February, 1928 Research Bulletin No. 107

The Influence of Temperatures and Certain Other Factors Upon the Percentage of Fat in Milk

BY EARL WEAVER AND C. A. MATTHEWS

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

ANIMAL HUSBANDRY SECTION
DAIRY HUSBANDRY

AMES, IOWA

SUMMARY

The percentage of fat in cows' milk varied definitely with seasonal changes. The fat test was highest during the first half of winter, or January. It gradually declined to the second half of summer, August and early September, when the lowest test occurred, and then it rose rather rapidly in the fall.

Ayrshire and Holstein tests were approximately 0.6 percent lower in the second half of summer than in the first half of winter. Guernsey and Jersey tests were approximately 1.1 percent lower.

The butterfat tests were found to be lower with higher outside and inside temperatures.

As measured by regression coefficients, butterfat tests were affected more by changes in environmental temperatures than by the other factors studied.

It was not determined whether variations in outside or inside temperature had the greater influence upon the fat test, altho there was an indication that variations in the fat test were more closely related to variations in outside temperature.

The butterfat test, during the lactation period, tended to be high immediately following freshening, declining for two or three months, and then rising during the rest of the lactation.

An increase in the fat test followed an advance in the stage of gestation.

There was considerable variation in the butterfat test which could not be attributed to the effect of the factors studied in this trial.

The Influence of Temperatures and Certain Other Factors Upon the Percentage of Fat in Milk

By Earl Weaver and C. A. Matthews*

Variations in the percentage of fat in milk that occur with the changing seasons have attracted considerable interest. The dairy farmer who sells milk according to the butterfat test knows from experience that the test is lower in summer than in winter. The explanation of this variation is not readily apparent and milk plant operators are kept busy proposing satisfactory reasons for lower tests in summer.

As the season of lower butterfat tests comes at approximately the time cows are given access to pasture, the casual theory has been presented that the lower percentage of fat was the result of going onto pasture. Substantiation for this theory is found in the greater quantity of milk produced at this time. It has been said that pasture stimulates a greater flow of milk, but at the expense of "thinning" it down. There is a general idea that the percentage of fat in milk is inversely proportional to the quantity of milk produced.

A more logical explanation has been sought in the theory that environmental temperature is an important controlling factor in the seasonal variation of the percentage of fat in milk. It is also known that variation may be produced by other factors, particularly those associated with the stage of lactation. Therefore, in any study of the effect of environmental temperature, the other possible influencing factors must be accounted for or controlled.

PREVIOUS WORK

The possible causes of variation in the percentage of fat in cows' milk have had considerable investigation and the positive or negative effect of many causes has been generally established. Much of the work has had to do with the influence of season and temperature.

White and Judkins (17) from seven years' records on 49 cows found the butterfat tests higher in winter and lower in summer. During five months of the year the test of the Holsteins averaged below the Connecticut state standards for fat and other

*Professor G. W. Snedecor, of the Mathematics Department, advised and helped with the mathematical methods used. His assistance is greatly appreciated.

breeds were below state standards for solids not fat for some months of the year.

Similar results were obtained by Woodward (18) from a study of 830 samples of milk from grade and purebred Jerseys, Guernseys and Holsteins. He found differences between January and July tests ranging from 0.04 percent to 0.72 percent, with the average for all breeds being 0.33 percent higher in January than in July.

Ragsdale and Turner (14) report an extensive study of the variation of the percentage of fat with season. They found that the percentage of fat in milk, irrespective of the stage of lactation, usually rose in the fall and winter to December and declined again to August. Turner (15) in reviewing this study gives figures showing the extent of this variation, which is presented in table I.

TABLE I. EXTENT OF THE SEASONAL VARIATION OF THE BUTTERFAT TEST

Breed	No. of records	Average percent fat	December percent fat	August percent fat
Guernsey	3763	5.08	5.24	4.88
Jersey	299	5.39	5.76	5.03
Holstein	95	3.15	3.25	3.05

In reporting the effect of season on the milk and fat production of Jersey cows, Wylie (19) states that, regardless of the time the cows freshened, the highest tests occurred in a period from November to January, inclusive, with an average of 5.73 percent fat. There was a very gradual decline to a low average of 5.2 percent occurring in July which was followed by a more rapid increase in the fall.

REPORTS OF VARIATION WITH ENVIRONMENTAL TEMPERATURE

As the seasonal cycle in the United States is associated with changes in temperature, a number of studies have been carried on to determine the possible influence of environmental temperature as a controlling factor in seasonal variation.

Hills (10) as early as 1892 reported the results of creamery tests on the milk from 30 herds. He found that while cows were on pasture the butterfat test varied inversely with the temperature.

Ragsdale and Brody (12) compared the daily butterfat tests of 10 cows with the average daily temperatures. Within a range from 30 to 70 degrees Fahrenheit they found an increase of about 0.2 percent in the percentage of fat in milk for each 10 degrees decrease in temperature.

Hays (9) reports a trial over a period of 258 days with a tem-

perature range of from 24.5 to 86.5 degrees Fahrenheit. He found an average difference of 0.489 percent in the fat tests between these extremes of temperature. This amounted to a 0.079 percent increase in the test for each 10 degrees decrease in the environmental temperature.

The same author reports a trial under controlled temperature conditions. During four to eight-day periods two Jersey cows were kept under seven different temperatures planned to range from 30 to 90 degrees Fahrenheit in 10 degree intervals. Over this range the difference was 0.863 percent in the fat test. There was an actual increase in the percentage of fat between 70 and 90 degrees, but at some point above 70 degrees, a lower percentage of fat was obtained.

It was the general conclusion of all these investigators that the environmental temperature is largely responsible for seasonal variations in the percentage of fat in milk, and that variations in the percentage of fat are inversely proportional to the temperature.

