6-1-1939

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Bulletin 331 June 1939

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By

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Summary

A knowledge of the factors affecting the composition of milk is of paramount importance to everyone engaged in the production and distribution or use of milk in order that a satisfactory basis of trade may be maintained. Milk is not a commodity of uniform composition but is subject to the influence of many factors including the breed of cows, the stage of lactation, the season of the year, and other minor influences not considered in this work.

The investigation reported here is designed to answer some of the questions regarding fluctuation in tests and to suggest methods of obtaining a more uniform product by herd management practices. The results of tests made at monthly intervals over a five year period on cows of the Holstein, Guernsey, Jersey, and Ayrshire breeds are reported. Analyses for fat, total solids, ash or mineral, calcium, and phosphorus content were made and the influence of each of the factors: breed, stage of lactation and season on these components is shown.

Although minimum standards for fat and solids in milk are set by state law there is considerable variation in milks which are within the legal range. From the standpoint of food value then, one milk supply may be superior to another and a price differential is justified.

The tendency for low tests is associated with the flush period of the lactation especially during the summer months. Since the Holstein breed tests somewhat lower in fat and solids than the other breeds, the occurrence of illegal samples is most frequent in this breed. Samples of milk which are below the legal minimum of 8.50 percent in solids are found more frequently than are samples of illegal fat content.

The results of this work suggest that the difficulty with low test variations can be avoided by selecting cows for high test, balancing the freshening dates throughout the year and standardizing by admixture of higher testing milk.

Factors Affecting the Composition of Milk

By D. H. Jacobsen and G. C. Wallis

Introduction

Many problems are raised by the fact that milk is not a uniform product having the same composition at all times. For instance, minimum requirements have been established by law relative to the fat and solids content of market milk. This has been done to protect consumers against the purchase of milk that has been adulterated by the addition of water or by other means, and to protect producers against the use of such unscrupulous methods of competition. It is difficult, however, to determine if the milk in question is illegal because of the normal variations in composition or because of adulteration. No doubt, injustices have been suffered by innocent producers or distributors for this reason. The problem then arises as to where the minimum requirements should be set so that adequate protection may be provided for all parties concerned without working an unnecessary hardship on anyone.

Furthermore, variations in the composition of milk are closely associated with its nutritive value. Milk that is high in fat and solids content will supply more protein and more energy than milk that is low in solids content. Milk that is high in mineral content has an added value for supplying the elements necessary for the building of strong bones and good teeth. As the average American diet is likely to be deficient in these bone-building elements, variation in the mineral content of milk and the factors responsible for them are undoubtedly worthy of more study and attention than they have received in the past. This is especially true in view of the fact that milk is one of our best food sources of calcium and phosphorous. Milk of a high food value is worth more on the market than milk of a lower food value but price differentials seldom reflect the real differences in the food value of different milks.

Such problems as those indicated above can best be solved when more information as to the variations in the composition of milk from apparently normal, healthy cows is available. Variations in the fat, solids, and mineral content of milk have been studied in the present investigation and the relation of breed, stage of lactation, and season of the year to such variations has been observed.

Experimental Methods

The cows used in this investigation were a part of the college dairy herd and were in apparently normal, healthy condition throughout the testing period. The experimental group was fed and cared for in the same manner as the rest of the herd. They were milked and fed grain and corn silage twice daily and when not on pasture they were allowed all of the alfalfa and meadow hay they would consume.

The results cover a period of five years and include the analyses of milk from 10 Holsteins with 21 lactations, 3 Ayrshires with 6 lactations, 9 Jerseys with 20 lactations, and 6 Guernseys with 13 lactations. In sev-

eral cases, more than one lactation of a cow was studied while in others only one lactation was included because of removal from the herd. The total number of individual samples analyzed was as follows: Holstein 308, Ayrshire 86, Jersey 307, and Guernsey 193.

During the first year of this work the samples were taken at 15-day intervals throughout the lactation but due to the large amount of laboratory work entailed by such a large number of samples it was found necessary to place the work on a monthly basis. In addition to the 15-day or monthly samples there were extra samples taken of colostrum and of the last milking at the end of the lactation period. The samples consisted of equal parts of night's and morning's milk and therefore represented one day's production. The samples were preserved by the addition of approximately one-half percent of formalin to the fresh milk and kept in the laboratory refrigerator until analyzed.

The butterfat and total solids were determined by the Mojonnier method. Results were recorded to the nearest hundredth percent. Samples for Mojonnier fat analysis were weighed instead of measured as directed in the Mojonnier method to insure greatest accuracy.

Ash was determined according to the methods recommended by the Association of Official Agricultural Chemists except that a 10 ml. sample with the addition of 1 ml. of nitric acid was used instead of a 20 ml. sample. The ash was then used for the determination of calcium and phosphorous. Calcium was determined by an adaptation of the method of Clark and Collip. Phosphorous determinations were made by the Fiske-Subbarow method. The results of the ash, calcium and phosphorous analyses were expressed as milligrams in 100 ml. milk.

The data obtained were then used to show the influence of breed, stage of lactation, and season on the composition of milk. The study included the effect of these factors on the fat percentage, total and serum solids percentage, ash content, total calcium content, and total phosphorus content.

Experimental Results

Influence of the Colostrum Period

One of the factors which may influence the composition of milk as delivered to the plant is the colostrum or the first milk produced by the cow after freshening. Although it is commonly recognized that colostrum milk is abnormal, the milk from fresh cows is included in the milk supply in some cases before it has reached normal composition. The work presented here shows how the composition of milk changes from the first day to the third day. It also provides a comparison of the composition of colostrum milk with that obtained on the fifteenth day after freshening when milk is regarded as normal in composition.

The data presented in Figure 1 cover 20 lactations from 11 Holstein cows. The first day's sample represented the first milk drawn after parturition while the third and fifteenth days' samples were composites of the night's and morning's milk on these days. Each point on the lower part of the graph represents a fat test. The wide distribution of these dots on the first day indicates that wide variations in fat content occurred in the first milk drawn. The range in fat test was from 1.3 percent to

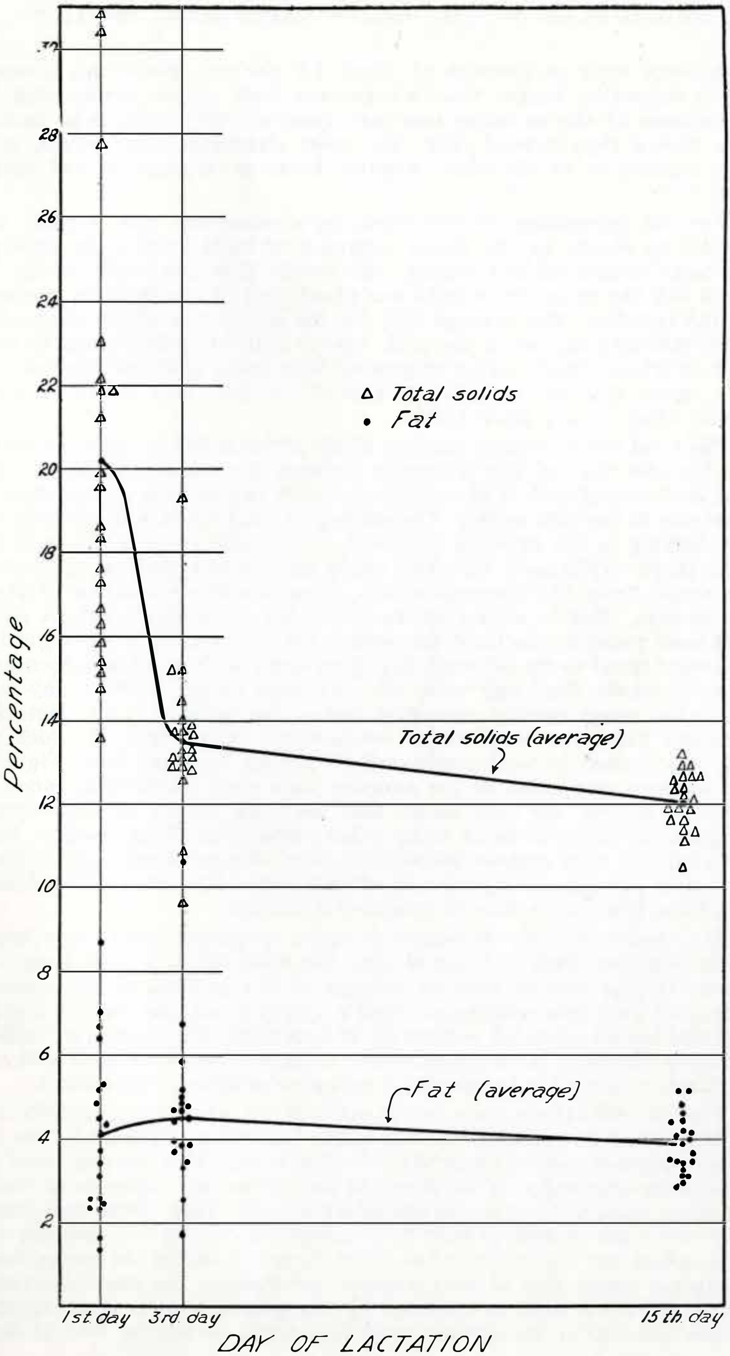

Fig. 1. The percentage of fat and total solids in Holstein milk during the colostrum period.

