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Factors Affecting the Composition of Milk

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The milk of all cows contains the same constituents: namely, milk sugar, protein, fat, minerals, and vitamins, but the proportions of these nutrients vary to a considerable extent (Table 1). Variation in the proportion of these individual constituents among the breeds of cattle is far less than between the several mammals, but greater than between individuals of a single breed. The composition of the milk of an individual cow changes to some extent during the lactation period and from one lactation to another.

Dairy scientists have long studied the composition of milk and the factors causing alterations in the amount of the various constituents. As milk fat is commercially the most valuable single constituent of milk the greatest attention has been given to the causes of variation in the fat content of milk.

These studies indicate that there are two fundamental causes of variation, genetic or inherited, and environmental. It is not easy to separate these two factors. Thus the variation between the Holstein cow testing 3.4 per cent fat and the Jersey cow testing 5.3 per cent fat is largely genetic. Yet the tests of these same cows kept under other conditions of environment might change considerably. As the inheritance is fixed at the time of conception, the only possibility of changing the genetic factors concerned in the composition of milk rests upon the selection of breeding animals having the desired characters.

On the other hand, during the dry period and throughout the period of lactation there are a host of factors that may be grouped under environment that tend to alter the composition of milk to a greater or less extent. Some of these factors increase the percentage of fat while others lower it. Some factors which may be classed under management and nutrition may be said to be under the control of the feeder and milker while others are the result of changes in the internal condition of the animal and may be classed as physiological factors.

The object of this bulletin is to describe the effect of these various factors on the composition of milk and explain if possible why the composition of milk changes as it does with changing environmental conditions.

COMPOSITION OF THE MILK OF VARIOUS MAMMALS

The composition of the milk of various mammals is of interest for two reasons. The milks of a number of animals, in addition to the cow, are used for food. It is of interest, therefore, to be able to compare their compositions. In using cow's, goat's or mare's milk in infant feeding the relation between these milks and human milk is important. In raising other domestic animals, it frequently happens that cow's milk is substituted for the mother's milk. Here the problem is to alter the composition of cow's milk in such a way as to approach more closely the milk of the other animal.

TABLE 1.—AVERAGE COMPOSITION OF THE MILK OF VARIOUS MAMMALS

Species	Fat %	Protein %	Lactose %	Ash %	Total Solids %	Authority
Cow	4.00	3.50	4.90	0.70	13.10	Computed
Goat	4.09	3.71	4.20	0.78	12.86	Frahm
Woman	3.70	1.63	6.98	0.21	12.57	Gardner & Fox
Mare	1.59	2.69	6.14	0.51	10.96	Linton
Ass	1.50	2.10	6.40	0.30	10.30	Fleischmann
Sow	6.77	6.22	4.02	0.97	17.98	Hughes and Hart
Ewe	6.18	5.15	4.17	0.93	16.43	Konig
Water buffalo	12.46	6.03	3.74	0.89	23.91	Levine
Camel	5.40	3.00	3.30	0.70	12.39	Barthe
Reindeer	18.70	11.10	2.70	1.20	33.70	Yeppo
Whale	22.24	11.95	1.79	1.66	38.14	Takata

BREED VARIATION

The most extensive data on the yield and percentage fat content of the milk of representatives of the various breeds of cattle are obtained from the official tests of the various breed organizations. Where available the milk yield and fat percentage for both yearly records and herd improvement records are presented in Table 2. While there are some slight differences in the two tests, they are not as marked as might be expected from the differences in the conditions under which the cows are kept and the duration of

TABLE 2.—BREED VARIATION IN THE YIELD AND COMPOSITION OF MILK

Breed	Summaries of records to Jan. 1, 1936, or latest available							
	Official Yearly Records				Herd Improvement Records			
	Number Cows	Milk (lbs.)	Fat (%)	Fat Corrected Milk (lbs.)	Number Cows	Milk (lbs.)	Fat (%)	Fat Corrected Milk (lbs.)
Ayrshire	6,999	10,427.0	3.97	10,385.75	13,296	8,133	4.05	8,188.2
Brown Swiss	721	13,697.8	4.00	13,697.80	231	8,618	4.08	8,721.4
Dutch Belted	99	10,570.0	3.94	10,474.90				
Guernsey	32,562	10,346.6	4.95	11,821.04	1,807	8,431	4.96	9,645.1
Holstein	37,598	16,787.7	3.41	15,302.00	33,286	11,081	3.40	10,083.7
Jersey	29,495	9,072.0	5.37	10,936.20	10,349	6,555	5.28	7,813.5
Red Poll	1,125	8,841.1	4.32	9,265.50				
Shorthorn	6,155	8,419.8	3.94	8,344.02				

the records. In general, the breeds producing the larger amounts of milk secrete milk of lower fat content. This relation also holds true of cows of the same breed.

To compare the milk production of cows varying in fat test, it is necessary to correct the yield to a uniform fat content. Dr. W. L. Gaines has formulated a simple method for equalizing records as follows:

Fat Corrected Milk (4% milk)=0.4 milk+15 fat

Thus, if a cow produced 15,000 pounds of 3.5 per cent milk containing 525 pounds of fat, its 4 per cent equivalent would be obtained as follows:

(15,000×.4=6000)+(525×15=7875)

Fat corrected milk (F. C. M.)=6000+7875=13,875 lbs.

Complete analyses of the milk produced by each breed are far less extensive and due to individual variations may not be typical for the breed. The data published by the Illinois Station on the composition of milk produced by the several breeds of cattle has been corrected to the breed average for the fat percentage observed with cows on official test (Table 3).

TABLE 3.—THE COMPOSITION OF THE MILK OF THE BREEDS OF DAIRY CATTLE

(From Ill. Bul. 325 by Overman et al.)*

Breed	Fat %	Protein %	Lactose %	Ash %	Total Solids %
Ayrshire	4.00	3.53	4.67	0.68	12.90
Brown Swiss	4.01	3.61	5.04	0.73	13.41
Guernsey	4.95	3.91	4.93	0.74	14.61
Holstein	3.40	3.32	4.87	0.68	12.26
Jersey	5.37	3.92	4.93	0.71	14.91

*The writer is indebted to Dr. O. R. Overman for permission to use unpublished data on the composition of milk produced by Brown Swiss cattle (Table 3).

INDIVIDUAL VARIATION

Individuals of each breed may vary widely from the above average composition of milk. Studies show that the fat is the most variable constituent of milk followed closely by protein. Milk sugar (lactose) and ash vary only about half as much as fat and protein. Because fat, and to a less extent, protein are the most valuable constituents of milk, the study of the causes of their variability is of greater economic importance.

The individual variation in the percentage of fat of the four principal breeds of dairy cattle is shown in Figure 1. Only official yearly records were included.