REPORTS OF VARIATIONS DUE TO OTHER FACTORS

In all studies on the effects of changing season and environmental temperature upon the percentage of fat in milk, other factors which may cause variations in the percentage of fat have to be controlled or their effect measured and accounted for. Besides the seasonal factors just discussed, there are those of a cow's individual inheritance, those connected with the reproductive cycle, those connected with the plane of nutrition and the condition of the cow and the age factor.

Ragsdale and Turner (13) state from a study of 4,157 records that, independent of the season of the year or character of the diet, the stage of lactation has a definite influence upon the percentage of fat in milk. This change was described as a noticeable decline in the fat test to the second and sometimes to the third month. Following the low period there was a gradual increase which became more pronounced during the last months of the lactation period.

Grady (8) found the butterfat test varied but little in the first four months and then increased gradually as lactation advanced.

Closely associated with the stage of lactation is the effect produced by advance in the stage of gestation. Gaines and Davidson (6) concluded that after the fetus reached four months of age there was an increase in the percentage of fat in milk above the normal increase due to advance in the stage of lactation. No attempt was made to measure this change, but it was stated that this additional rise could be expressed as an exponential change.

The effect of oestrum upon the butterfat test, stated by Doane (1) and Hooper and Bacon (11), is quite variable, according to the temperament of the cows and, at the most, affects the test for only a few milkings.

Considerable literature has been published upon the possible effect of different feeds on the percentage of fat. This material, as summed up by Eckles (2) and Turner (15), established the conclusion that the kind of feeding has no permanent influence upon the percentage of fat in milk, altho the feeding of a ration high in oil or protein may influence the test for a time.

Eckles and Palmer (4) and (5) found that overfeeding had no influence upon the percentage of fat. Underfeeding tended to increase the percentage depending upon the state of flesh of the animal and the degree of underfeeding which followed freshening. In this connection Eckles (3) states that, while cows in a fat condition at the time of freshening had an increased percentage of fat in their milk, cows that freshened in a poor or thin condition did not show a higher test at the time of freshening.

Influence of age upon the percentage of fat in milk, according to White and Judkins (17), is so slight that other more significant influences may offset it. Gowen (7) states that the butterfat percentage seems to decline uniformly but slightly with age.

EXPERIMENTAL METHODS

OUTLINE OF THE STUDY

This work reports the results of a study of the variations in the fat test of all milking cows in the station herd, with the exception of those producing for less than four months from the beginning of the experiment. The number of cows so included ranged from 37 to 53 with an average of 43. The primary object of the study was to observe the correlation between variations in the fat test and variations in the environmental temperatures. Other factors known to affect the fat test were also considered as contributing causes in the variations in the fat test.

This study is based upon a year's records beginning November 2, 1925. All data have been obtained upon a weekly basis. Each experimental week began with Monday records. The data obtained include average temperatures inside and outside the barn during each week, average daily milk production and the average butterfat test for the week. Computations were also made from the herd record of each cow to give weekly data on her age, stage of lactation, stage of gestation and condition.

SOURCES OF DATA

Recording thermometers were used to obtain the environmental temperatures. One recording thermometer was placed in the milking barn and the other was placed in a shaded situation on the north side of the barn. The value for the average weekly temperature was the average of the readings from the thermometer charts at the hours of 6:00 a. m., noon, 6:00 p. m. and midnight of each day of the week. A previous trial had been made comparing the weekly average based upon observations at these hours with an average based upon hourly readings during the week. It was found that the weekly average from the four daily readings varied little from an average of hourly readings during the week.

The weekly Babcock test of the milk from each cow was obtained from a composite sample from each milking during the week.

Milk production was expressed in terms of average daily production for the week.

The number of days in lactation for each cow was calculated as the number of days from the date of freshening to the last day of the week under consideration. The stage of gestation was calculated in the same manner from the date of service.

The figure for the age of each cow was that of her age in years, regardless of additional months, at the time she entered the experiment. A year was added to her age on the week in which her next birthday occurred. In this way cows classed as 4-year olds, for instance, would average approximately 4.5 years in age.

The value for condition, or gain or loss of live weight, was obtained from the regular monthly weights on the cows in the herd. These were taken on three consecutive days in the middle of each month. The figure for condition on each cow is the difference in weight from one month to another. This value for condition was used for the weeks included between the two monthly weighing dates.

MANNER OF HANDLING DATA

Nearly all data were coded for ease in computation. Season, age and condition were coded by grouping into less than 10 class intervals. The butterfat test was multiplied by 10 to remove the decimal. The other variables were divided into approximately 20 class intervals.

Results of this study are presented both graphically and thru correlation studies. A graph shows the situation practically at a glance while a statistical study gives a more precise interpretation of the results and, thru regression coefficients, gives a measure of the individual influence of the several characters.

There is such a difference in the breed characteristics regarding the average butterfat test and quantity of milk produced that it was considered advisable to keep separate the data for each breed.

GRAPHICAL INTERPRETATION OF RESULTS

A series of graphs has been made showing the changes in the average butterfat test that occur with changes in the various factors believed to influence the fat test. However, the graphs showing the variations in the fat test with variations in each factor do not take into consideration the possible influence which other factors may have had upon the butterfat test. To illustrate, the curves in the first graph show the seasonal trends of variations in the fat test, but they do not take into consideration nor involve corrections for the possible effect which may have been exerted by other factors.

VARIATION WITH SEASON

The study was made of the trend of the variations in the butterfat test with the changing seasons. The weeks in each season were divided so as to furnish eight seasonal groups, thus giving a more detailed grouping than four seasons and allowing for more points to plot on the graph. As weeks fail so widely to correspond with monthly divisions, grouping by months would have been awkward.