8.5 percent with an average of about 4.1 percent. Since this average test is somewhat higher than the general level of fat percentages for the balance of the lactation one may conclude that colostrum usually tests higher than normal milk. The most significant observation, however, appears to be the wide variation between the highest and lowest tests.

The fat percentage in the third day's colostrum was slightly less variable as shown by the closer grouping of tests around the average. The tests ranged slightly higher than on the first day while on the fifteenth day the variation in tests was about that of normal milk throughout the lactation. The average test for the group was about 3.9 percent on the fifteenth day when the milk was considered to be normal in composition. These results agree in general with those of other workers who have shown that the variation in test of the first milk drawn is much greater than at any later period.

The total solids of milk consists of all of the solids in milk and therefore includes the fat. The difference between the solids content of colostrum and normal milk is of importance as an explanation of the effect of colostrum in the milk supply. The change in total solids content from the first milking to the fifteenth day with 11 Holstein cows is shown in the upper curve of Figure 1. The total solids content of colostrum on the first day varied from 13.7 percent to 31.1 percent with an average of about 20.2 percent. This is almost double the value for normal milk. A sharp downward trend to the third day was noted followed by a more gradual downward trend to the fifteenth day. Extremely high and low percentages persisted on the third day while the variations on the fifteenth day were within the range usually occurring during the balance of the lactation. Although individual cows varied considerably in the time at which the milk was normal in total solids content, it may be noted from Figure 1 that a large proportion of the samples were near the normal range on the third day. It has been stated that the milk usually reaches normal composition within 48 to 72 hours after parturition. These results, however, indicate that certain individuals show abnormal tests up to three days after calving and a period of at least three days must elapse before milk from fresh cows may be considered normal.

The results of other investigators agree in general with those stated above. Van der Burg (1) found that the total solids varied from 13.6 percent to 38.2 percent with an average of 23.8 percent for the samples tested. Of this total solids the protein content was the largest component and varied from 6.6 percent to 26.6 percent. The protein of milk is therefore shown to be the main cause of high total-solids tests and also the factor responsible for the thick syrupy character of colostrum.

The changes taking place in the mineral, or ash, content of milk during the colostrum period are shown in the top curve in Figure 2. The ash content dropped rapidly from the first day to the third day and then declined more gradually to the fifteenth day when the values were within the range usually found in normal Holstein milk. There were wide variations in the ash content of milk from individual cows on the first day and on the third day while the values at 15 days fell within the range found during the major part of the lactation. Here again, the abnormal condition in colostrum milk in indicated by the great variability among individuals and also by the distinct downward trend during the first 15 days.

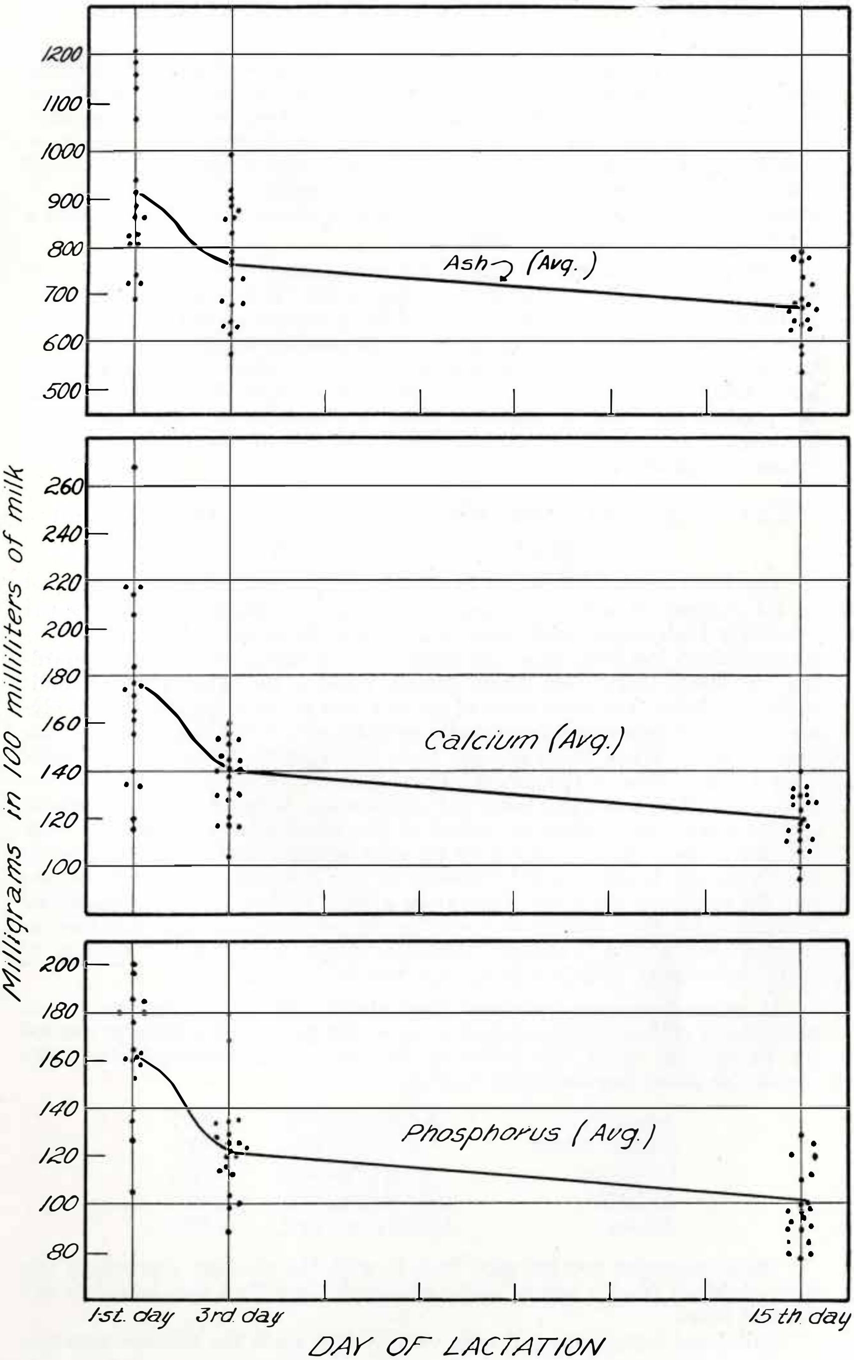

Fig. 2. The mineral content of Holstein milk during the colostrum period.

The calcium and phosphorous contents of milk during the colostrum period are shown in the middle and lower curves respectively of Figure 2. A comparison of the curves for calcium and phosphorous content with the curve for ash indicates that the trends are very similar. One may conclude that colostrum is richer in these important minerals than normal milk. As in the case of ash, the range of variation between tests is greater on the first day for both calcium and phosphorous than at either three days or 15 days after calving.

The general practice of excluding colostrum from the market milk supply during the first three or four days after freshening appears to be justified on the basis of the abnormal composition shown in this work. The first milk drawn varied widely in fat, solids, and mineral content. On the third day after freshening the values for these components were less variable but did not reach normal milk levels. It is evident that the product could not be regarded as normal until after the third day of lactation even though certain individual cows might reach a normal condition at this time.