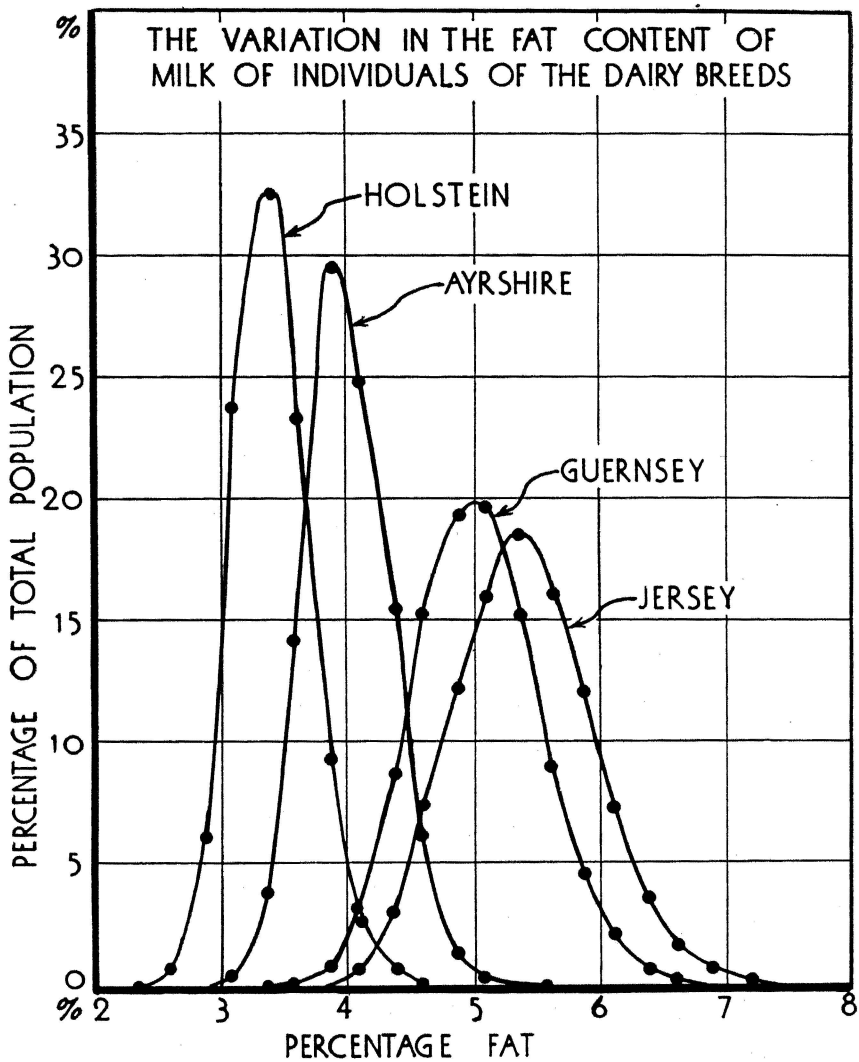

Fig. 1.—The variation in the average fat content of the milk of individuals of the dairy breeds. Only Advanced Registry records over 306 days in length were used. Included were 2665 Ayrshire records averaging 4.03 per cent, 36,861 Guernsey records averaging 5.05 per cent, 26,773 Holstein record averaging 3.41 per cent and 31,297 Jersey records averaging 5.41 per cent. The higher the curve the less is the variation from the average. The fat content of the milk will not alone characterize the breed as some cows of the four breeds have the same average yearly fat test.

If the average composition of the milk secreted during an entire lactation period by an individual cow was determined entirely by inheritance, it might be expected that the composition would remain practically unaltered from lactation to lactation, except as influenced by age. However, environment influences not

only the yield of milk but the composition as well. Using the first lactation as a standard, the variation in the percentage fat content of milk in succeeding lactations has been studied by the writer. Only yearly records were compared. The results of the study are presented in Table 4. The study shows that the breeds with the lowest fat content, vary the least from the first lactation test. It will be noted that from 33.5 to 42.65 per cent of the fat tests vary less than ±0.25, while from 77 to over 90 per cent vary less than ±0.5 per cent.

TABLE 4.—VARIATION IN AVERAGE FAT TEST OF FIRST RECORD WITH RE-ENTRY RECORDS

Fat Percentage Deviation	Ayrshire		Guernsey		Holstein		Jersey	
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency
		%		%		%		%
−1.25							6	0.11
−1.00	1	0.24	25	0.43	2	0.06	28	0.50
−0.75	3	0.71	115	1.97	16	0.47	146	12.59
−0.50	26	6.16	562	9.61	144	4.19	718	12.72
−0.25	108	25.59	1519	25.97	711	20.72	1385	24.53
0.00	180	42.65	2035	34.80	1634	47.63	1891	33.50
+0.25	94	22.27	1237	21.15	764	22.27	1101	19.50
+0.50	9	2.13	249	4.26	142	4.13	283	5.01
+0.75	1	0.24	89	1.52	12	0.35	68	1.20
+1.00			15	0.26	1	0.03	13	0.23
+1.25			1	0.02	----	----	5	0.09
+1.50					4	0.11		
Total	422		5847		3430		5644	

The variation in fat percentage of individual cows considered here covers the entire lactation period. The variation in the composition of milk of cows during short intervals will be discussed later.

RELATION BETWEEN FAT AND OTHER CONSTITUENTS OF MILK

In the following discussion, the factors influencing the percentage fat content of milk will receive major consideration. However, as the fat fluctuates up and down other constituents of milk usually increase or decrease in a characteristic manner. Thus, when the fat content of milk increases, the protein and ash content increases also but the lactose content decreases slightly. When the fat content declines, the protein and ash also declines, but the lactose increases in amount. From Figure 2 the average change in the various constituents of milk may be noted. It is possible to read from the chart the average composition of milk of any given fat content; thus, 4 per cent milk (fat) will have approximately

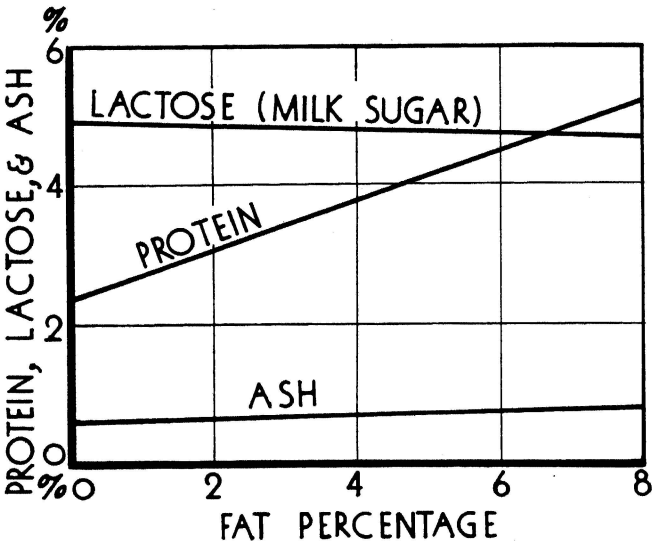

Fig. 2.—The change in the composition of milk as the fat content increases. The composition of 4 per cent milk is protein 3.5 per cent, lactose 4.9 per cent, and ash 0.7 per cent. (Data from Ill. Bul. 325).

the following percentage composition: protein 3.5, lactose, 4.9, and ash 0.7.

NUTRITIONAL FACTORS AFFECTING THE COMPOSITION OF MILK

The amount and composition of the feed in the ration of the dairy cow notably influences the yield of milk. It would seem reasonable to expect that certain feeds would alter the composition of milk. In the case of a few constituents of milk this is indeed true, while in other cases little or no effect has been observed.

The Vitamins

The vitamin A content of milk is dependent upon the amount of carotene, a yellow pigment, and vitamin A in the feed. Cows on pasture produce milk very rich in this vitamin. In the winter the vitamin A content of milk may be maintained by feeding well cured (green) hay and silage. The addition of mineral acids to preserve silage called the A. I. V. method has been shown in several recent studies to prevent the loss of carotene in the ensiling process. Milk is usually considered a good source of vitamin A.

Vitamin B is formed in the rumen of the cow"s stomach by bacterial action. The amount of vitamin B present in milk is low. Recent studies indicate that the kind or quality of the feed has no discernible effect on the vitamin B content of milk.

The amount of vitamin C in a cow's ration apparently has little if any influence on the vitamin C content of the milk produced. No difference was noted between pasture feeding and barn feeding. There is considerable evidence that this vitamin is synthesized in the body of the cow.

The vitamin D content of milk depends upon the vitamin D content of the feed. The amount of this vitamin in milk can be increased greatly by feeding irradiated yeast or by direct irradiation of milk.

Milk is a good source of vitamin G, which is identified with the yellow pigment of milk whey (lactoflavin). Feeds such as pasture grass and properly cured leguminous hays increase the amounts of this vitamin present in milk.

Fat

The fat in milk can be formed by the cow from the other constituents of the feed, yet for the most abundant secretion it has been found desirable to provide in the ration sufficient fat to equal the fat in the milk. This would amount to about 5 or 6 per cent of the grain mixture.

In the past various oils have been added to the ration of dairy cows to increase the percentage of fat. Recently, two fish oils (cod liver and menhaden fish) have been shown to have a depressing effect upon the fat content of milk. The decrease may amount to as much as 0.5 to 1.0 per cent and continue as long as the oil is fed. Oils from plant sources, on the other hand, usually cause a temporary increase in test. Upon continued oil feeding, however, the test has usually been observed to return to the normal level. The feeding of butterfat has recently been observed to increase the fat content of milk for a considerable period. While feeding butterfat is not practical it raises the hope that a cheap fat may be found which will have a similar effect.

