, on the other hand, still of fair quality after five months. Each of the samples would have satisfied the ordinary standards for table butter altho the butter from Group 1 was probably somewhat inferior to that from the other two groups. The cottonseed oil taste which has been mentioned seemed to be considerably more pronounced in the case of the group receiving the largest amount of cottonseed products than when the butter was freshly made.

The general conclusion drawn from this phase of the experiment was that the lots of butter from the cottonseed products rations showed decidedly better keeping qualities than the lots which received no cottonseed products. This was in keeping with our other observations in regard to the beneficial effects of feeding cottonseed products on the keeping quality of butter.

PERMANENCY OF THE EFFECTS OF FEEDING COTTONSEED PRODUCTS

In all the experiments which we have thus far reported, the influences of feeding cottonseed products on the composition and properties of the butter fat and the properties of the butter have been determined in feeding periods never exceeding a few weeks in length. A careful study of the whole matter raised the question whether the pronounced

time the animals had been on this ration was not ascertained, but it had been at least four to six months.

Each of these samples of butter was judged for its general quality and flavor as soon as it was received, which was within a few days after the butter was made. The standing up quality of the butter and the physical and chemical constants of the fat were also determined.

Effects on the butter fat constants and the standing up quality of butter.—The butter fat constants and the standing up quality of the butter for the cottonseed meal feeding experiment described previously and the two samples, A and B, secured from the South, are shown in Table 16.

TABLE 16.—DATA IN REGARD TO PERMANENCY OF EFFECTS OF FEEDING COTTONSEED PRODUCTS

Period	Amount of Meal in Ration	Length of Time Meal Was Fed	Saponification Value	Reichert-Meissl Number	Iodin Value	Melting Point	Standing-up Temperature of Butter
	Lbs.	Months			Hübl	°C	°C
1	0	0	226.7	27.92	33.64	33.65	34
2	4	0.5	222.5	26.63	34.16	38.70	40—41
3	4	1.5	221.3	27.22	33.63	38.85	41
4	4	2.5	217.7	24.35	34.89	38.40	41
5	5	3.5	215.9	24.62	35.77	41.00	41—42
6	6	4.5	217.9	25.20	34.89	41.85	42
Sample A	5	6	223.5	27.76	31.29	38.00	40
B	6 ¹	4—6	216.6	24.56	37.09	41.70	41—42

¹ Whole seed fed instead of cottonseed meal.

There are several outstanding features of the results of these studies to which attention may be called. With regard to a recovery from the effects of cottonseed meal feeding these data indicate that there may be a part recovery in the case of certain of the fat constants. Such appears to be the case with the Reichert-Meissl and iodine values in this experiment. These constants are at least less abnormal in the final period than in the preceding one. It should be stated also in connection with these two fat constants that they showed fewer abnormalities throughout this experiment than in any one previously conducted by us in which cottonseed meal was fed with timothy hay. This is especially true with regard to the iodine value. Certain data already reported indicated that four pounds of cottonseed meal had less effect upon the Reichert-Meissl value than might be expected. Whether these results were due to some factor not yet apparent or to the fact that our experimental periods were much longer and thus allowed a part recovery from the first effects to take place is not definitely settled by these data. In view of the care with which the experi-

mental conditions were controlled, however, the weight of opinion seems to us to favor the view that a certain recovery from the effects of cottonseed meal feeding upon the Reichert-Meissl number and iodine value does occur in a long-continued experiment. No such recovery occurred in connection with the saponification value and melting point of the fat in this experiment. The effect on these constants became more, rather than less pronounced as the experiment continued. The increase in the melting point during the last two periods was no doubt due, however, to the increase in the meal in these periods, since the melting point remained stationary throughout the periods in which the same amount of meal was fed. This result in connection with the melting point is identical with that secured in the experiment shown in Table 15. The conclusion seems justified that the effects of feeding cottonseed products upon the melting point of the butter fat are permanent. These effects are also manifested in the high standing up temperature of the butter.

The constants of the butter fat of the samples secured from the South bear out our own experimental results in every particular. The fat constants of the butter of Sample A where cottonseed meal was fed with a liberal ration of corn silage were normal in every particular with the exception of the melting point. Our own experiments with silage feeding in connection with cottonseed meal also showed an effect on the melting point only.

The fat constants of Sample B are typical of high cottonseed oil feeding. These cows were receiving about 1.25 pounds of cottonseed oil per day in the whole seed which they were fed. Since the roughage was hay or corn fodder it is little wonder that the fat constants were abnormal. On the other hand the Reichert-Meissl number and iodine value of the butter were less abnormal than would be expected considering the character of the ration and the amount of cottonseed products fed. It seems to us that the data in connection with this sample also suggest that some recovery from the first abnormalities with respect to the Reichert-Meissl number and iodine value may occur when the feeding of cottonseed products is long continued. These data therefore bear out the other data in Table 16 in this regard.