The Influence of Breed, Stage of Lactation, and Season on the Composition of Milk

The Fat Content. There has been more experimentation on the subject of fat content of milk than any other milk constituent because of the relatively high commercial value of fat. In spite of the voluminous information which has been collected, there are a number of questions regarding variations in fat test which remain unanswered. The factor of individual variation has been covered up in many reports because the analyses have been reported on composite samples of several milkings, or from several cows. When abnormal fat tests occur either from herds or individual cows there is the possibility of natural variation as well as the possibility that some physiological disturbance is involved. The purpose of this work was to show the effect of the various factors affecting milk test which must be considered by all milk producers. The factors considered were the breed and individuality of the cow, the stage of lactation, and the season of the year. The ration or kind of feed was not considered because extensive research on the effect of feed on fat percentage has indicated that within practical limits the influence of kind of feed is of little importance in determining the test of milk.

In general it may be stated that the breeds producing the larger amounts of milk produce milk of a lower fat percentage. Data presented by Turner (2) show the following average fat percentages for cows tested for Herd Improvement records.

Ayrshire	13,296 cows avg.	4.05%
Brown Swiss	231 cows avg.	4.08%
Guernsey	1807 cows avg.	4.96%
Holstein	33,286 cows avg.	3.40%
Jersey	10,349 cows. avg.	5.28%

These averages are included here to give the average test which has been obtained from a much larger group of cows than was tested in the present work.

Individual tests, however, may vary widely from the average percent-

age for the breed. In the course of this work tests were made on 219 samples of Holstein milk, 214 samples of Jersey milk, and 133 samples of Guernsey milk. The Holstein tests ran from as low as 1.5 percent to as high as 5.5 percent, the Guernseys from 3.5 to 8 percent, and the Jerseys from 3.5 to 9 percent. To show in more detail how the fat tests varied, the milk samples from each breed were grouped according to the fat test of the sample. The number of tests falling in each group was converted to a percentage basis to aid in comparing the breeds on this point. The results obtained are shown in Figure 3. The solid line in this chart represents the results for Holsteins. The fat tests are shown along the bottom of the chart and the height of the line above the base line indicates the percentage of samples having that particular test. For example, the line for Holsteins reaches the figure 35 on the 3 percent fat line. This means that 35 percent of the Holstein milk samples, or 35 out of each 100, tested 3 percent fat. Likewise the line shows that only 13 percent, or 13 out of 100, tested 4 percent. The lines for Jerseys and Guernseys are interpreted in the same way. It is an interesting observation that a number of samples of Holstein milk tested higher than the lowest testing group of Jersey samples. Since 3.25 percent is the legal minimum fat test in this state, it is obvious that more than half of the Holstein samples were below the standard and therefore could not be sold as legal milk.

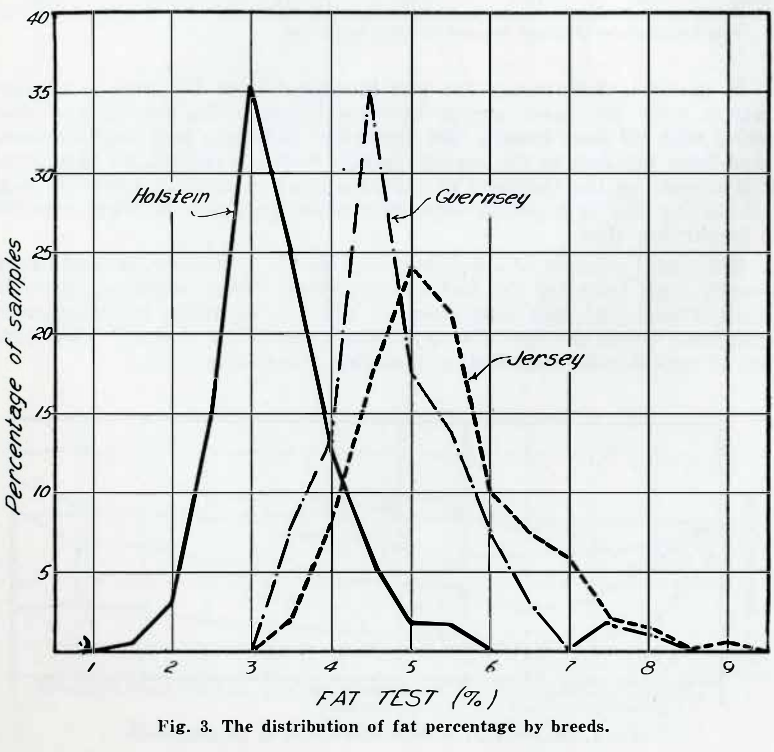

Fig. 3. The distribution of fat percentage by breeds.

A comparison of the fat percentage of milk of each of the four breeds is shown in Table 1, in which the average tests were computed by breeds for the three months, or quarter lactation periods. The colostrum milk was excluded from the first period average; the first month's production being represented by the test made on the fifteenth day after calving. Certain lactations did not extend throughout the last three-months period and the average test represents whatever number of monthly tests that were obtainable. The level of fat test is highest with the Jerseys and lowest with the Holsteins with a difference of approximately 2 percent in each period. The higher testing breeds increased their fat test more rapidly with advanced lactation than the Holstein breed and therefore the difference in test was greatest in the last period when the cows were nearly dry.

TABLE 1. The Influence of Breed and Stage of Lactation on Fat Percentage

Breed	Number of Cows	Number of Lactations	Period of Lactation: 1st quarter 15-90 days Avg. % fat	2nd quarter 105-180 days Avg. % fat	3rd quarter 195-270 days Avg.% fat	4th quarter 285-360 days Avg. % fat
Holstein	8	19	3.29	3.12	3.37	3.51
Ayrshire	3	5	4.00	4.12	4.51	4.83*
Guernsey	6	11	4.58	4.69	5.09	5.23
Jersey	9	19	4.99	5.15	5.60	5.68

* Only two samples obtained because of short lactations.

In general, the average fat test increased from the first to the last quarter with the most abrupt increase between the second and third period with all four breeds. The trend for Holsteins was slightly downward from the first to the second quarter which is typical for this breed. It is caused by the tendency of Holstein cows to show a relatively high test during the first month especially when they are in high condition at freshening time.

The small number of Ayrshires included in the study showed exceptionally high tests for the last two quarters. This condition, no doubt, resulted from the fact that three of the five Ayrshire lactations were completed within the first 270 days. The effect of "drying off" was therefore of considerable importance in raising the average test.

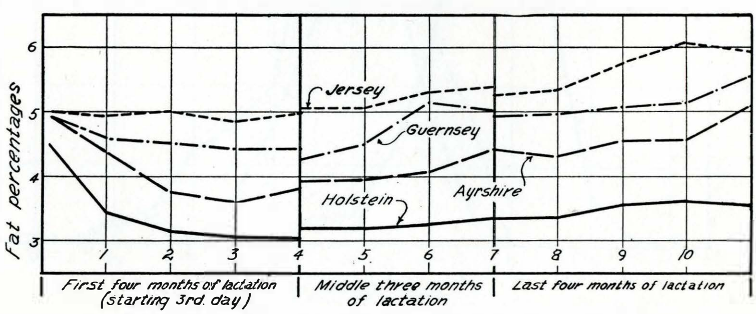

Fig. 4. The influence of stage of lactation on fat percentage.

The difference between breeds and the comparative influence of different stages of lactation on the fat test are indicated in more detail by the lactation curves shown in Figure 4. In order to compare lactations of different lengths, the monthly fat tests for the first four months, the middle three months, and the last four months of the lactation were used, thereby avoiding the difficulty of comparing lactations of uneven length.

The tendency for Holsteins and Ayrshires to produce milk of relatively high test at the beginning of the lactation and then reach a low point after three months is shown by the lower curves in Figure 4. The Jersey and Guernsey fat tests show much less of a downward trend in the first four months of lactation, but show about the same general upward trend as the other breeds near the end of the lactation. The effect of freshening is therefore of more importance in the Holstein and Ayrshire breeds as a factor influencing the test of milk produced by these same breeds.

The variability in fat percentage among individual tests for the same breed is indicated in Figure 5 in which the fat tests were plotted by months. The data include the following: 21 Holstein lactations from 10 cows, 20 Jersey lactations from 9 cows, and 13 lactations representing 6 Guernsey cows. The extreme variation between samples from different cows of the same breed is indicated when the high and low tests within any one month are compared. This spread on Jerseys reached a maximum of 5.5 percent in May. Such a wide difference however, was unusual as indicated by the fact that the greatest number of samples tested between 4.0 and 6.5 percent fat. These variations are similar to those noted by Anderson (3) in a study of the variations in butterfat content of milk. His study covered the variations in fat tests of individual cows under official test conditions as well as common herd conditions. From his results he suggested that the following range of variation might by expected. About two-thirds of the cows would show a difference of 1 percent or less, one-fifth to one-fourth would vary up to 2 percent and the remainder would vary more than 2 percent in test.