Protein

Extensive experiments with rations low and high in protein indicate that the nutritive ratio has very little if any influence on the composition of the milk produced. If the rations are sufficiently unbalanced to decrease the yield of milk seriously, then the fat content may increase slightly. It was formerly thought that the feeding of high protein feeds was a stimulant to milk secretion but

recent extensive work indicated no advantage in protein when fed in excess of the protein requirements.

Mineral Matter

While milk is an excellent source of calcium (lime) and phosphorus, it may be deficient in other minerals such as copper, iron, and iodine. Many attempts have been made to increase the amounts of those minerals in which milk is low. With the exception of iodine, mineral feeding does not increase the amount of the various minerals in milk sufficient to be of any practical importance.

Feeding Watery or Succulent Feeds

While succulent feeds may increase the palatability of the ration, the feeding of a ration containing a large quantity of water does not increase the percentage of water in the milk or reduce the percentage of fat. Heavily lactating cows require an abundance of water but this can be furnished in the drinking water.

Overfeeding and Underfeeding

Studies at this Station indicate that an abundant well balanced ration has a tendency to maintain the constancy of the composition but the reduction of the feed below the normal level causes the percent of fat to increase with a lowering of the milk yield. The yield of fat is reduced also. The rise in test usually occurs within two or three days after the cut in feed. After a short time the fat percentage tends to return to normal (Fig. 3).

Rapid Changes in Feeds

Most of the changes which have been found to occur in the composition of milk as a result of feeding certain feeds have been temporary in nature, and as soon as the cows become accustomed to the new feeds the composition becomes normal. Just after a change in feed there is a general tendency for the fat to become abnormal and the usual change is for the milk yield to decline slightly and the fat percentage to increase.

The Effect of Drought Conditions on the Composition of Milk

The conditions of drought experienced in the Middle West during the past few years have aroused interest in the effect of such conditions upon the composition of milk of dairy cows during such periods. As a number of factors are involved, it is necessary to consider how they affect each other.

During summer drought conditions, the pastures furnish little feed, the temperatures are high, and drinking water may be scarce. Under such conditions, the rations fed may be deficient either in

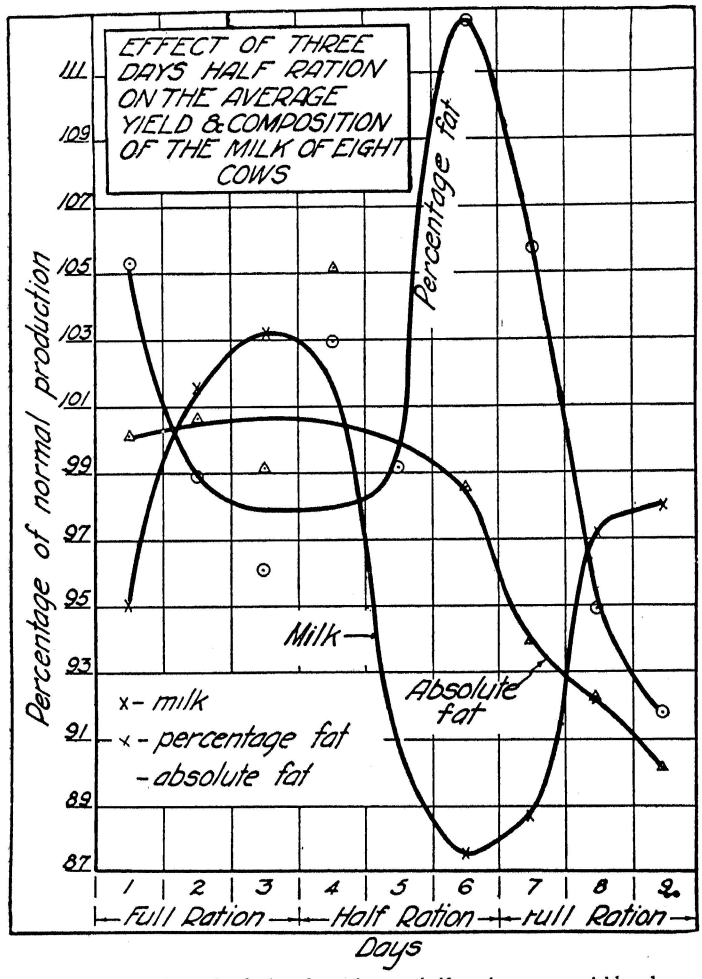

Fig. 3.—The effect of reducing the ration one-half on the average yield and composition of milk. The percentage of fat showed a very decided increase by the third day on the reduced ration.

the amount or kind of nutrients or both. Add a water scarcity and the yield of milk will be seriously depressed. Under such conditions it would be expected that the fat and protein content of milk would increase while the sugar would be depressed. The chlorides might increase sufficiently to impart a salty taste to the milk. On the other hand, the high temperatures which usually accompany drought conditions have an opposite effect upon the fat content of milk causing a decline in fat test. (The temperature effect, however, would probably not equalize the effect of underfeeding).

During the winter following a drought, the factors to be considered would be the scarcity and low quality of the feeds, especially roughage. The underfeeding resulting would increase the fat test and the lowered winter temperatures would have a similar influence.

From the standpoint of the nutritive value of milk produced under drought conditions, it would be seen that the fat and protein will tend to be above normal with a deficiency in the milk sugar. However, the most serious deficiencies will be in the milk pigments and vitamins A and G which vary with their presence in the feed. Milk produced by cows on pasture contains an as yet unknown growth-promoting factor which would also be lacking during droughts.

When, due to deficient or unbalanced rations, the physical conditions of dairy cows become very low, good management should indicate that their remaining reserve strength should be conserved by ceasing to milk such cows.

The Effect of Hormones, Drugs and Condiments

The hormone which stimulates milk secretion in the normal female after parturition has been discovered. It is produced by a tiny gland located at the base of the brain, called the pituitary. The use of this chemical substance, called galactin, is still in the experimental stage. Its practical usefulness with dairy cattle must await further trials. The hormone, thyroxin, secreted by the thyroid gland has been shown to stimulate milk secretion and also causes a rise in the fat percentage during the declining phases of the lactation period. Its usefulness at present is limited by the high cost.

Other drugs and condiments have been tried without success in stimulating an increase in milk yield. It is true that some drugs cause the animals to refuse feed and as a consequence there is a depression of the milk yield and a temporary increase in the fat percentage. The use of condiments increases the cost of milk production without any benefit to the animals to which it is fed.

Condition at Calving Time

From experience, breeders know that it is advisable to have cows in a good physical condition at calving time. The reserve flesh aids in starting lactation at a high level and in maintaining persistent production. The test is always higher for a time after calving, usually resulting in a slightly higher average test for the year (Figs. 4 and 5).

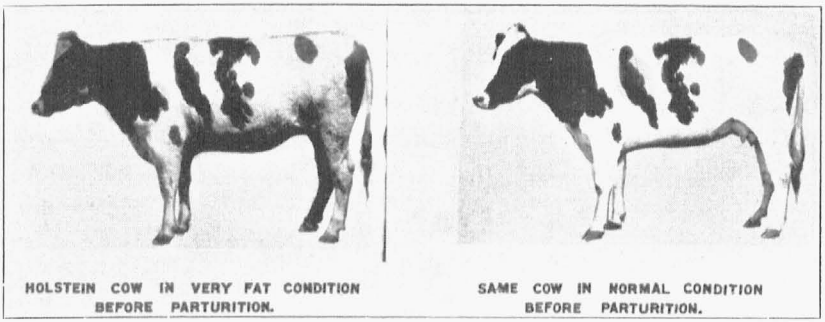

Fig. 4.—Influence of the fatness of the cow at parturition upon the percentage of fat in the milk A Holstein cow calving in a very fat condition averaged 5.1 per cent fat for 7 days and 3.3 per cent for the year. The same cow in normal condition averaged 3.8 per cent fat for 7 days and 3.1 per cent fat for the year.