TABLE II. THE DIVISION OF THE EXPERIMENT INTO SEASONAL GROUPS

Season	Beginning	Ending	No. of weeks
Fall 2nd half	Nov. 9, '25	Dec. 20, '25	6
Winter 1st half	Dec. 21, '25	Feb. 7, '26	7
Winter 2nd half	Feb. 8, '26	March 21, '26	6
Spring 1st half	Mar. 22, '26	May 9, '26	7
Spring 2nd half	May 10, '26	June 20, '26	6
Summer 1st half	June 21, '26	Aug. 8, '26	7
Summer 2nd half	Aug. 9, '26	Sept. 19, '26	6
Fall 1st half	Sept. 20, '26	Nov. 1, '26	7
	Nov. 2, '25	Nov. 8, '25	

Table II shows the period covered by each of these seasonal groups.

It has been reported in literature previously cited that the butterfat test was normally lower in summer than in winter. The curves on fig. 1 show such to have been the trend in this trial.

The behavior of each curve is very similar, except that there happens to be a rise in the butterfat test for the Guernseys from the last half of spring to the first half of summer.

Taking all breeds into consideration, the period for the lowest butterfat test was in the second half of summer which in-

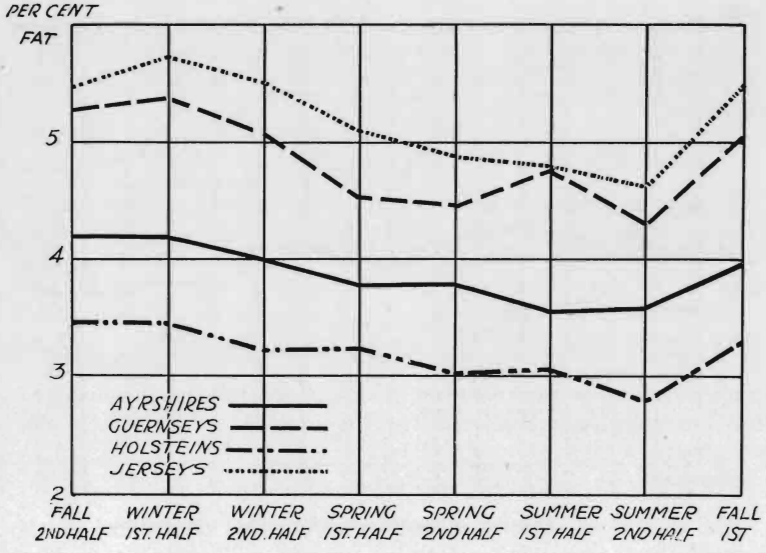

Fig. 1. Variation of the fat test with season

volves August and early September, altho the Ayrshires tested slightly lower during the first half of summer. In like manner, the highest average butterfat tests occurred during the first half of winter or in January. From this period to the second half of summer the percentage of fat declined constantly, and then increased rapidly during the fall. Table III gives the extreme range of these seasonal variations in the butterfat test.

TABLE III. EXTREME SEASONAL RANGE IN THE AVERAGE BUTTERFAT TEST, IRRESPECTIVE OF THE POSSIBLE INFLUENCE OF OTHER FACTORS

Breed	Average test during the year	Average test during first half of winter	Average test during second half of summer	Difference	Percent lower in summer
Ayrshires	3.87	4.18	3.58	0.60	14.5
Guernseys	4.81	5.36	4.31	1.05	19.6
Holsteins	3.19	3.44	2.83	0.61	17.7
Jerseys	5.16	5.72	4.62	1.10	19.2

The first half of winter and the second half of summer are used as extremes. This table serves to illustrate the circumstances that occur with the dairyman selling milk who finds his reported butterfat test to be considerably lower in summer than it was during the winter.

VARIATIONS WITH ENVIRONMENTAL TEMPERATURES

The factors of season, outside temperature and inside temperature may be considered as associated causes producing an ef-

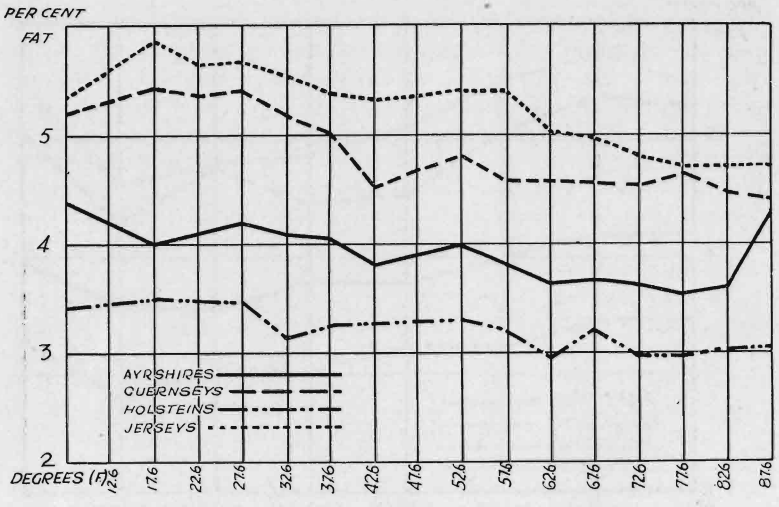

Fig. 2. Variation of the fat test with outside temperature.

fect upon the butterfat test. Fig. 2 shows a tendency for the butterfat test to be lower with higher outside temperature, and fig. 3 shows a tendency for it also to be lower with higher inside temperatures.