The broken lines in Figure 5 indicate the legal minimum for butterfat in South Dakota. The scarcity of dots below this line in the Jersey and Guernsey breeds shows how infrequently the tests for these breeds were below the legal limit. In contrast to these two breeds the Holstein tests fell below the 3.25 percent line in more than half of the cases. In fact the average test of all Holstein samples fell below the line during the five summer months.

The average fat percentage represented by the solid line shows the trend throughout the year with the tests averaged by months. A tendency for lower tests during the summer months was evident in all breeds with the highest point for the year recorded in December and January. This trend was much more noticeable with the Guernseys and Jerseys than with the Holsteins.

Further information on the influence of season on fat percentage is presented in Table 2 in which the cows were classified according to time of freshening. To keep the influence of stage of lactation at a minimum, only cows which freshened previous to May 1 and continued to milk two months after October 1 were included in the study of the summer season. For a study of the influence of winter season only those lactations which were started previous to December 1 and continued two months after

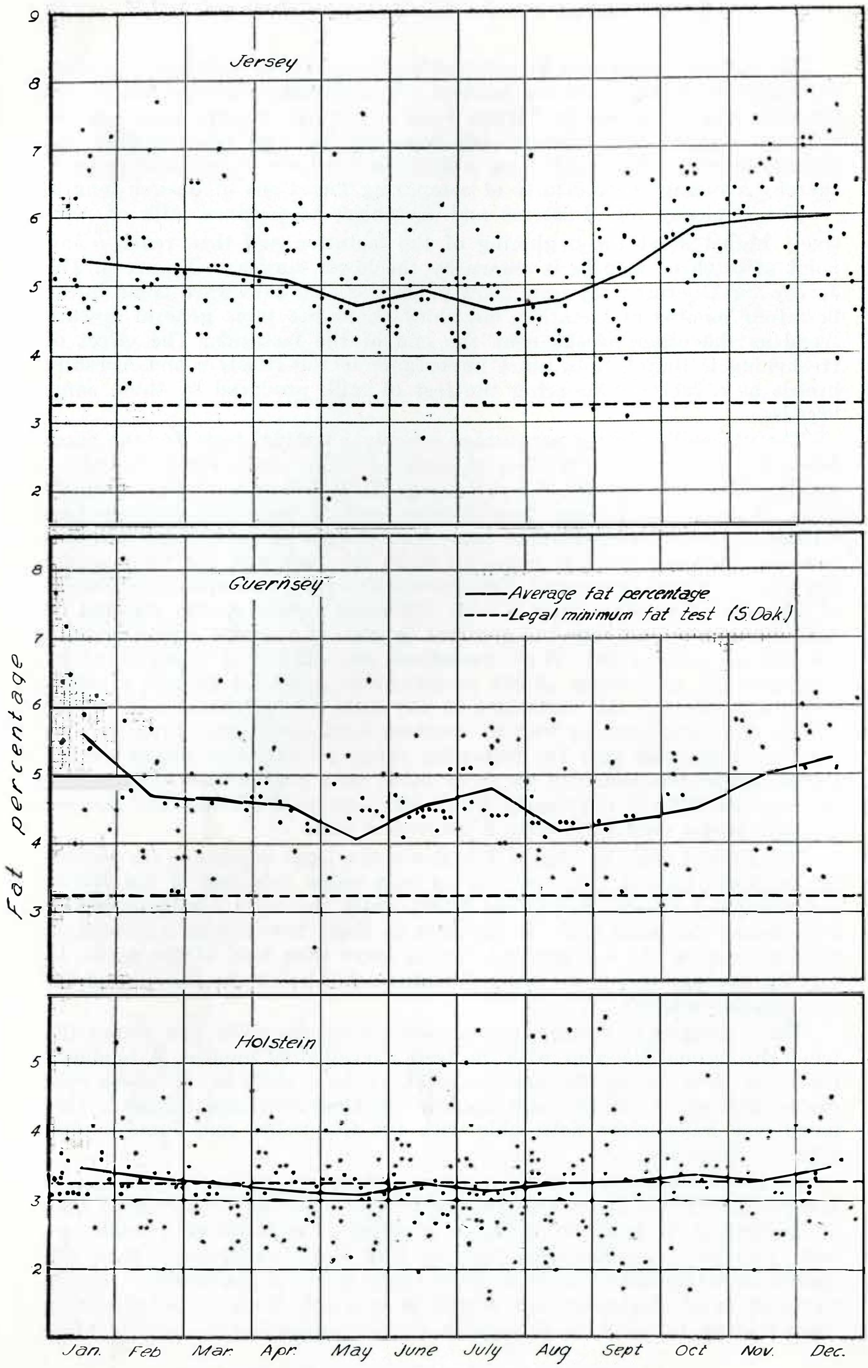

Fig. 5. The seansonal trend of fat tests by months.

April 1 were included. This classification necessarily limited the number of lactations which could be considered. The average values presented in Table 2 indicate a marked tendency for a decrease in fat percentage during the summer season with the lowest point usually reached in August. The small number of lactations included in this study detracts somewhat from the reliability of the results but the fact that the trend is so consistent appears to be significant.

TABLE 2. Influence of Season on Fat Percentage

	Summer[1]						
	Number of		Average fat percentage				
Class	Cows	Lactations	May	June	July	Aug.	Sept.
All cows	11	20	4.55	4.28	4.23	4.04	4.74
Holstein	2	3	3.27	2.85	3.01	2.71	3.05
Jersey	6	11	5.10	4.94	4.77	4.53	5.51
Guernsey	2	3	4.68	4.49	4.42	4.11	4.69
Ayrshire	1	3	3.69	3.31	3.25	3.63	3.69

	Winter[2]					
	Number of		Average fat percentage			
Class	Cows	Lactation	Dec.	Jan.	Feb.	Mar.
All cows	12	19	4.43	4.33	4.32	4.20
Holstein	4	9	3.38	3.33	3.22	3.43
Jersey	3	5	5.64	5.31	5.32	5.02
Guernsey	4	4	4.95	5.32	4.84	4.35
Ayrshire	1	1	4.53	4.96	5.06	5.18

1. Lactations which started previous to May 1 and continued at least two months after October 1 were used.
2. Lactations which started before December 1 and continued at least two months after April 1 were used.

There appeared to be no sound basis for comparison of summer and winter milk with the data at hand because the cows in the winter group were a different group from those included in the summer. The trend upward in the late summer, however, does result in higher tests during the winter as shown by the relatively high values for all breeds in September.

The low fat tests during the summer have been attributed to the high temperature and humidity of the summer season although other environmental factors such at flies and short pastures may be involved. Trials by Bartlett (4) in which cows held in artificially heated rooms at 80 degrees were compared with cows held at the prevailing air temperature of about 40 degrees F. showed a small reduction in fat test for the cows held in the heated room. Work at the Missouri station (5) also showed that temperature was a significant factor in changing the fat test in milk. The increase in fat percentage as the weather became colder was about 0.2 percent for each 10 degrees F. This study was made between the limits of 30 to 70 degrees F. Becker and Arnold (6) at the Florida Experiment Station found a decrease in fat content of 0.31 percent for each 10 degree rise in temperature between the limits of 57 and 81 degrees F. They concluded that under Florida conditions the influence of season was greater in lowering the test than the influence of prolonged lactation in raising the test.

The most important factor influencing fat percentage of a milk supply is the breed of cows in the herd. The season and stage of lactation

were of secondary importance as factors influencing fat test. The milk from Holstein cows ranged generally lower in tests than any of the other breeds studied and the fat percentage fell below the 3.25 percent level frequently. The downward trend during the summer months and during the early stages of the lactation period was noticed in all breeds but was more of a problem in the Holstein breed because of the lower general level of fat test in this breed. These results emphasize the importance of spacing the freshening dates in a herd uniformly throughout the year when a uniform level of fat percentage is desired. It also shows the need for selecting breeding stock of higher fat percentage inheritance in order to maintain a safe margin above the minimum requirements of a milk market. The great variability in test of different cows and of the same cow from day to day emphasizes the fact that the larger the number of individuals in the herd the greater the probability that the milk will be of uniform composition.