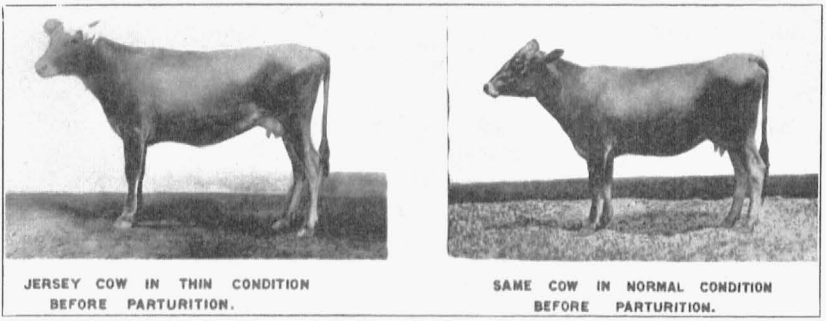

Fig. 5.—Influence of the fatness of the cow at parturition upon the per cent of fat in the milk. A Jersey calving in a very thin condition averaged 3.1 per cent for seven days and 4.97 per cent fat for the year. Calving again in normal condition she averaged 4.8 per cent fat for 7 days and 5.07 per cent fat for the year.

The Effect of Turning Cows on Pasture

It is frequently observed that cows calving in the fall increase in milk production when turned on pasture in the spring. During this period the percentage fat content of the milk usually increases for a week or two. At the same time the body weight of the cows decreases. Some investigators ascribe the increase in fat test to a type of underfeeding resulting from the fact that pasture grass stimulates milk secretion, yet due to the high water content of the grass fails to supply sufficient nutrients to maintain the yield with subsequent loss in body weight. Other workers suggest that the higher test is due to the increase in exercise on pasture. It is likely that both factors play a part.

After several weeks on pasture, the composition of the milk returns to normal or may even dip a little below normal for a time.

PHYSIOLOGICAL FACTORS AFFECTING THE COMPOSITION OF MILK

There are a number of physiological changes occurring in the body of the dairy cow which affect the yield and composition of milk. Some of these changes are due to the external environment varying with the season and the changes in temperature and humidity; others are associated with the reproductive system (heat or estrum and pregnancy); still others are due to changes in the udder with the advance of lactation and age. While some of these factors are partly under the control of the herdsman, for the most part little can be done concerning these factors to favorably affect the composition of the milk.

Colostrum

The first milk secreted after parturition, called colostrum differs greatly in composition from normal milk. The composition of colostrum is difficult to study because of the rapid changes occurring each day after parturition. In general, colostrum is characterized by a high specific gravity and percentage of total solids, ash and protein, and by a low percentage of lactose. The fat content shows more variation, sometimes being high, other times low.

All the proteins of milk are present in amounts above normal, but the globulin and albumin exceed the casein in amount, which is the reverse of normal cow's milk. Globulin exceeds the albumin which is the reverse of that in normal milk. The gradual transition of colostrum into normal milk is shown in Table 5 and Fig. 6. Associated with the globulin of colostrum are immune bodies which pass unchanged into the blood of the newborn calf from the alimentary canal. These immune bodies protect the calf from some common calf diseases. It is important that calves be fed their mother's colostrum.

TABLE 5.—DATA ON THE COMPOSITION OF MILK DURING THE FOUR DAYS FOLLOWING CALVING

(Average of analyses from five cows)

Milking After Parturition	Milk lbs.	Specific gravity	Total Solids %	Ash %	Total Protein %	Fat %	Sugar %	Casein %	Globulin %
1	10.2	1.067	24.0	1.163	14.9	5.3	2.07	4.36	3.25
2	8.8	1.040	17.7	.948	10.1	4.6	3.07	3.44	1.56
3	12.2	1.037	14.5	.893	6.7	4.4	3.33	3.07	.90
4	13.2	1.034	14.4	.850	5.2	4.5	3.50	2.61	.50
5	15.9	1.033	14.5	.819	4.5	4.8	3.50	2.59	.38
6	13.0	1.033	14.2	.827	4.4	4.6	3.73	2.52	.33
7	17.6	1.034	14.2	.809	4.0	4.5	3.90	2.77	.30
8	16.5	1.032	14.3	.800	3.8	4.7	----	2.32	.22

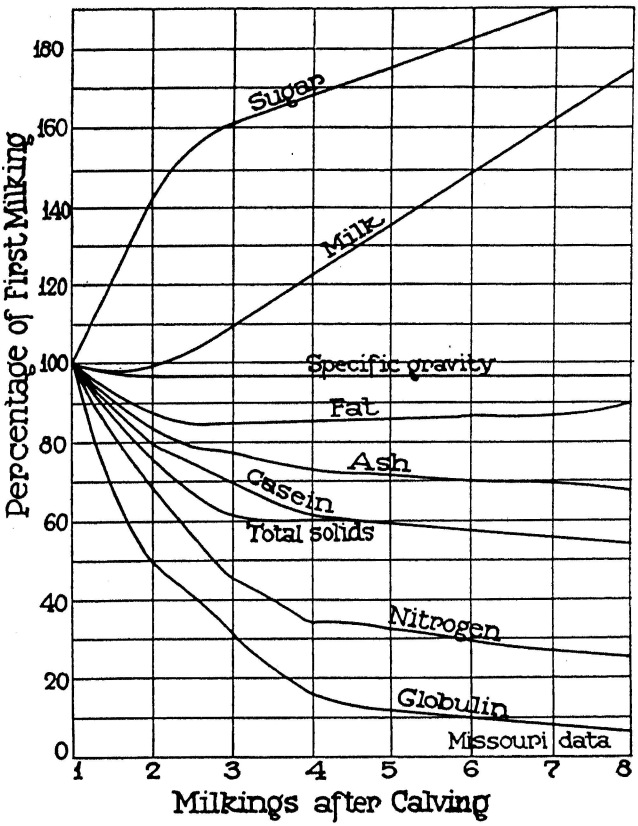

Fig. 6.—The change in the composition of milk during the first four days (8 milkings) after calving. The percentage value for each constituent in the milk from the first milking is represented by 100 per cent, and the values for the subsequent milkings are represented in terms of percentage of the first milking.

Advance of Stage of Lactation

When cows are in good condition at the time of calving, the percentage fat content of the milk is usually somewhat higher than when the same animals are in thin condition. Thus in fat animals, the test will be found to decline slowly for a month or more and then increases gradually with the advance of the stage of lactation. In thin animals, the percentage fat content of the milk secreted is usually low shortly after parturition, and does not decline further. Instead, there begins a slow gradual rise. When cows become pregnant, the yield of milk declines somewhat more rapidly than normal after 4 or 5 months. With this decline in milk yield there is an increase in the fat test.