Effect on market and keeping qualities of butter.—The experimental samples will be considered first. The butter obtained in all the experimental periods was of good quality when first made with the exception of the third cottonseed meal period. An unfortunate accident in regard to obtaining the starter delayed the churning of

the butter in this case and caused it to be somewhat rancid when first made. The other samples made during the feeding of four pounds of cottonseed meal would have been readily marketable altho they would not have been judged as superior butter. The butter made during the five and six pound periods had a decided oily flavor which would have detracted considerably from its market value. It also had the very firm consistency which would be expected to accompany the high standing up temperature shown in Table 16. This was also manifested in the slowness with which the butter melted when placed on the tongue.

Several one-pound samples of butter from each period were stored in the refrigerator in tightly sealed glass jars. The first observation was made after the last sample made had been in storage two months. The basal butter had been in storage seven months at this time. It had developed a very rancid taste and smell as of butyric acid. The first cottonseed meal sample was in similar condition altho much less pronounced. The other cottonseed meal samples were in as good condition as when first packed in the jars. They had been in storage five, three and two months respectively. Other jars of these three churnings were again judged after they had been in storage seven, six, and four months, respectively. The first two samples had a slightly old taste at this time but were otherwise in as good condition as when put away. The sample from the six pound cottonseed meal period in storage four months appeared to be in an identical condition as when put away. Its gummy consistency and oily flavor were, however, still apparent.

The general qualities of Samples A and B when received by us offer points of interest. Sample A was of a quality comparable with the butter obtained during the periods when four pounds of cottonseed meal were fed. It was not of superior quality but would have been readily marketable. Its body was characteristic of a high melting point fat. The oily flavor characteristic of much cottonseed products was not lacking but at the same time was not sufficiently pronounced to be objectionable. The quality and characteristics of this butter in fact were striking evidence of the advantages of feeding corn silage with cottonseed meal.

The quality of Sample B, on the other hand, was strictly characteristic of much butter produced in the South where large quantities of cottonseed meal or cottonseed are fed. As far as flavor was concerned its characteristic was its lack of flavor rather than any pronounced bad flavor. It possessed the oily taste which has been previously mentioned to a very high degree. Its sticky, gummy consistency was so

pronounced that one could fairly chew the butter. This would be expected from the high melting point of the fat and the high standing up temperature of the butter. The butter would have found no general market for table use.

The observations made upon the quality of the experimental butter and upon samples A and B indicate that the effects of feeding cottonseed meal upon the general characteristics studied were permanent, that is, they continue as long as the cottonseed products are fed.

DISCUSSION AND PRACTICAL APPLICATION OF RESULTS

The results of the individual studies have been discussed in detail in connection with their presentation and need no further description. It is desired, however, to discuss certain features of the general results because of the great practical importance which is attached to them.

The use of cottonseed products as a feed for dairy cattle is so closely related to the economics of the dairy industry in many sections of this country, particularly in the South, that it is neither a sound nor a desirable policy to recommend that their use be discontinued on the grounds that they have a detrimental effect upon the quality and market value of butter. At the same time it is recognized that the excessive feeding of these products in some parts of the South stands in the way of any extensive development of the dairy industry so far as buttermaking is concerned. While local markets may take butter showing marked effects from cottonseed products, it can not be sold to any advantage in a general market. It has not been determined whether the quality of cheese is also influenced by the feeding of cottonseed products but since cheese of the cheddar type, as made in this country, is approximately one-third fat it is not improbable that some effects would be noticeable upon the character of the curing process or the quality of the cured cheese.

These conditions show the great practical importance to the development of the dairy industry of devising some means of reducing the detrimental effects accompanying the feeding of cottonseed products.

Our studies seem to us to have demonstrated two factors of importance in accomplishing this result. These factors are, (1) controlling the character of the roughage fed with the cottonseed products, and (2) controlling the character and amount of cottonseed products fed.

As pointed out earlier in the bulletin the importance of controlling the character of the roughage in connection with the feeding of cotton-

seed products is already recognized to some extent in a practical way in certain localities where large amounts of cottonseed products are fed. We believe that our studies are the first to demonstrate this experimentally. Our experiments have shown conclusively that corn silage fed in liberal amounts counteracts in large measure the effects of cottonseed products on the composition of the butter fat, and also has a very beneficial effect on the market qualities of the butter. No doubt other feeds will be found to exert a similar effect. We are at present studying the cause of this effect of corn silage so that other feeds having a similar effect may be recommended. There seems to be no question that the Southern farmer must limit the amount of cottonseed products fed with cottonseed hulls, or corn fodder, or hay of the quality usually fed, if his butter is to compete on the market with the high grade butter produced in those sections of the country where cottonseed products are not used so liberally as a dairy feed.

This raises the question as to what kind of, and how much, cottonseed products it is safe to feed without having a detrimental effect on the butter. Our study of this question has led to the conclusion that the use of the whole seed as a dairy feed is to be strongly discouraged when the products are to be utilized in the manufacture of butter. Cottonseed meal, on account of the smaller amount of oil contained, is the only safe cottonseed product to feed where the butter industry is involved. If cottonseed hulls are to be fed, they should not be the only roughage used but should be fed in a ration containing considerable silage.