The Solids Content of Milk. Since fat is one of the principal solids making up the total solids content of milk, it is obvious that factors causing variation in fat content would also effect the total solids in milk. The level of total solids content in milk is therefore effected by breed to a great extent. Overman et al. (7) reported the following total solids content in milk of the four common dairy breeds.

Ayrshire	208 tests avg.	13.11%
Guernsey	321 tests avg.	14.87%
Holstein	268 tests avg.	12.50%
Jersey	199 tests avg.	14.69%

The average level fails to indicate the wide variability among individuals and the conditions under which low solids milk is produced. The data presented in the following tables and graphs are presented to show the individual variations and variations between groups of cows under different conditions.

The variation in total solids tests within each breed and a comparison of the three breeds is shown in Figure 6. The number of samples for each different test is shown on a percentage basis to allow for a comparison of the different breeds. The data cover one or more lactations from 11 Holstein cows with 219 samples, 9 Jersey cows with 214 samples, and 6 Guernsey cows with 133 samples.

The range of total solids tests was as follows: Holstein 9 to 14 percent, Guernsey, 12 to 18 percent, and Jersey, 11 to 18 percent. The curve on the left shows that the majority of the Holstein tests were at the 11 and 12 percent levels. In the Guernsey breed the extremes were wider but 85 percent of the samples tested between 13 and 15 percent total solids. Among the Jerseys there were tests as low as 11 percent and as high as 18 percent with the greatest number of samples testing between 14 and 15 percent total solids. It may be noted that the variation between tests was greatest with the higher testing breeds.

The state of South Dakota defines legal milk as a product containing not less than 3.25 percent fat and not less than 8.50 percent solids-not-fat. One might say roughly that a level of 11.75 percent represented the minimum for total solids. This, however, is not quite the case because a total solids test of above 11.75 percent may be due to a high fat content balanced by low solids-not-fat content.

The data in Figure 6 indicate that at certain times the milk of individual cows in each of the breeds may fall below the level of 11.75 percent in total solids. This difficulty is more likely to be encountered with milk from Holstein cows, if we may judge from these results in which more than half of the Holstein samples tested below 11.75 percent total solids.

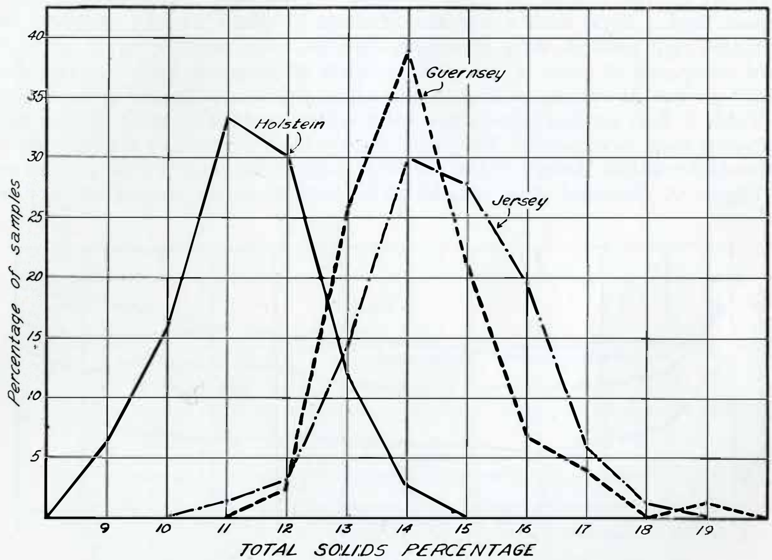

Fig. 6. The distribution of total solids percentage by breeds.

A comparison of the total solids content in the milk of four breeds is presented in Table 3 to show the variation between breeds and during the different stages of lactation. The total solids in milk of the four breeds ranked in the same order as the fat contents previously shown in Table 1. When the minimum test of 11.75 percent is considered as a base, it may be noted that the average test of the Holstein samples failed to reach the minimum standard. The average of the samples obtained from the other breeds all exceeded this standard.

TABLE 3. The Influence of Breed and Stage of Lactation on Total Solids Percentage

Breed	Number of Cows	Number of Lactations	Period of Lactation: 1st quarter 15-90 days Avg. % fat	2nd quarter 105-180 days Avg. % fat	3rd quarter 195-270 days Avg.% fat	4th quarter 285-360 days Avg. % fat
Holstein	8	19	11.26	11.02	11.40	11.73
Ayrshire	2	5	12.89	13.03	13.35	14.79*
Guernsey	6	11	13.73	14.15	14.20	15.15
Jersey	9	19	14.02	14.31	15.03	15.28

* Only two samples obtained because of short lactations.

In general, the total solids content increased as the lactation period advanced. The slight decrease in the total solids content for Holstein milk between the first and second quarter is an exception to this trend but this may be explained by the tendency for Holsteins to produce milk of a high fat test and consequently high total solids test during the first two months of the lactation. In most cases the average test in the fourth quarter represented fewer samples than the earlier periods because the majority of the lactations were of about 11 months duration. One may expect that a herd with a number of cows in their "fourth quarter" of lactation will produce milk of relatively high total solids content while a herd composed of cows in the early periods of lactation may be from 0.5 to 2.0 percent lower, according to the breed concerned. It has been shown in Table 3 that an increase in the total solids content of milk during the lactation may be expected. The trend within each period and a comparison between breeds is shown by the lactation curves for total solids presented in Figure 7. The data were assembled by periods in the manner described

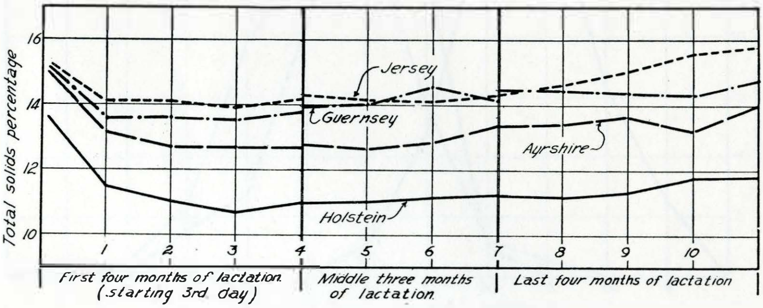

Fig. 7. The influence of stage of lactation on total solids percentage.

in connection with Figure 4 and represent the same cows. There was a decrease in total solids content during the first three months of lactation with all four breeds. A general trend upward was noted during the middle months and the last four months.

The test at the end of the lactation, however, failed to reach the high level recorded at the beginning of the lactation except in the case of the Guernsey breed. These results are in agreement with those of other investigators who have found the lowest percentage of total solids occurring in the third or fourth month of lactation and a steady rise in the following months.

The causes of the change in total solids during the lactation were studied by Bartlett (8) who followed the records of a herd of cows through 10 years of production. A total of 294 complete lactations were studied involving nearly 10,000 tests. The results of this work showed that the total solids content of milk was high immediately after calving but decreased rapidly and reached a fairly constant level about 40 days after calving. This level was maintained for most of the lactation period until the last three months of lactation when a continuous rise in solids content of milk occurred. A comparison of farrow cows with pregnant cows showed that the increase in solids at the end of the lactation was

due to pregnancy since the farrow cows failed to show an increase. It was also noted that the age of the cow affected the trend in solids content. The first lactations showed higher solids content throughout and showed a more pronounced rise at the end of the lactation than later lactations of the same cow.

The data in Figure 8 show the distribution of solids-not-fat tests for each breed as well as indicating the seasonal trend throughout the year. The solids-not-fat content of milk was determined by subtracting the fat test from the total solids test. Although variations up to 4 percent within any one month were found, the tendency was for percentages to fall within a range of about 2 percent. A trend downward in summer is evident for the Jerseys and Guernseys while the average values for Holsteins fluctuate within narrow limits and fail to show any definite trend. The high average values for Holsteins in August and September were caused by two abnormally high tests recorded in these months. The only explanation which can be offered is that the majority of these Holstein cows freshened in the late winter and early spring months and therefore they were finishing their lactations during the fall and winter months. This caused an upswing in August and September and reduced the number of tests in October, November and December when a number of cows were dry.

The broken lines in Figure 8 show the 8.50 percent level which is the legal minimum for solids-not-fat in South Dakota. Dots below this line therefore represent illegal milk. An examination of the graphs for the three breeds indicates that the Jerseys and Guernseys were generally above the minimum while the Holstein tests were generally below the line. The average level for solids-not-fat in Holstein milk was consistently below the 8.50 percent and fluctuated near the 8.0 percent line. Although these results appear to be abnormally low they are not far out of line with similar data collected on Holstein herds by other workers.