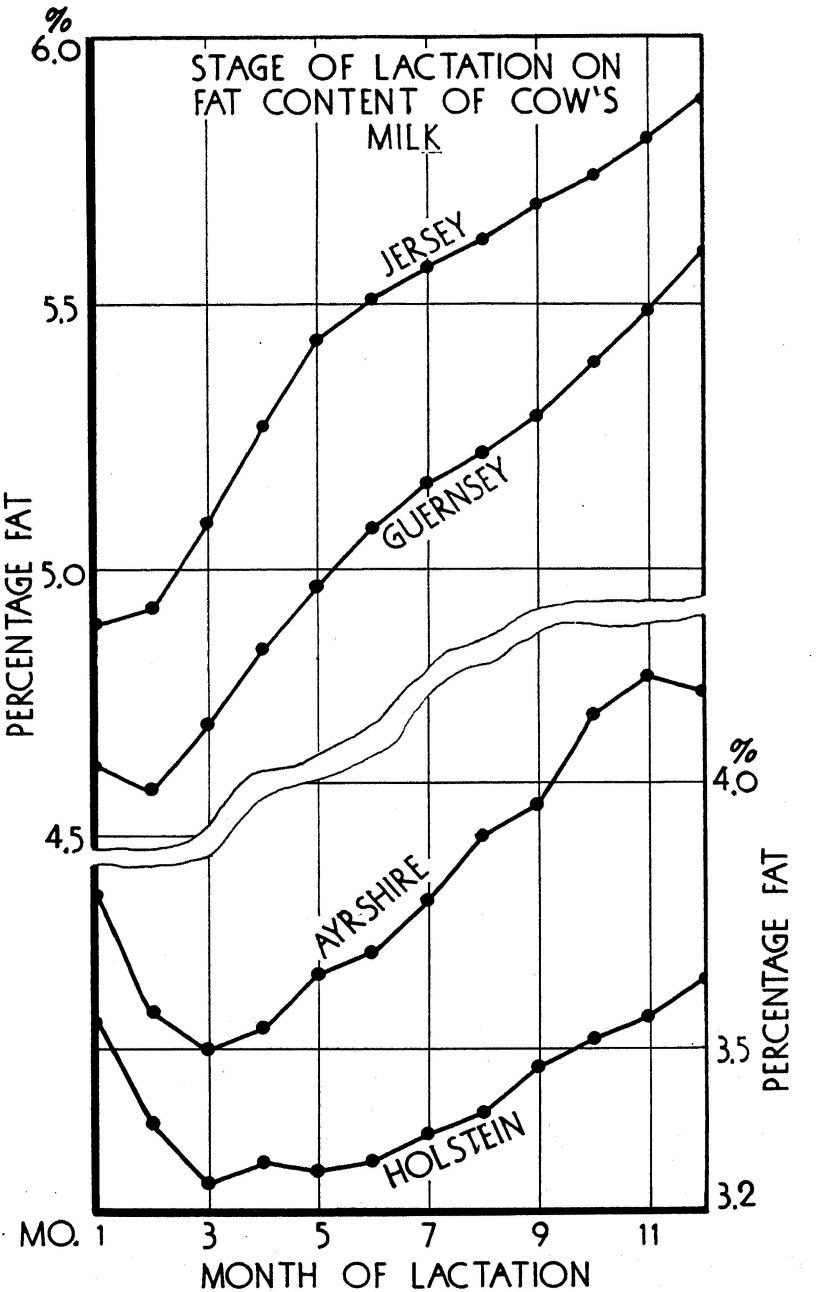

Fig. 7.—The influence of the stage of lactation on the average fat content of the milk of the four breeds of dairy cattle.

The variation in the fat percentage is greatest in those breeds having the higher fat content. Thus in the Jersey breed, the range in test may equal one per cent whereas in the Holstein breed the range is about 0.3 to 0.4 per cent (Table 6 and Fig. 7).

TABLE 6.—INFLUENCE OF THE STAGE OF LACTATION ON THE PERCENTAGE OF FAT IN COW'S MILK

Month of Lactation	Ayrshire (891) Hogstrom Fat %	Guernsey (3763) A. R. tests Fat %	Holstein (764) Eckles Fat %	Jersey (3203) Copeland R. of M. tests Fat %	Thin at parturition (13) Eckles Fat %	Fat at parturition (12) Eckles Fat %	Guernsey	
							Non-pregnant (900) Fat %	Bred 3 and 4 months of lactation Fat %
1	3.79	4.63	3.55	4.90	3.7	4.7	----	----
2	3.57	4.59	3.36	4.93	3.7	4.3	4.58	4.68
3	3.50	4.71	3.25	5.09	4.0	4.2	4.71	4.80
4	3.54	4.85	3.29	5.27	4.3	4.1	4.83	4.90
5	3.64	4.97	3.27	5.43	4.3	4.2	4.89	4.92
6	3.68	5.08	3.29	5.51	4.5	4.2	5.07	5.03
7	3.78	5.16	3.34	5.57	4.6	4.5	5.14	5.17
8	3.90	5.22	3.38	5.62	4.6	4.6	5.21	5.27
9	3.96	5.29	3.47	5.69	5.0	4.9	5.29	5.40
10	4.13	5.39	3.52	5.74	5.0	5.1	5.35	5.52
11	4.20	5.49	3.56	5.81	5.0	5.2	5.43	5.74
12	4.17	5.60	3.63	5.89	5.4	5.4	5.51	6.17
Maximum difference	0.67	1.01	0.36	0.99	1.7	1.3	0.93	1.49

Season of the Year

It has been known for many years that the fat percentage of milk increases during the fall months and declines during the spring months. The amount of the change is modified to some extent by the season of calving and the stage of lactation. The seasonal variations are usually of less magnitude than the changes associated with the advance of lactation, averaging about 0.5 per cent between the minimum and maximum tests (Table 7 and Fig. 8).

TABLE 7.—INFLUENCE OF THE SEASON OF THE YEAR ON THE PERCENTAGE OF FAT IN COW'S MILK

Month	Ayrshire (Sweden) (891) Hogstrom Fat %	Guernsey 3753 cows Fat %	Holstein Headley Fat %	Jersey 38,424 cows Copeland (1931) Fat %	DHIA records 67,992 Cannon (1933) Fat %
January	3.86	5.22	3.86	5.70	3.93
February	3.83	5.17	3.71	5.64	3.91
March	3.87	5.13	3.58	5.50	3.88
April	3.73	5.07	3.54	5.39	3.87
May	3.71	5.01	3.49	5.33	3.85
June	3.59	4.95	3.45	5.24	3.83
July	3.62	4.89	3.36	5.14	3.85
August	3.81	4.88	3.45	5.18	3.89
September	3.85	5.02	3.62	5.35	3.93
October	4.00	5.15	3.76	5.56	3.97
November	4.05	5.22	3.87	5.70	3.98
December	3.93	5.24	3.84	5.73	3.97
Average	3.82	5.08	3.63	5.46	3.90
Maximum difference	0.46	0.36	0.51	0.59	0.15

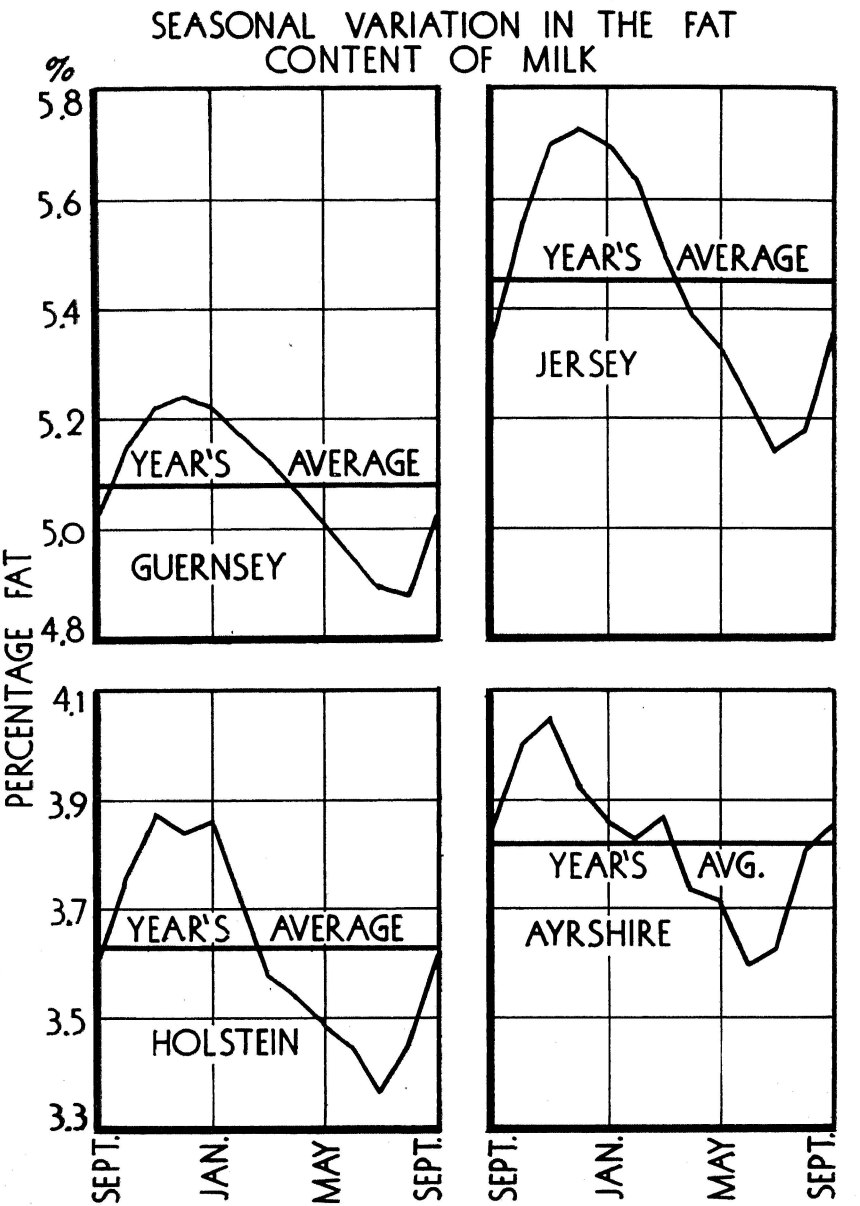

Fig. 8.—Seasonal variation in the fat content of milk.