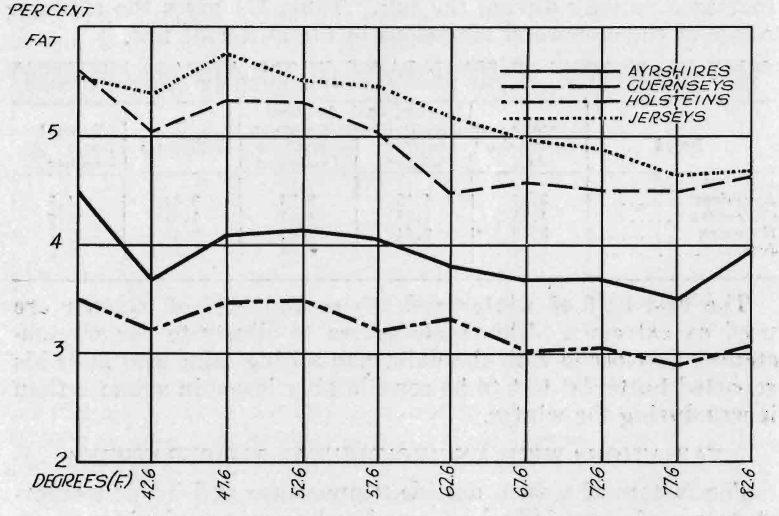

Fig. 3. Variation of the fat test with inside temperature.

High temperatures occurred during the second half of summer, the season having the lowest average butterfat tests. Altho the inside temperature did not go so low in winter as the outside temperature, the two were for the most part directly proportional. The direct proportion between these two was upset a little in the spring and fall thru methods of barn management. When windows and doors were left open in the fall, the inside temperature became quite low and was but a little higher than in the winter when the doors and windows were closed and animal heat conserved.

The sudden rise in the test for the Ayrshires at the outside temperature mark of 87.6 degrees Fahrenheit may be explained as a result of too few observations, as the average included only the records of seven cows for one week. It is also possible that there was a condition similar to that reported by Hays (9) in which he found an actual increase in the fat test somewhere between 70 and 90 degrees.

There was a sudden lowering of the fat test at the point indicated by an inside temperature of 42.6 degrees. The reason for this sudden variation in the butterfat test may be that changes in inside temperature have not at all times followed changes in outside temperature. While changes in outside temperature followed closely the seasonal cycle, changes in inside temperature are controlled partially by barn management. Thus in the fall while doors and windows were left open, the inside temperature on cool nights might have averaged but little higher than it did two months later when the outside temperature was lower, but closed doors and windows kept the barn warmer. It is probable that in the group of records at the inside temperature of 42.6 degrees are included records from spring and fall when tests are lower, altho the records at that end of the curve are mostly winter records. Attributing some effect upon the butterfat test to outside temperature, a number of records with a lower fat test would be involved at this point.

VARIATION WITH AGE

The variation that occurs with age may be dismissed with but little comment. Figure 4 shows no significant trend of the variation of the fat test with age in this one year's study of the problem.

Where there is only a one year's record on each cow, the difference in the fat test that can be attributed to age is slight compared to that caused by individual inheritance and character. For these reasons the study of the variation in the fat test with age is not carried into the correlation studies.

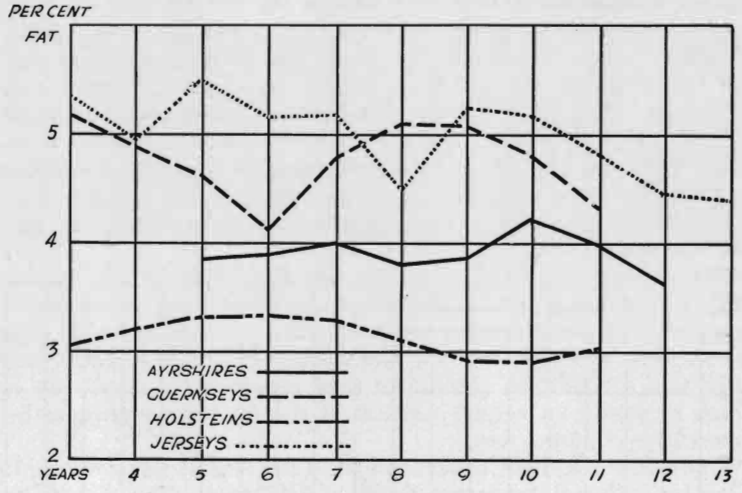

Fig 4. Variation of the fat test with age.

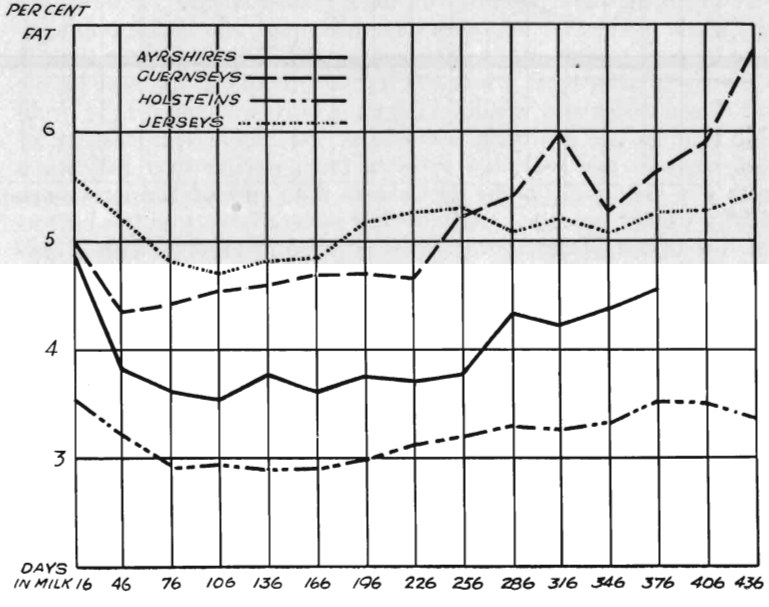

Fig. 5. Variation of the fat test with the stage of lactation.