It may also be noted that more of the samples of Jersey and Guernsey milk were below the "minimum" line in solids-not-fat than were below the "minimum" line on fat content. From these results one might conclude that the fat standard of 3.25 percent is not as difficult to meet as the solids-not-fat standard of 8.50 percent.

The effect of season on the total solids content of milk is shown more clearly in Table 4 by data on selected groups of cows. To avoid the effects of stage of lactation as much as possible the cows were selected as described in the table footnotes. The tendency for the total solids to drop off during the hot months was indicated by the low values obtained during July and August. Three of the four breeds reached the lowest average level in August. A sharp increase in percentage of solids in the September milk was noted in all breeds and a comparison of this test with the data for the winter months, indicated a tendency for higher tests as the season progressed.

The seasonal variation in solids content of milk has been associated with the changing temperature between the seasons. White and Judkins (9) found that regardless of the time of calving the percentage of fat as well as solids-not-fat tended to be lower during the hot months and higher during the cold months of the year. The influence of season in lowering the test appeared to interfere with the tendency for advanced

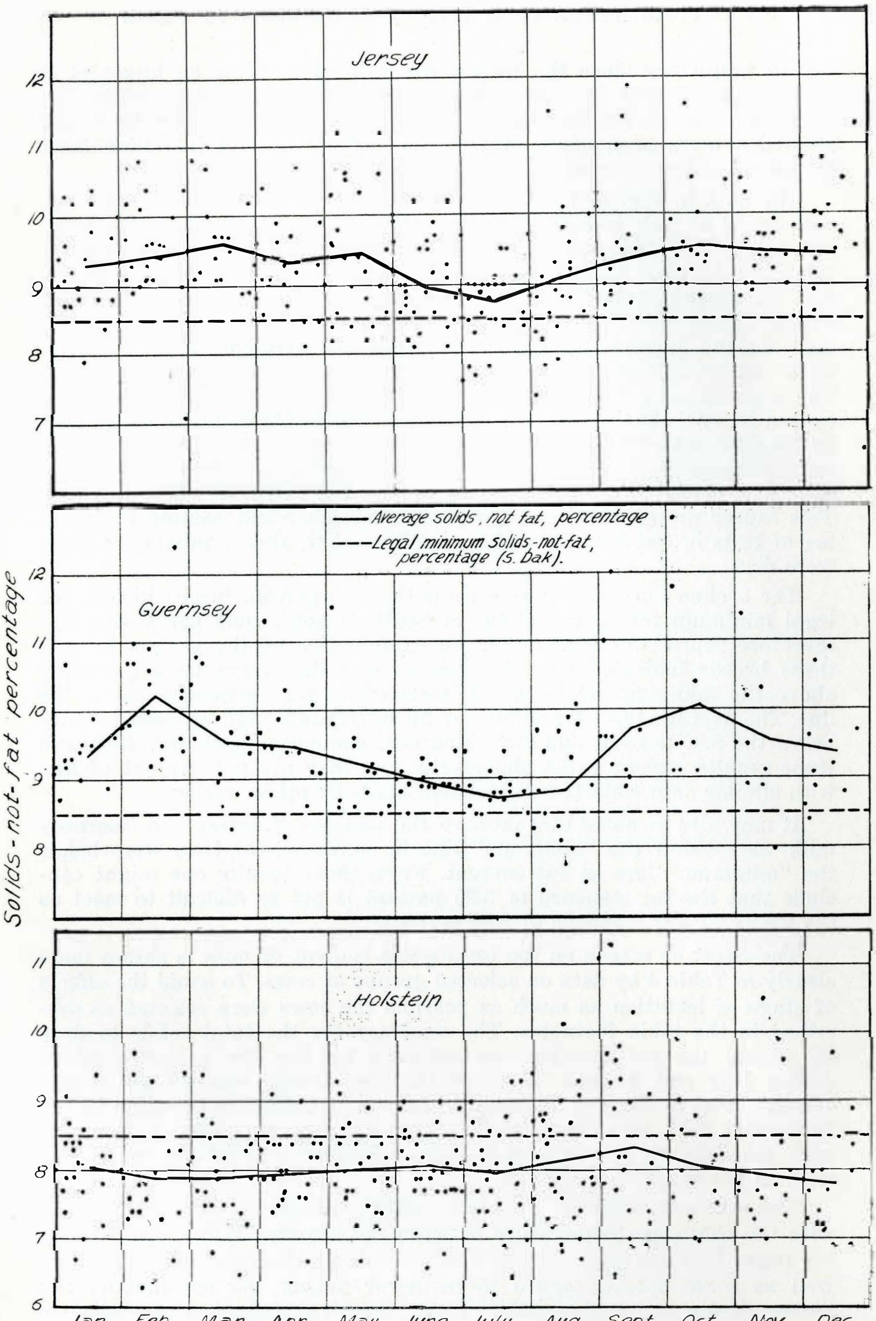

Fig. 8. The seasonal trend of solids-not-fat percentage by months.

TABLE 4. The Influence of Season on the Total Solids Percentage of Milk

Class	Number of Cows	Number of Lactations	Summer[1] Average fat percentage May	June	July	Aug.	Sept.
All cows	11	20	13.23	12.88	12.75	12.69	13.83
Holstein	2	3	10.89	10.53	10.51	10.02	10.91
Ayrshire	1	3	12.34	12.06	11.74	11.97	12.56
Guernsey	2	3	13.71	13.23	13.02	12.89	14.19
Jersey	6	11	14.20	13.73	13.75	13.65	14.87

Class	Number of Cows	Number of Lactation	Winter[2] Average fat percentage Dec.	Jan.	Feb.	Mar.
All cows	12	19	13.07	13.44	13.28	13.32
Holstein	4	9	11.36	11.48	11.17	11.68
Ayrshire	1	1	13.60	14.32	14.94	14.59
Guernsey	4	4	14.27	15.54	15.14	14.75
Jersey	3	5	15.08	15.08	15.27	14.87

1. Lactations which started previous to May 1 and continued at least two months after October 1 were used.
2. Lactations which started before December 1 and continued at least two months after April 1 were used.

lactation to raise the test as indicated by the fact that even the cows in advanced stages of lactation showed a tendency to drop in test during the hot months. They summarized their findings by the statement:

"Briefly, the general direction of the curves for winter calving cows is up, down and up; for summer calving cows, down and up; and for fall calving cows gradually, though slightly, up and down."

The tendency for lower solids content of milk during the summer was investigated by Bartlett (4). When cows were kept at 80 degrees F. the milk yield dropped and the solids-not-fat decreased by 0.15 percent below the level which occurred at the prevailing outdoor temperatures of about 40 degrees F.

This study would indicate that the milk producer is more likely to experience difficulty with low solids milk when his herd is made up of Holstein cows because of their comparatively low level of solids test. The arbitrary minimum of 8.50 percent solids-not-fat was too high for most of the cows of the Holstein breed and occasioinally samples from the Jerseys and Guernseys tested below this level. The stage of lactation and season had much the same effect on solids tests as was shown in relation to the fat tests. The lowest tests were recorded after the third or fourth month of the lactation in all breeds. When this decline came during the summer months it resulted in extremely low solids tests during this period due to the combined effect of lactation and season in lowering the solids percentage. The importance of distributing the calving dates throughout the year and also selecting cows of higher test is emphasized if one is to avoid difficulty with low solids milk.

The Mineral Content. Nutrition experts generally agree that every adult should have a pint of milk, and every child a quart of milk daily along with an otherwise good diet in order to make sure that a sufficient amount of the mineral elements is being supplied for bone and teeth building and certain other body needs. Since it is such an important item, one is naturally interested in knowing whether one quart of milk

is as good as another as far as the mineral content is concerned. Some figures have been presented in Table 5 which give an idea of the relative amount of mineral, or ash, in milk from the different breeds of dairy cattle. The results are expressed in milligrams per 100 milliliters of milk. [A quart contains about 1000 milliliters (ml). Also 1000 milligrams of ash per quart would make roughly 0.1 percent of ash.] The lactation period was broken up into quarter periods of three months each. All of the ash determinations made on milk samples obtained during the first three months of lactation for any one breed were averaged to represent the ash content of milk for the first quarter. The figure for the second quarter was obtained by averaging the ash determinations made during the second quarter, or the fourth, fifth, and sixth months, of the lactation. The figures representing the third and fourth quarters of the lactation period were obtained in a similar manner. Figures were obtained in this manner for each breed.