The influence of the season of the year upon the fat percentage in relation to the advance of the stage of lactation may be shown by separating the lactations beginning each month. The average

curve showing the influence of the stage of lactation was then superimposed upon the curve for each month. The differences observed indicate the influence of the season (Fig. 9).

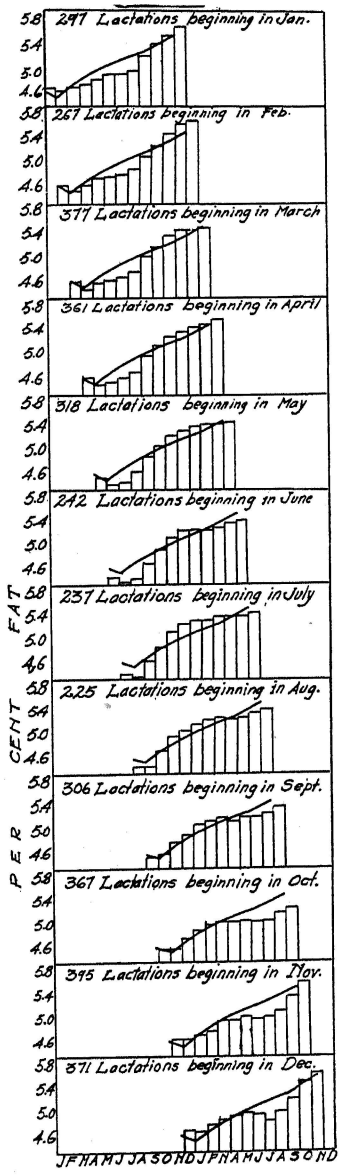

Fig. 9.—Influence of the season of the year on the per cent fat in cow's milk (Guernsey). Continuous lines show influence of the stage of lactation on the percentage of fat. The columns show seasonal variations in percentage of fat for cows grouped according to the month in which the lactation began.

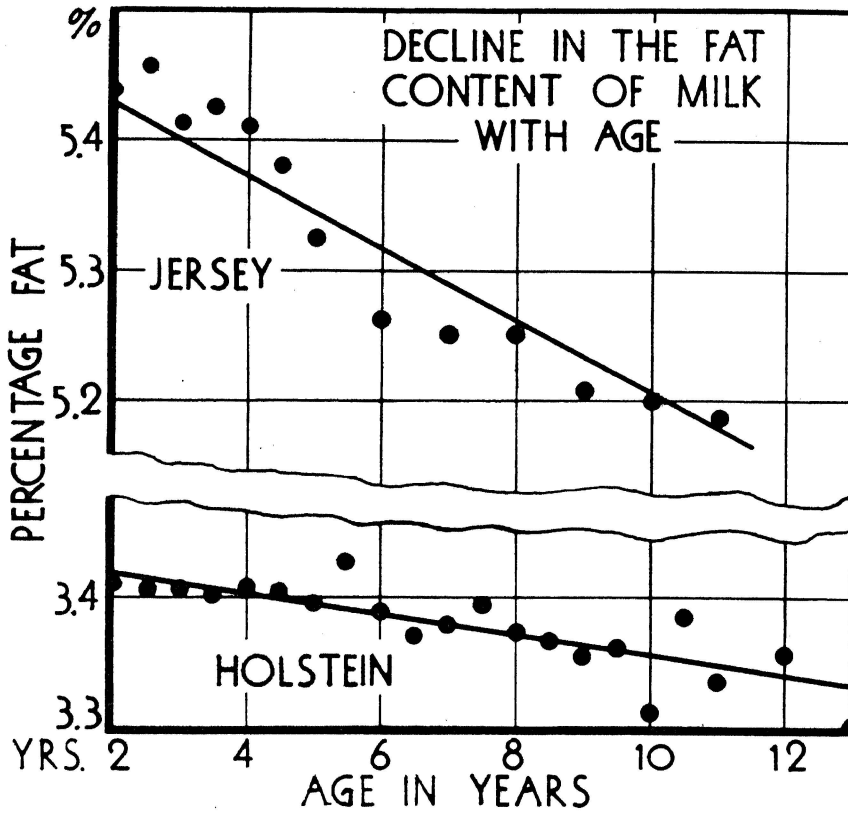

Fig. 10.—Decline in the fat content of milk of Jersey and Holstein cows with advancing age.

The cause of the seasonal variation has been ascribed to the seasonal nutritional conditions by some of the earlier investigators whereas others believe the temperature is the controlling factor. Recent investigations in which cows were kept on uniform rations throughout the year yet showed a seasonal variation as to fat test indicate that nutritional conditions are not of great importance.

Due to the increase in the fat percentage during the fall and winter months, cows which freshen in the fall may produce from 10 to 50 pounds more fat in a year's period. In the spring the test will remain high due to the advance of the stage of lactation.

Temperature

Experimental evidence accumulating during recent years points quite conclusively to the influence of temperature upon the variation in fat percentage during the seasons of the year.

Work at this Station showed that when other conditions were the same, the lower the environmental temperature, the higher was the percentage of fat in cow's milk. There was an increase of almost 0.2 per cent in the fat for a decrease of 10 degrees F in the temperature between the limits of 30 to 70 degrees F. Cows kept under controlled temperature conditions for periods showed similar changes with the lowering of the temperatures. Following sudden changes in temperature a variation in fat test may be expected.

As with other factors, temperature changes will be expected to influence cows with higher fat tests to a greater extent than cows with low fat tests.

Fat Content of Milk Declines Slightly with Age

The fat content of the milk of young animals is usually high but then gradually declines with age. The decline appears to be greatest in the breeds secreting milk with the highest fat content (Table 8 and Fig. 10).

TABLE 8.—INFLUENCE OF AGE ON THE PERCENTAGE OF FAT IN COW'S MILK

Age Years	Ayrshire (Heizer-1932) Fat %	Guernsey (Gowen-1923) 10,644 A. R. Fat %	Holstein (Norton) 22,841 records over 325 days Fat %	Jersey (Copeland-1931) 26,068 R. M. Fat %	D. H. I. A. records (Dorman 1933)	
					Purebreds 59,606 Fat %	Grades 89,000 Fat %
2	4.136	5.07	3.411	5.439	4.0	4.1
2½		5.07	3.407	5.457		
3	4.116	5.09	3.408	5.414	4.0	4.0
3½		5.09	3.402	5.427		
4	4.068	5.07	3.409	5.412	3.9	4.0
4½		5.03	3.407	5.380		
5	4.008	4.98	3.395	5.326	3.9	4.0
5½		5.00	3.429			
6	3.985	4.96	3.391	5.263	3.8	4.0
6½		5.00	3.373			
7	3.975	4.94	3.380	5.251	3.8	3.9
7½		4.97	3.394			
8	3.942	4.91	3.375	5.251	3.8	3.9
8½		4.86	3.368			
9	3.941	4.93	3.356	5.209	3.8	3.9
9½		4.87	3.360			
10	3.902	4.89	3.312	5.202	3.8	3.9
10½		4.82	3.385			
11	3.864	4.85	3.336	5.185	3.8	3.9
11½		4.88				
12	3.881	4.91	3.358		3.9	3.9
12½		4.88				
13	3.814	4.71	3.301		4.0	3.8
13½		5.05				
14	3.846				4.0	3.9
15	4.042				3.9	4.0
16	3.920				3.9	3.9
17	3.940				4.1	3.8
18	3.300					

The Effect of Exercise and Work

It is generally agreed that all dairy cows are benefitted by a certain amount of exercise. However, the milk production of cows producing at a maximum will be adversely affected if the

exercise is excessive. In Europe it has been noted that the milk production of cows is decreased when cows are driven up the mountains for summer pasture. With the depression in the milk yield there is found a corresponding increase in the percentage of fat. Light farm work also has been found to decrease milk yield and increase the fat content.

The value of a daily walk of three miles on the percentage of fat in the milk produced has been determined. In all but two instances out of 22 comparisons there was an increase in test when changed from rest to exercise and a decrease when changed from exercise to rest. In further experiments, it was observed that during a period of exercise, the feed consumption was increased, the milk production maintained, and the percentage of fat increased over a corresponding period of rest.