VARIATION WITH THE STAGE OF LACTATION

In fig. 5 is shown a distinct relationship between variation in the stage of lactation and variation in the butterfat test. However this relationship is not of a linear character and is therefore not satisfactorily handled in statistical correlation studies of a linear character.

The trend of the curves in fig. 5 shows a tendency for the butterfat test to be high immediately following freshening during the period commonly referred to as that of physiological

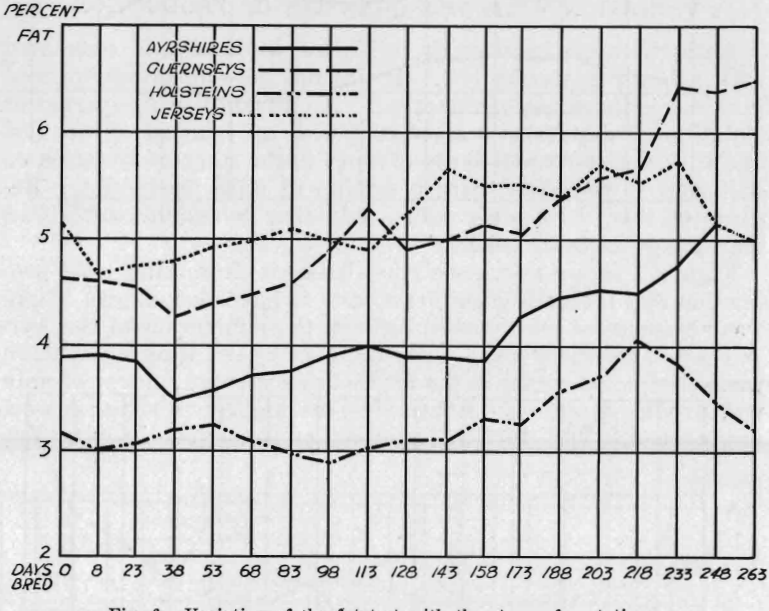

Fig. 6. Variation of the fat test with the stage of gestation.

underfeeding. During the two to four months following freshening the butterfat test declined markedly. For the rest of the lactation period there was a gradual increase.

VARIATION WITH THE STAGE OF GESTATION

Effect of the stage of gestation upon the butterfat test is closely associated with that of the stage of lactation. Figure 6 shows a more nearly linear relationship between the variations of the butterfat test and advance in pregnancy.

The records on cows not bred, indicated by the zero group, show a tendency toward a higher butterfat test. This group includes the high testing records occurring during the first few months of the lactation period. The stage of gestation covers

much of the same time in the production cycle as the stage of lactation, depending upon the time at which the cow is bred. The average time at which the cows in this trial were bred was not until after the third month of lactation. The delay in the start of the gestation period largely eliminates the element of curvilinearity that occurs in the same records when grouped according to the stage of lactation. The variation of the fat test with the stage of gestation, therefore, will be more adaptable to a correlation study.

VARIATION WITH THE QUANTITY OF PRODUCTION

With the same individuals, a higher production is associated with a lower butterfat test. It has not been definitely proved that one is the cause of the other. An advance in the period of lactation or gestation is associated with an increase in the test and it is equally true that an advance in the stage of lactation or gestation is associated with a decline in milk production. Because of this, decreasing milk production is associated with an increasing butterfat test.

Figure 7 shows this association between decreasing milk production and increasing butterfat tests to have been slight. There was no apparent relationship between these factors with the Ayrshires and the Holsteins. With the Jerseys and Guernseys, there was a distinct decrease in the fat test as a greater amount of milk was produced until the figures for the highest production were approached. The highest production occurred in the few

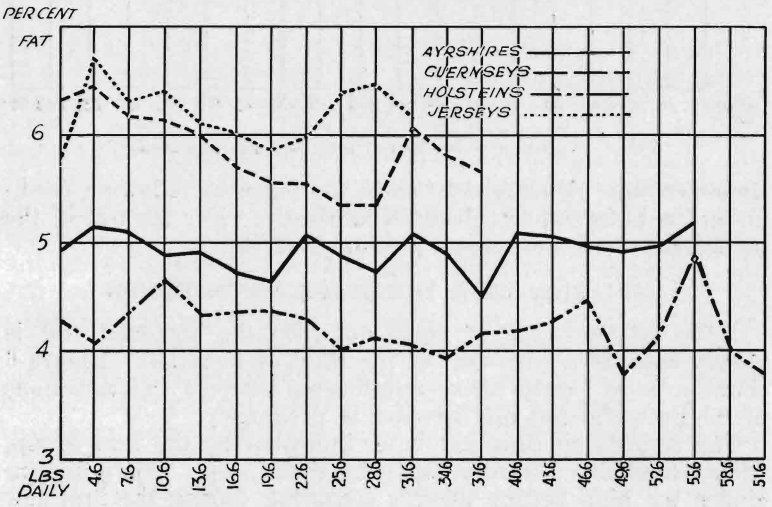

Fig. 7. Variation of the fat test with milk production.