With regard to the amount of cottonseed meal which it is safe to feed without undue influence on the butter, it is clear that a larger amount may be fed with certain roughages than with others. Our studies indicate that as high as five pounds a day may be fed with a liberal ration of corn silage without seriously affecting the market quality of the butter. With the dry feeds about three pounds a day would be a liberal cottonseed meal ration if the production of high-grade butter is at stake. Much larger quantities of cottonseed meal are fed in many parts of the South than our studies indicate can be done without seriously affecting the quality of the butter. These statements make it evident that the feeding of cottonseed products as still practiced in many localities in the South must be considerably modified before butter made in that section of the country can compete successfully in the general markets.

In this discussion of the detrimental effects of cottonseed meal feeding and means for reducing them we must not lose sight of the fact that the feeding of cottonseed products may exert a beneficial

effect on the butter under certain conditions. Our experiments uniformly indicate that cottonseed products cause a firmer butter and one that withstands a higher temperature without losing its body or shape. A decidedly better keeping quality also characterized all the cottonseed product butters in the experiments in which this question was studied. The effect on the body of the butter has been demonstrated by other investigators as well. Our studies are the first to indicate that cottonseed meal feeding is of importance in connection with the keeping quality of the butter.

It has been pointed out in an earlier paragraph that a firmer body and a better keeping quality are properties which it is especially desirable to impart to the butter made when cows are first turned to pasture in spring. The experimental study of this question, which has been reported, demonstrated the value of feeding cottonseed products with fresh pasture in bringing about a marked improvement in the body and keeping qualities of the butter. Since it was apparent that it was the oil in the ration that brought about this result, there is no reason why the whole seed cannot be used in this connection if desirable. The results indicate that a pound to a pound and a half of whole seed, or two to three pounds of cottonseed meal added to the ration of cows on fresh pasture will exert a decided improvement on the quality of the butter. Such a practice would also be of value in preventing the underfeeding which cows frequently suffer, often with serious results upon the milk flow, when first turned to pasture.

SUMMARY

1. The feeding of cottonseed products exerts characteristic effects upon the physical and chemical constants of butter fat and upon the properties of butter. These are manifested, in general, by a decrease in saponification value and Reichert-Meissl number, and an increase in the iodine-absorption value and melting point of the butter fat; the effects on the butter are to cause a firmer body, frequently a gummy consistency, a higher standing up quality or ability to withstand a higher temperature without losing its body, a flat, oily taste, and a better keeping quality.

2. The effects of feeding cottonseed products in the directions indicated are due largely, if not entirely, to the amount of cottonseed oil which they contain.

3. The extent of the effects in the directions indicated is, in general, proportional to the amount of cottonseed oil in the products fed.

4. The extent of the effects of feeding cottonseed products is greatly modified by the character of the roughage fed. The effects are most pronounced when cottonseed products are fed with dry feeds, such as timothy hay, timothy hay and corn stover, cottonseed hulls, or alfalfa hay. The effects are least pronounced when the cottonseed products are fed with a liberal ration of corn silage, and some of the effects may be counteracted entirely. Studies of the cause of the counteracting effects of corn silage are being made by the authors with the view of selecting other roughages with similar properties.

5. Small amounts of cottonseed products may be fed to cows on fresh pasture with very beneficial effects upon the body and keeping qualities of the butter.

6. The effects of feeding cottonseed meal upon certain of the constants of the butter fat, particularly the Reichert-Meissl number and iodine value may be somewhat modified with continuous feeding. The effects on the melting point of the fat and the other properties of the butter continue, however, as long as the cottonseed meal is fed.

7. The feeding of large quantities of cottonseed meal and whole cottonseed as still practiced in many localities in the South must be considerably modified if the butter industry of that part of the country is to attain its proper place in the butter industry of the nation. The use of the whole seed as a feed for dairy cattle is to be strongly discouraged on account of its excessive oil content.

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C. H. Eckles has represented the Missouri Experiment Station thruout the investigation. R. H. Shaw, Matthew Steele, and L. S. Palmer represented the Dairy Division in the succession named thruout the cooperative work. The major part of the chemical data were taken under the direction of L. S. Palmer, who has been responsible for the preparation of this bulletin. Credit is also due R. R. Graves (1911-12) and J. B. McNulty (1912-13), graduate students in the Department of Dairy Husbandry, University of Missouri, who assisted in the investigation during the years indicated and presented theses for the degree of A. M. on the work which they did.

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23. The usual grain ration of corn, 4 parts; bran, 2 parts; and linseed meal, 1 part was fed. In addition one of the cows received 1 pound of gluten meal in the basal period to satisfy her energy requirements.
24. These samples were secured thru the courtesy of W. H. Howell, of the U. S. Department of Agriculture, Bureau of Animal Industry, Dairy Division.