It is interesting to note that the increase in the test when cows are turned on pasture is ascribed by some to the increase in exercise obtained during grazing.

The Effect of the Period of Heat or Estrum

At intervals of about 21 days, cows not pregnant come into heat or estrum. The effect of this period upon the composition and yield of milk has been studied extensively. It has been believed by some that the estrus producing hormone which is being secreted in abundance at this time may depress the milk yield slightly. The writer is of the opinion that the slight variation in milk yield may be due in part also to the increased excitability or nervousness, causing some animals to hold up their milk for one or more milkings and others to give less. When this occurs, the yield may be lower as well as the fat test or the yield may be lower and the test higher. Later the milk yield will be increased and as the last milk will be obtained, test slightly more.

In a study of 211 supervision periods of Register of Merit Jersey cows, Copeland observed that in 43 cases both milk yield and fat percentage increased during the heat period and in 58 cases they both declined. There were 73 times in which the milk yield declined slightly and the fat percentage increased a small amount, and in 27 cases the reverse was true. In the remaining 10 cases either butterfat percentage or milk yield remained constant.

As the fundamental causes of the variation in composition and yield may be different the effect of heat is difficult to predict. If the milk yield is depressed the fat percentage will increase; however, if the milk yield is lower due to the "holding up" of the last milk, the fat percentage will be lower.

MANAGERIAL FACTORS AFFECTING THE COMPOSITION OF MILK

The management of dairy cattle and the method of milking are important factors affecting the milk yield and composition. The cow is a creature of habit and changes in feeding and management may be sufficient to upset her. As indicated by the following discussion, the variation in the composition of milk which occurs from milking to milking, and day to day is far greater than would be expected by those unfamiliar with cows.

Individual Variation Occurring from Day to Day

In an earlier section there was discussed the variation in the composition of milk produced by individual cows during entire lactation periods. At this point there will be discussed the variations in the fat content of milk which occur between morning and evening milk, the interval between milkings, during the milking process, the order of milking the quarters, composition of milk of individual quarters and similar factors.

Studies have been made to show the extent of variation in the percentage of fat in milk of individual cows during short periods such as 7 day tests or during the two day test of the semi-official yearly record. The observations of Anderson of the Michigan Station are presented in the following table (Table 9).

TABLE 9.—RANGE OF VARIATION IN FAT PERCENTAGE DURING TEST PERIOD

Kind of Record	Range of Fat Content (From highest to lowest)					
	0.0 to 1.0%	1.1 to 2.0%	2.1 to 3.0%	3.1 to 4.0%	4.1 to 5.0%	5.1 to 6.0%
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency
	%	%	%	%	%	%
2,000 7-day records (Holstein)	28.45	54.55	13.40	2.65	0.80	0.15
1,000 R. of M. 2-day test (Jersey)	63.20	26.70	7.70	1.60	0.70	0.01
1,000 A. R. S. O. 2-day tests (Holstein)	69.10	24.70	5.00	1.10	0.10	----

These data show the great variability that may occur in the fat tests of individual milkings of cows during periods of 7 days and two days. The two-day test periods show greater uniformity because milk secretion is more stabilized and because of the shorter period of time included.

Eckles and Shaw of the Missouri Station tested the milk of a number of cows in the herd under very uniform conditions and yet obtained the variations noted in the following table (Table 10). The extreme variation reached almost 2 per cent. Only 56 per cent of the samples were within ±0.3 per cent of the average; 27.7 per cent ranged between ±0.3 to 0.6 per cent; 11.7 per cent

TABLE 10.—AVERAGE VARIATIONS IN FAT CONTENT FROM MILKING TO MILKING

Breed	Number of milkings	Fat Content			Variations from Average			
		Average	Highest	Lowest	Less than 3%	Between 0.3 and 0.6%	Between 0.6 and 0.9%	Over 0.9%
		%	%	%	%	%	%	%
Ayrshire	27	3.93	4.36	3.49	77.7	22.3	----	---
Holstein	28	3.07	3.79	2.40	39.3	46.4	14.3	---
Holstein	28	3.18	3.67	2.71	85.7	14.3	---	---
Jersey	28	5.31	6.31	4.56	50.0	25.0	17.9	7.1
Shorthorn	27	4.08	5.29	3.46	63.0	29.6	3.7	3.7
Holstein	20	2.98	3.63	2.24	45.0	30.0	25.0	---

ranged from ±0.6 and 0.9 per cent, and 4.6 per cent varied more than ±0.9 per cent from the average.

These data show that single milk samples are of little value in indicating the quality of milk secreted by individual cows. Further, that it is the usual rather than the unusual for considerable variation to occur in the fat test from milking to milking and from day to day. While much of this variation is eliminated when mixed herd milk is tested, the milking to milking variation may still be considerable.

Variation between Night and Morning Milking

When cows are milked twice per day, it might be expected that the composition of the milk would be approximately the same whether obtained at night or in the morning. Upon further consideration, however, there may be a number of factors which might influence the composition of the milk obtained at one milking more than at the other. The first factor is the interval between the two milkings. Unless the interval is about equal that in itself would have a considerable influence as indicated later.

Considering equal intervals, there might be a difference due to the environmental temperature at night as compared to the day. The night temperature is usually colder than the day temperature. However, there may be a lag between the temperature and its effect upon the composition of the milk.

A second factor is the amount of exercise obtained on pasture and stall feeding. Under normal conditions cows probably take more exercise during the day than at night. There are, therefore, at least two factors both of which might increase the percentage of fat content of the milk coming at opposite times of the day.

The available studies of this problem are inconclusive. It is true that a majority of the results indicate that the milk secreted during the day and removed at the evening milking tests higher than the milk secreted during the night and removed at the morn-

ing milking. It should be recognized that there is a tendency for the day interval to be shorter than the night interval and this may be partly responsible.

A study of Jersey 2-day supervisors' reports by Copeland are summarized in the following table (Table 11).

TABLE 11.—VARIATION IN FAT CONTENT OF MILK OBTAINED AT EQUAL INTERVALS
(Copeland—American Jersey Cattle Club)

	Milk lbs.	Fat %	Cases test highest
	2 Milkings per day (821 tests)		
A. M.	13.5	5.23	269
P. M.	12.7	5.50	498
	3 milkings per day (1515 tests)		
A. M.	11.3	5.01	232
Noon	9.8	5.55	705
P. M.	9.5	5.41	491

From this Copeland concluded that when cows are milked twice daily at regular intervals there is a tendency for the milk production to be highest in the morning and for the butterfat percentage to be slightly higher for the evening milking. On cows milked three times a day, there seems to be a tendency for the butterfat percentage to be highest at noon and lowest in the morning, while the milk production is highest for the morning and lowest for the evening.

It is believed that the interval between milking, the amount of exercise, and the variation in temperature are chiefly responsible for the variation in the composition of morning and evening milk. Under standard conditions the milk secreted during the day and night will tend to be quite uniform in fat content.

Interval between Milkings

It has been observed that the greater the interval between milkings the less will be the percentage of fat and the greater the amount of milk. Thus, if cows are milked 11 and 13 hours apart the milk produced after the 11-hour interval will usually contain the larger percentage of fat. It has been suggested that the secretion of milk fat is more rapid when the udder is free of milk after the previous milking period. As milk is secreted and the pressure within the udder increases, it is believed that the cells of the udder discharge the fat with greater difficulty. Thus fat secretion is interfered with as the udder pressure increases to a greater extent than milk secretion, although the latter is also affected.

When cows are secreting milk at their maximum capacity it is probable that the fat content as well as the yield of milk is

benefitted by increasing the frequency of milking to three and even four times per day. When the udder is capable of holding all the milk secreted at each milking, there is little or no benefit in more frequent milking, neither will the length of the interval between milkings affect the fat content as markedly.

The Fat Content of Milk Increases during the Milking Process.—It is well known that the first milk obtained during the milking process is usually very low in fat and that as the milking act continues the fat content gradually increases. The last milk or strippings are, therefore, very rich in fat. The constituents other than fat are only slightly affected. There is, however, great variation in the increase in the fat content of the milk of different cows and even in the four quarters of the same cow. Two very definite factors influence this condition. It is known that when the cows' udder is thoroughly massaged before milking is started, the first and last milk will differ far less than when the undisturbed cow is milked. The second factor is the order of milking the quarters. This latter factor will be discussed separately.