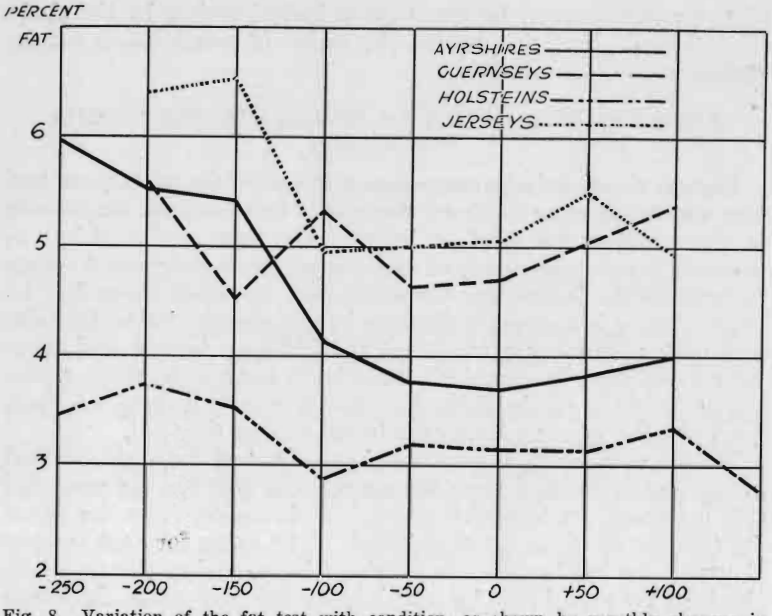

Fig. 8. Variation of the fat test with condition, as shown by monthly changes in live weight.

months following freshening and fig. 5 has shown a higher test at that time.

VARIATION WITH CONDITION

One object sought in the comparison of the trend of the butterfat test with condition was to find the possible effect of weeks when the cows were on short pasture and experiencing a subnormal plane of nutrition as evidenced by a loss in weight. It was also planned to find the possible effect of a high plane of nutrition as shown by a gain in weight.

The most apparent variation shown in fig. 8 is the high test occurring at periods of a rapid loss in weight such as occurs in the period of physiological underfeeding following freshening. As previously observed the fat test is usually higher at this time. A cow during her lactation period loses weight rapidly for a short time; later her loss becomes gradually less until she is maintaining a normal balance and, finally, she gains in weight at the end of the lactation period. With these facts in mind, it is most probable that changes in live weight have been those caused by advance in the stage of lactation, instead of those caused by changes in the plane of nutrition. Thus, it appears that the variations in the fat test measured by condition have been influenc-

ed to a greater extent by the stage of lactation than by the plane of nutrition. For this reason the factor of condition is not included in the later studies.

EFFECT OF THE VARIATION OF ALL FACTORS DURING THE SEASON

Figure 9 shows the average seasonal variations of various factors which influence the butterfat test. In this study the results of these factors for all four breeds have been combined by expressing the average value of each factor for each seasonal group in terms of its percentage deviation from its mean value for the year. There is a great difference in the average butterfat tests and milk producing capacity of the different breeds and these values could not be combined directly to form an average representative of the whole where the records were not from a certain fixed number of cows from each breed during the trial.

Within each breed the average butterfat test for each seasonal group was subtracted from the average fat test for the year and this expressed in terms of percent of deviation from the mean fat test for the year for that breed. The value for each seasonal group for all breeds was obtained by summing the products obtained for each breed by multiplying the percentage deviation of each particular factor by the number of records involved in that seasonal group. Dividing by the total frequency for all breeds for that seasonal group gave the average percentage deviation appearing on fig. 9.

In fig. 9, the curve for the variation of the butterfat test with season is compared to the curves for the seasonal variations of other factors, the factors of age and condition being omitted. According to the literature cited and results of this trial, a rise in the butterfat test would be expected with a fall in outside temperatures, with a lower milk production and with an advance in the stage of lactation and of gestation. A study of the lines on fig. 9 shows how closely these theories may be applied and also shows the results when some causes are in conflict with each other. Undoubtedly the decrease in the average stage of lactation and of gestation has an influence which acted with that of an increase in inside and outside temperatures to lower the butterfat test in the spring. The peak for inside temperature was reached later than for outside temperature.

Figure 10 is an attempt to show the same results as fig. 9 in a simpler manner. The line showing the average variation of the butterfat with changing season is duplicated from fig. 9. However, instead of plotting the variations in the factors influencing the fat test, the probable effect of a change in each has been assumed upon the basis of results in literature cited and in

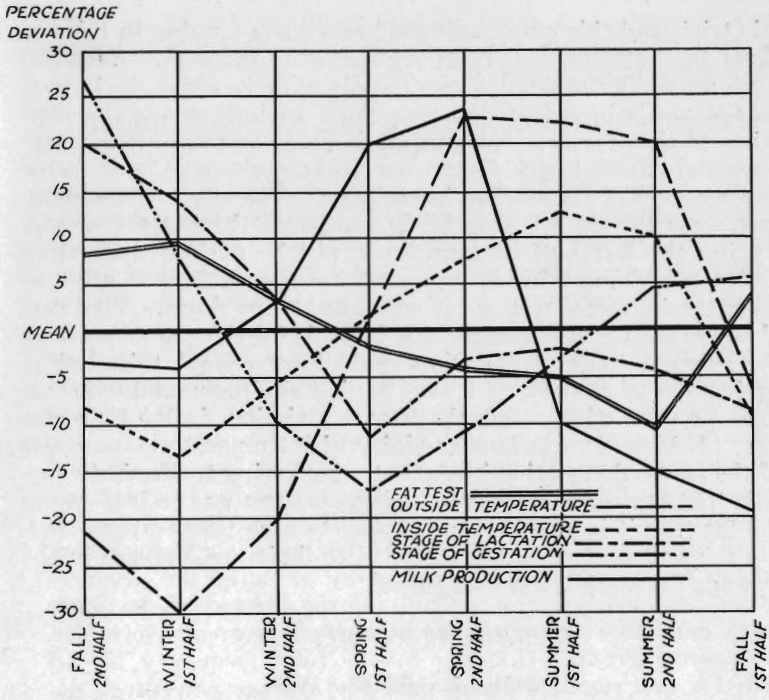

Fig 9. Seasonal changes in terms of average percentage deviation of all factors from their means (outside temperature, inside temperature, and gestation plotted on one-half scale).