TABLE 5. The Influence of Breed and Stage of Lactation on the Ash Content of Milk

Breed	Number of Cows	Number of Lactations	Mgm. of Ash in 100 ml. milk: 1st quarter of lactation 15-90 days	2nd quarter of lactation 105-180 days	3rd quarter of lactation 195-270 days	4th quarter of lactation 285-360 days
Holstein	8	19	662	678	702	718
Ayrshire	2	5	667	697	721	752
Guernsey	5	8	744	747	757	744
Jersey	9	19	747	758	783	790

By referring to Table 5 it may be seen that the ash content of Holstein and Ayrshire milk was nearly the same, being 662 and 667 milligrams per 100 millimeters of milk for the first quarter of the lactation. Guernsey and Jersey milk also compared closely as to ash content but the figures of 744 and 747, respectively, are distinctly higher than for the other two breeds. There was a tendency for the ash content of the milk to increase for each of the breeds as the lactation period progressed except for a slight decline in the fourth quarter for the Guernseys. Taking all the figures into consideration the Jersey milk was highest, with the Guernsey, Ayrshire, and Holstein following in succession for lower ash content. These results agree in general with the figures reported by Overman and coworkers (7) as obtained from the Illinois Station herd. Their results covering the entire lactations for the cows tested were given as follows:

Ayrshire	208 samples	average ash	0.683%
Guernsey	321 samples	average ash	0.742%
Holstein	268 samples	average ash	0.681%
Jersey	199 samples	average ash	0.702%

The effect of the stage of lactation on the mineral, or ash, content of milk is indicated in more detail in Figure 9. The lacation curves were built up by using only those cows for which comparable figures were available. The ash content of the milk samples for the different parts of the lactation period were then averaged by months as indicated in Figure 9. Cows of the four breeds are represented in the results for "all cows," which also includes the Jersey and Holstein data shown separately in the

curves below. A sharp decrease occurred in the ash content of milk from the third to the fifteenth day, followed by a more or less constant level for the greater part of the lactation and then a steady rise during the last three months. Although the line representing the ash content of Jersey milk is above that for the Holstein indicating a higher ash content for the Jerseys, the lactation trends are essentially the same for both breeds.

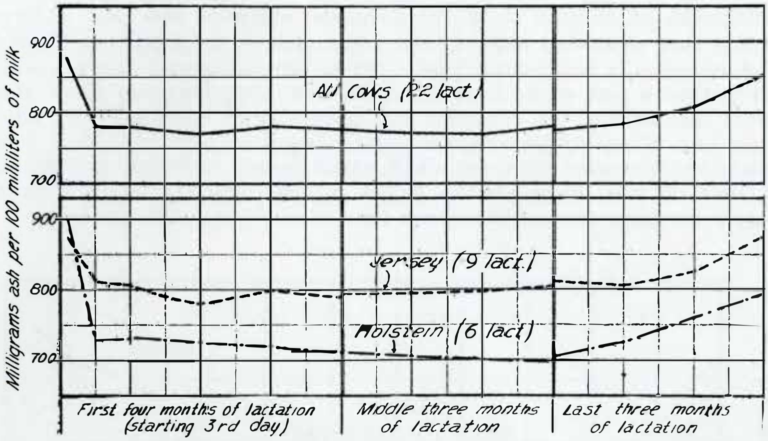

Fig. 9. The influence of stage of lactation on the ash content of milk.

Calcium and phosphorus make up a considerable portion of the mineral content of milk and have special significance because they are the mineral elements largely concerned in the building of strong bones and good teeth. American diets are frequently low in calcium content unless liberal amounts of milk, one of the best sources of this element, are included. Variations in the calcium content of milk, therefore, are of interest

TABLE 6. The Influence of the Breed and Stage of Lactation on the Calcium Content of Milk

Breed	Number of Cows	Number of Lactations	Mgm. Calcium in 100 ml. milk: 1st quarter of lactation 15-90 days	2nd quarter of lactation 105-180 days	3rd quarter of lactation 195-270 days	4th quarter of lactation 285-360 days
Holstein	8	19	114.62	106.68	112.75	122.58
Ayrshire	3	5	124.96	130.27	130.18	145.46
Guernsey	6	11	138.57	144.37	142.27	158.61
Jersey	9	19	141.16	137.30	146.20	160.32

to everyone. The results in Table 6 show the comparative calcium content of milk from the four breeds over a period of a year. The figures were obtained for each quarter of the lactation period as previously explained in connection with Table 5. The four breeds ranked in the order of Jersey,

Guernsey, Ayrshire, Holstein, going from the highest to the lowest in calcium content. The order is the same as that previously noted for ash content. The difference between Jersey with the highest value and the Holstein with the lowest is of considerable magnitude and amounts to about 25 percent based on the lower value. The indicated trend toward higher values in all breeds as the lactation progresses agrees with the results of other investigators.

It is commonly stated that adult human beings require about 700 milligrams of calcium daily for adequate nutrition and that children should have somewhat more. If one assumes from the figures in Table 6 that mixed milk will contain about 125 to 150 milligrams per 100 milliliters, then a pint would have about 600-750 milligrams and would thus about take care of the minimum safe allowance of calcium for an adult for a day. Since children require more mineral a quart of milk is commonly recommended for them which would supply 1200-1500 milligrams. If Holstein milk were used it would require somewhat more milk to supply the same amount of calcium than when Jersey milk was used.

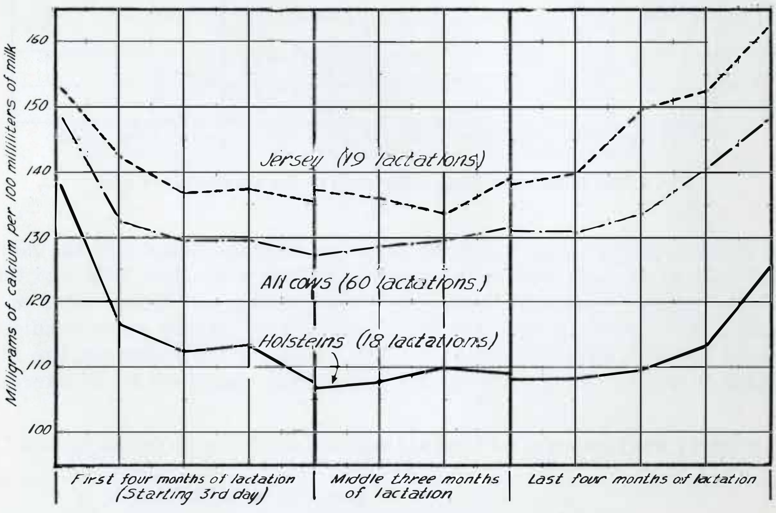

Fig. 10. The influence of stage of lactation on the calcium content of milk.

The influence of the stage of lactation on the calcium content of milk is shown in some detail by the graphs in Figure 10 where lactations have been reduced to a comparable basis by averaging the figures for the different months of the lactation. The decrease in calcium content of the milk of Holsteins and Jerseys, as well as for "all cows" was very evident during the first two months and continued more gradually to the end of the fourth month. During the three or four months in the middle of the lactation the calcium content remained fairly constant after which there was a decided increase for the last three or four months of the lactaton.

During the middle of the lactation the line for the Jersey milk shows slightly more than 135 milligrams of calcium per 100 milliliters while that for Holsteins runs somewhat below 110. The mixed milk of all cows, which includes all four breeds, shows about 130 milligrams for much of the lactation period, being higher at the beginning and end.

TABLE 7. Influence of Breed and Stage of Lactation on the Phosphorous Content of Milk

Breed	Number of Cows	Number of Lactations	Mgm. Phosphorous in 100 ml. milk: 1st quarter of lactation 15-90 days	2nd quarter of lactation 105-180 days	3rd quarter of lactation 195-270 days	4th quarter of lactation 285-360 days
Holstein	8	19	92.41	87.49	82.72	85.11
Ayrshire	3	5	109.77	101.72	103.43	104.58
Guernsey	6	11	112.90	109.61	104.80	101.94
Jersey	9	19	118.40	112.93	107.23	109.55

The phosphorous content of milk from the four breeds is shown in Table 7 which was constructed in the same manner as previously explained for ash and calcium. A considerable difference in the phosphorous content of the milk from the different breeds is shown with the same ranking indicated as for ash and calcium. Again, there is about a 25 percent difference between the Jerseys with the highest phosphorous content and the Holsteins with the lowest. The Guernseys and Ayrshires rank in between. There was a gradual decline in phosphorous content during the first half of the lactation for all four breeds, then a gradual levelling off followed by a barely perceptible increase for all except the Guernseys.