The early theory advanced for the increase in the fat content of the milk as due to the retardation of the forward movement of the fat globules due to friction in the ducts has not been confirmed by examination of gland tissue. It has also been suggested that this phenomenon was due to the effect of gravity acting upon the fat causing it to rise to the higher parts of the udder and coming down in larger amount with the last milk. This may be the major cause, but a contributing mechanism is believed to lie in the discharge of the milk from the cells which are laden with fat as the pressure in the udder declines. The last milk is especially rich in fat as it represents the milk coming from the ruptured cells which is less diluted with milk in the storage system.

Complete milking is important because the last milk is high in fat and milk left in the udder tends to suppress the rate of milk-secretion earlier during the next milking interval and eventually hasten the decline in lactation. Systematic massage of the udder at the close of the milking act aids in obtaining the last milk.

Gentle rapid milking is also distinctly beneficial in securing a maximum of the milk present in the udder. This is due to the fact that the cow forces down the milk as a result of the contraction of the gland tissue. The last milk is difficult to milk out if the muscles relax before milking is complete. One cannot leave a cow after starting to milk her without sacrificing a little in milk yield of the highest testing milk.

Barking dogs, painful teats or udders, or kicking or hitting cows during the milking act will frequently cause the cows to "hold up" their milk. In such cases the milk yield as well as the fat content will be low.

In tests conducted to determine the effect of leaving milk in the udder upon the composition of the milk subsequently produced, it was observed that the fat content of the milk produced during the following two days could be increased from 0.1 to 0.3 per cent when 25 to 40 per cent of the milk was left in the udder. It is interesting to note that the highest fat percentage was not always reached at the milking following the partial milking, almost one-half of the tests being highest at the second milking.

The variation in the fat content of the fore and last milk may be taken advantage of if it is desirable to secure a higher testing milk. Some let the calves suck the first milk and then remove the last rich milk by hand. In the case of certain breeds whose milk tests rather low, it has been suggested that the test might be increased by eliminating the first streams of milk. At the Cornell Station it was found that the removal of 20 streams of fore milk from each quarter represented 10.5 per cent of the entire milking of Holstein cows, yet the remainder of the milk tested only 0.17 per cent higher.

The Order of Milking the Quarters.—When the four quarters of a cow's udder are milked at the same time by a milking machine, the composition of the milk secreted by each quarter tends to be similar but many individual exceptions occur. In a study at the Missouri Station it was observed that 7-day composite tests of the four quarters revealed a difference of less than 0.2 per cent in 41 cases out of a total of 73 records. In 20 cases the variation was between 0.2 and 0.4 per cent; in three cases between 0.4 and 0.6 per cent; in seven cases between 0.6 and 0.8 per cent, and in two cases between 0.8 and 1.0 per cent fat. No tendency was observed for either the front or rear quarters to secrete milk richer in fat than the other even though the fore quarters average about 40 per cent and the rear quarters about 60 per cent of the milk yield.

If the four quarters are milked one at a time Babcock observed as early as 1889 that the quarter milked second in order produced the most and the richest milk, the others ranking in the following order: first, third, and fourth. Others since have made essentially the same observation, the quarters milked first yielding the richest milk and that drawn from the last quarters poorest in fat.

These results are explained by the observations that following the initial stimulation of the teats at milking time there is an increase in the pressure within the udder which forces the milk into the cistern. If the milk is not quickly removed the pressure soon decreases and the last milk is difficult if not impossible to remove.

The Fat Content of Milk Increases when the Yield of Milk Decreases.—When the yield of milk declines with the advance of the stage of lactation there is a slight compensatory increase in the fat content of the milk produced. When cows are pregnant over five months during the lactation period, the yield declines more rapidly and the fat test increases still more.

When cows go off feed or other conditions occur which affect the milk yield adversely, the fat content of the milk is almost certain to increase. (One exception is when cows "hold up" their milk, in which case the fat test will be low due to the fact that the last milk is not obtained). The most probable explanation of this relationship is that if for any reason the yield of milk is reduced, the fat content of the milk will be higher due to the lessened milk pressure developed and the reduced interference with fat secretion. (For full discussion read Mo. Agr. Exp. Sta. Bul. 346).

Methods of Estimating Fat Production

It might be thought from the previous discussion that a representative test of the fat percentage would be difficult to obtain. Making a test of every milking is too expensive. It has been found that a test period of two days, during which each milking is separately tested, gives a close estimate of the fat percentage. These tests are repeated at monthly intervals. Slightly less accurate are the tests run at bi-monthly intervals. Somewhat less accurate is a one day test each month. In the Dairy Herd Improvement Association a single composite of the night and morning milking is tested each month. The slight fluctuations up and down which occur in the one day tests tend to be equalized during the course of a year and thus provide a satisfactory estimate of yearly fat production.

Effect of Chronic Mastitis on the Composition of Milk

A few cows become infected with organisms which cause intense inflammation of the udder, high temperature and almost complete cessation of milk secretion. The milk is so altered it is at once apparent that it is unfit for use. There is another more common type of mastitis which is of great importance because of

its insiduous nature. The cows may show no external appearance of an infection, the milk may remain normal in appearance and the udder uninflamed, yet examination of the milk may show the presence of long chain streptococci. The infection progresses gradually causing alterations in the composition of the milk and a depression of the yield. The individual quarters infected gradually lose their secreting tissue and an increase of connective or scar tissue develops. In advanced cases the affected quarters may be detected by manual palpation.

The most important changes in the composition of such milk is an increase in the chlorides and a corresponding decrease in the lactose or milk sugar. This alteration affects the flavor of milk due to the increased saltiness and decreased sweetness. The fat content may either increase or decrease slightly or remain about the same. Such milk also becomes slightly more alkaline than milk from uninfected quarters. The increase in alkalinity is the basis for the brom thymol blue and other color tests.

VARIATION IN FAT CONTENT OF HERD MILK

Patrons of fluid milk plants frequently wonder why their milk does not always test uniformly from day to day and from week to week. It will be seen from the multitudinous causes of variation that some variation will occur in herd milk from day to day even under apparently normal conditions and there will be definite seasonal trends.

The fat tests of herd milk from day to day may vary as much as one per cent in Jersey herds and correspondingly less with breeds producing lower test milk.

These natural variations, however, should not cause milk plant operators to be lax in their obligations to their patrons to do everything possible to secure a representative sample of milk and test it accurately. Recent work has shown that considerable error may result in obtaining samples from the weigh vat when milk with a heavy cream layer is not stirred either before or after dumping. The partly skimmed milk and cream may form pools in different parts of the vat and make accurate sampling difficult if the milk is not stirred. The size and shape of the dump tank and the extent to which the milk has creamed in the cans are factors affecting the distribution of fat in the milk in the vat. Thorough stirring is of course always necessary when samples are taken from individual cans.

Details of aliquot sampling and methods of preserving milk for composite tests are presented in Missouri Exp Sta. Circular 189. It might be pointed out that recent studies at the Ohio Station indicate that there is a tendency for composite samples to test a little lower than the fresh milk going into the composite. The average of 290 composite samples was 5.13 per cent, while that for fresh milk going into these samples was 5.22 per cent. In 225 samples, the composite gave lowered tests.

RECENT PUBLICATIONS OF INTEREST TO MISSOURI DAIRY FARMERS

Experiment Station Bulletins

No. 336 Growth Standards for Dairy Cattle. A. C. Ragsdale, May 1934.
No. 338 Feed Consumptions of Dairy Cattle During Growth. A. C. Ragsdale, June 1934.
No. 339 The Causes of the Growth and Function of the Udder of Cattle. C. W. Turner, July 1934.
No. 344 The Structure of the Cow's Udder. C. W. Turner. January 1935.
No. 346 The Secretion of Milk and the Milk Process. C. W. Turner. February 1935.
No. 351 Evaluating the Efficiency of Dairy Cattle. S. Brody and A. C. Ragsdale. May 1935.
No. 354 Estimating Live Weights of Dairy Cattle. A. C. Ragsdale and S. Brody. October 1935.
No. 355 Estimating Condition in Dairy Cattle. S. Brody and A. C. Ragsdale. October 1935.

Experiment Station Circulars

No. 189 Testing Milk and Cream. H. A. Herman. March 1936.

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