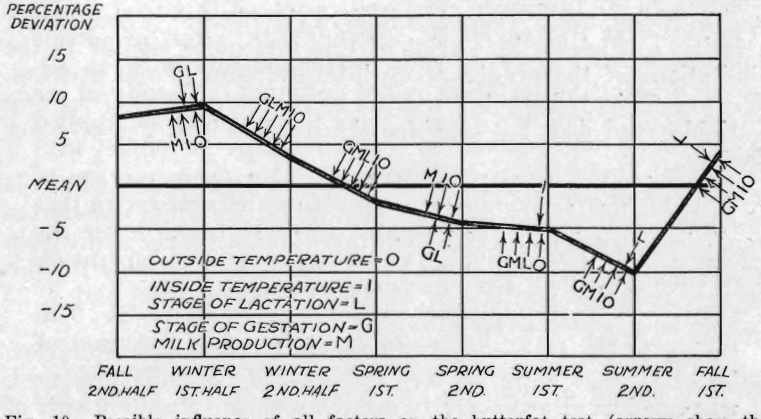

Fig. 10. Possible influence of all factors on the butterfat test (arrows show the expected effect of seasonal variations in each factor toward raising or lowering the fat test).

this trial, and this effect expressed as a force tending to raise or lower the butterfat test from one season to the next. Each lettered arrow on the graph shows the direction in which the butterfat test would be expected to vary from the influence of the variation of that factor. No attempt is made to measure the proportional effect of each factor, nor is the position of each factor any measure of its relative importance. The effect of temperature upon the fat test was fairly consistent thruout the season. During the last half of summer it will be noticed that, altho cooler outside and inside temperatures should have tended to force the butterfat test up, it continued to go down. This furnishes cause for speculation as it is doubtful that an advance in the average stage of lactation could have caused this decline against the other forces. It may be that environmental temperatures do not entirely control seasonal variations in the butterfat test. Eckles (2) mentions humidity with temperature as a cause of the seasonal variation in the test. Referring to Hay's (9) report that at some point above 70 degrees there was an increase in the fat test, it is possible the excessively high temperatures during the first half of summer tended to limit the decrease in the average fat test during that period.

CORRELATION STUDIES

SIMPLE CORRELATION

The next step, in attempting to discover the relationships of the various factors in this problem, was the calculation of simple correlation coefficients. The methods used here, as well as for the multiple correlation studies, were those described by Wallace and Snedecor (16). There is a limited significance to simple correlation coefficients in a trial of this sort quite similar to the limitations of the graphs as an interpretation of the problem. Each coefficient shows but a gross relationship between the two variables and does not consider the possible influence of other factors.

These simple correlation coefficients are listed in table IV. It is hardly advisable to establish any values for these correlation coefficients outside of which limit there is significance and within which there is no significance, but it does appear in table IV that those correlation coefficients which lie between —.25 and +.25 cannot be accepted as significant.

Owing to the pronounced differences in the breed characteristics of average butterfat test and quantity of milk produced, it was considered necessary to make a separate study of each of the four breeds.

There was, in all cases, a distinct negative correlation between

TABLE IV. SIMPLE CORRELATION COEFFICIENTS

	Ayrshires		Guernseys		Holsteins		Jerseys	
	Cor. Coef. r	Prob. error PE	Cor. Coef. r	Prob. error PE	Cor. Coef. r	Prob. error PE	Cor. Coef. r	Prob. error PE
Fat Test—with								
Outside Temp.	—.3033	±.0336	—.3575	±.0277	—.2929	±.0215	—.4693	±.0209
Inside Temp.	—.2916	±.0338	—.3498	±.0279	—.2833	±.0216	—.4780	±.0207
Age	.0515	±.0369	—.0901	±.0315	—.1922	±.0227	—.1885	±.0259
Stage of lactation	—.1136	±.0365	.4783	±.0245	.0649	±.0234	.2772	±.0248
Stage of gestation	.2030	±.0354	.4868	±.0243	.1599	±.0229	.1756	±.0260
Milk production	.0195	±.0369	—.3210	±.0285	—.0683	±.0234	—.1399	±.0263
Condition	—.3633	±.0321	.0728	±.0316	—.0517	±.0235	.1385	±.0263
Milk Production—with								
Outside Temp.	.1744	±.0358	—.1573	±.0310	.2150	±.0225	—.1109	±.0265
Inside Temp.	.2047	±.0354	—.1241	±.0313	.1674	±.0229	—.0532	±.0268
Age	—.0670	±.0368	—.0743	±.0316	—.1740	±.0228	—.0439	±.0268
Stage of lactation	—.6983	±.0189	—.7410	±.0143	—.7309	±.0110	—.6112	±.0168
Stage of gestation	—.5836	±.0244	—.4700	±.0248	—.2926	±.0215	—.4185	±.0221
Condition	—.4327	±.0300	—.3920	±.0269	—.3124	±.0212	—.3340	±.0238
Condition—with								
Stage of lactation	.5358	±.0263	.4444	±.0287	.3887	±.0200	.3047	±.0243
Stage of gestation	.4075	±.0308	.3039	±.0289	.2345	±.0222	.3000	±.0244
Stage of Gestation—with								
Stage of lactation	.7174	±.0179	.7607	±.0134	.3900	±.0200	.2496	±.0252
Inside Temp.—with								
Outside Temp.	.9277	±.0052	.9361	±.0039	.9346	±.0030	.9337	±.0034

both inside and outside temperatures and the butterfat test. In these studies higher correlation coefficients show the butterfat test to be influenced to a greater extent by environmental temperatures than by any of the other factors studied.