The influence of the stage of lactation on the phosphorous content of milk can be seen clearly from the lactation curves shown in Figure 11. These lines are similar to those for calcium during the first four months of the lactation. The lines gradually level off in the middle of the lactation but show scarcely any rise toward the end of the lactation. This

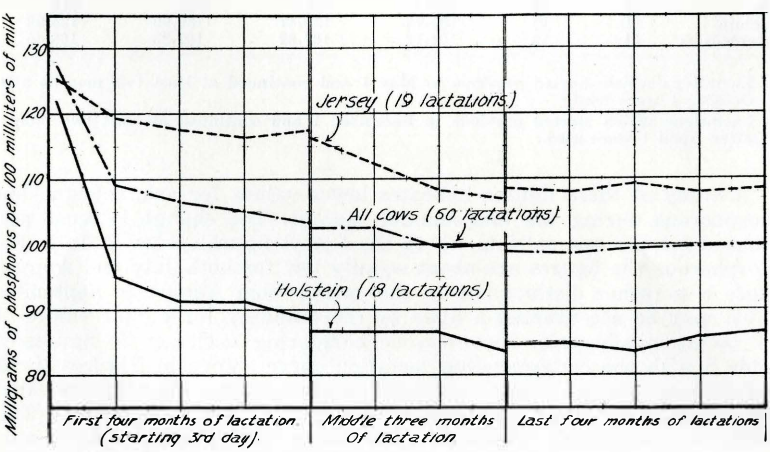

Fig. 11. The influence of stage of lactation on the phosphorous content of milk.

trend is noticeably different from that for calcium where the content increased markedly toward the end of the lactation. The phosphorous content of milk is less than the calcium as the line for Jerseys indicates about 110 milligrams per 100 milliliters during the middle and later part of the lactation, whereas, the comparable figure for calcium was about 135. The same relationship holds for Holsteins, and for milk of "all cows" where representatives of the four breeds are averaged. The Holsteins had about 85 milligrams per 100 milliliters during the main part of the lactation and the average for "all cows" ran at about 100 milligrams.

An attempt was made to show the influence of the season on ash, calcium, and phosphorous content of milk. For the effect of the summer season the monthly averages were calculated for samples of milk from only those cows that were in mid-lactation from May through September. During this portion of the lactation the ash, calcium, and phosphorous contents remain fairly constant as far as the effect of the stage of lactation is concerned so any decided change might be attributed to a possible seasonal effect. Likewise, cows in mid-lactation from December to March were selected to study possible effects of the winter season. Selecting the animals on this basis limited the number that could be used and, of course, the same animals could not appear in both seasons. The figures thus obtained are recorded in Table 8.

TABLE 8. The Influence of Season on the Mineral Content of Milk

	Number of		Summer[1] Mgm. in 100 ml. milk				
	Cows	Lactations	May	June	July	Aug.	Sept.
Ash	11	20	706	712	699	726	754
Calcium	11	20	130.58	125.61	121.28	127.56	138.00
Phosphorous	11	20	109.97	107.80	97.76	97.24	101.06

	Number of		Winter[2] Mgm. in 100 ml. milk			
	Cows	Lactations	Dec.	Jan.	Feb.	March
Ash	11	19	703	710	720	718
Calcium	11	19	131.73	129.47	133.90	124.98
Phosphorous	11	19	101.12	107.82	107.85	108.40

1. Lactations which started previous to May 1 and continued at least two months after October 1 were used.
2. Lactations which started previous to December 1 and continued at least two months after April 1 were used.

A study of these figures indicates lower values for ash, calcium, and phosphorous during the mid-summer months. The change is most pronounced for ash and calcium where the lowest figure occurs in July. For phosphorous the figures are about equally low for both July and August. There is a rather distinct rise in the values from August to September which may be accentuated a little by the tendency for higher values as the lactation advances. However, by comparing each set of figures in Table 8 with the corresponding lactation curve shown in Figures 9, 10, and 11, respectively, it may be seen that the seasonal changes are much more pronounced than could be accounted for by the lactation effect. This observation indicates a tendency for the warm humid weather of the summer season to lower the ash, calcium, and phosphorous content of the milk.

The changes for the winter months are not as distinct although there is a tendency for the values to increase slightly, reaching a high point in February for ash and calcium, and in March for phosphorous. Since the same cows are not represented in the two different groups direct comparisons between summer and winter values can not be made.

A general view of the information obtained about the mineral content of milk indicates that there is a distinct breed difference not only with respect to the total ash content, but also with respect to the calcium and phosphorous content which constitute two important portions of the total ash. In all cases, the Jerseys are highest followed in order by the Guernseys, Ayrshires, and Holsteins. There is about 10-12 percent difference in the ash content between the breeds which rank highest and lowest, and about 25 percent difference for both the calcium and the phosphorous. The stage of lactation also has an influence on the amount of these constituents in milk. The values for all three tend to be high at the beginning of the lactation and show a rather rapid decline during the first month followed by more gradual declines for three or four more months. The values remain fairly level in each case during the middle of the lactation. Toward the end of the lactation the calcium content shows a pronounced increase, the ash content increases somewhat less than the calcium, while the phosphorous increases little, if any. The summer season seems to influence the mineral content of milk definitely downward while the winter season exerts a less easily demonstrated upward influence.

Summary and Conclusions

One-day composite samples of milk from individual cows in the college herd were obtained at monthly intervals over a period of five years. These samples were analyzed for their fat, total solids, ash, calcium, and phosphorous contents.

Colostrum milk was also studied by taking samples of the first milking and from the third day's production of one or more lactations from 11 Holstein cows. The fat content of colostrum milk proved to be highly variable with a slight tendency to average higher than normal. The total solids and mineral content of colostrum milk were also highly variable and were generally higher than normal.

Tests were made of the fat content of 219 samples of milk from Holsteins, 214 samples from Jerseys, and 133 samples from Guernseys. The Holstein milk ranged from 1.5 to 5.5 percent with the greatest number around 3 percent. The Guernseys ranged from 3.5 to 8.0 percent with the greatest number of samples testing 4.5 percent. The range in fat test for the Jerseys was 3.5 to 9.0 percent with the greatest number around 5.0 to 5.5 percent. The fat tests decreased to the end of the third month of the lactation and then increased as the lactation period advanced. The Jersey and Guernsey tests reached their highest level at the end of the lactation while the Holstein samples averaged significantly higher at the beginning of the lactation than at the end. The effect of season upon fat percentage was studied by selecting groups of cows which milked through the entire period in question. A definite lowering of fat percentage was noted during the summer months in all breeds with the lowest test

usually coming in August. The highest average tests during the winter months were noted in December and January. Milk containing less than 3.25 percent fat, which is the minimum legal standard in South Dakota, occurred frequently among the Holsteins with the greatest number of illegal samples observed during the summer months.

Total solids tests made on the same samples as used for fat tests showed similar relationships between breeds. The largest number of Holsteins tested at the 10 and 11 percent level, the Guernsey samples in the region of 14 percent and the Jersey samples about equally distributed between 14 and 15 percent total solids.

The trend during the lactation was quite similar for the total solids and fat and the seasonal trend showed the same low point for total solids in August as was shown for fat. There appeared to be an even greater tendency for solids-not-fat to be below the legal minimum requirements than for fat among the Holstein samples tested. In fact, the average solids-not-fat percentage was below the legal minimum throughout the year.

The mineral content of the milk of the four breeds studied was lowest for Holsteins and highest for Jerseys with the Ayrshires and Guernseys falling in between. In general the ash, calcium and phosphorous decreased during the first month of the lactation, remained fairly constant until the last three months of the lactation and then increased steadily until the end of the milking period. The increase at the end of the lactation was not nearly as pronounced for phosphorous as it was for the calcium content. The mineral content appeared to be lower during the summer months with the lowest values generally appearing in July. There also appeared to be a tendency for the midwinter samples to show slightly higher mineral content.

It is evident from the data presented on fat, solids and mineral content of milk that wide differences may exist in the food value of the milk of different breeds as well as individuals and of the same individuals on different days.

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