Stage of gestation was found to be positively correlated with butterfat test. Other variables are positively correlated in some breeds and negatively in others. It would be expected that the stage of lactation would be correlated with the butterfat test in the same way as the stage of gestation. It does so with the Guernseys and Jerseys, but there is a slight negative correlation between these variables with the Ayrshires and no correlation with the Holsteins. By referring back to fig. 5 it will be observed that there is not a linear correlation between the stage of lactation and the butterfat test. The correlation instead is distinctly curvilinear. For this reason, a linear correlation coefficient has noticeable limitations. Compared to the other breeds, the Ayrshires, during the year of this study, were not so far advanced in lactation and a greater percent of the records are from the first few months of lactation. During the first three or four months following freshening, the fat test usually decreases. Where a large part of the records come from the first few months of lactation, it is natural that there should be a negative correlation. It is possible that there is a breed difference also concerned in this respect. Eckles (2) reports that Holsteins and Ayrshires upon official test feeding show a marked decline from the first to the third month, while Guernseys and Jerseys do not show this so apparently.

The stage of gestation covers practically the same ground as the stage of lactation, except that the stage of gestation starts at a later point in the lactation cycle. This delay leaves out the decline in the butterfat test during the first few months. Thus the stage of gestation begins with the butterfat test at a low point and the result is a consistent, positive linear correlation.

There was so little significance to be attached to the correlation between condition and the butterfat test, and age and the butterfat test, that these two variables are hereafter discarded and the other five used in the multiple correlation studies.

It is interesting to observe the relationships between factors which influence the butterfat test themselves. It will be noticed that there is a high degree of correlation between outside and inside temperatures. In this problem the outside and inside temperatures are thus a measure of the seasonal effect upon the butterfat test. Milk production is negatively correlated with advance in the stage of lactation and stage of gestation. As would be expected these last two are positively correlated with each other.

In this study there are two groups of associated factors. The first is a seasonal group containing the effects of inside and outside temperatures upon the butterfat test. The second consists of factors associated with the production or lactation cycle, namely; stage of lactation, stage of gestation and quantity of milk production. There is, as would be expected, no significant correlation between factors in these two groups.

MULTIPLE CORRELATION

Using the methods of multiple correlation, the simple correlation coefficients were combined to obtain both the multiple correlation coefficients and the regression equations for each breed. It is attempted by these studies to weigh the influence of all factors and in the regression coefficients to arrive at the net influence of each factor on the butterfat test, removing the possible effect of all other factors. The multiple correlation coefficients with their probable errors are shown below.

Ayrshires	$R = .4769 \pm .0285$
Guernseys	$R = .6219 \pm .0195$
Holsteins	$R = .3148 \pm .0212$
Jerseys	$R = .5552 \pm .0185$

These coefficients show a poorer determination of butterfat for the first five variables studied with the Holsteins than with any other breed, in spite of the larger number of observations. It is practically impossible to present an explanation, but the Hol-

stein records contained many observations from cows long in lactation and a greater percentage of the cows were not bred. In all breeds there remains a considerable proportion of the variations in the butterfat test unaccounted for.

The regression equations are given in table V in which $\overline{T}$ is the estimated fat test, **O**, outside temperature in degrees, **I**, inside temperature, **L**, days since freshening, **G**, days since the cow was bred, and **M**, the pounds of milk produced daily. The coefficient of each term in the regression equation is the estimated change in the fat test for each unit of change in that variable. For example, the fat test of the Ayrshires is shown to be reduced .0017 percent for each degree of increase in outside temperature.

TABLE V. REGRESSION EQUATIONS OF FIVE FACTORS INFLUENCING THE BUTTERFAT TEST

Ayrshires	$\overline{T} = 4.7161 - .0017O - .0092I - .003L + .0058G + .002M$
Guernseys	$\overline{T} = 5.3197 - .0103O - .0032I + .0016L + .0026G - .0071M$
Holsteins	$\overline{T} = 3.6651 - .0063O - .0023I - .00017L + .0016G - .00013M$
Jerseys	$T = 6.3493 - .0066O - .0148I + .00016L + .0011G + .0017M$

Altho regression coefficients for outside and inside temperatures are consistently negative, the regression coefficient for the stage of lactation is negative in the case of Ayrshires and Holsteins and positive with Guernseys and Jerseys. Aside from a possible breed difference, these figures may be partially due to the curvilinearity of the regressions. The regression coefficient for the stage of gestation is positive in all cases, indicating this factor to be the most significant in the group concerning the production cycle as long as the effect of the stage of lactation is treated only in a linear way. The regression coefficient for milk production is the least significant of all.

To consider the regression equation as a measure of the relative influence of various factors, it is necessary to know the range of variation thru which each term of the equation may be used.

Table VI is such a study of the regression equation. The subject is treated in the following manner. The extreme range of each variable during the trial was calculated. This range was applied to its corresponding term in the regression equation to give a measure of the maximum effect of each variable upon the butterfat test, assuming that all other factors were held constant.

Thus, with the Ayrshires, the outside temperature had a maximum influence of changing the butterfat test .136 percent and in the same way inside temperature had a maximum effect to change the butterfat test .414 percent during its extreme range. The sum of the two may be considered as a seasonal effect whereby the season was responsible for decreasing the butterfat test .55

TABLE VI. POSSIBLE EFFECT OF SEVERAL VARIABLE FACTORS UPON THE BUTTERFAT TEST APPLYING REGRESSION COEFFICIENT TO EXTREME RANGE OF THE VARIABLE

	Range of the variable and difference between extremes				Maximum effect upon the fat test			
	Ayrshires	Guernseys	Holsteins	Jerseys	Ayrshires	Guernseys	Holsteins	Jerseys
Outside temperature (deg. F.)	7.6– 87.6 80	7.6– 87.6 80	7.6– 87.6 80	7.6– 87.6 80	—.136	—.824	—.504	—.528
Inside temperature (deg. F.)	37.6– 82.6 45	37.6– 82.6 45	37.6– 82.6 45	37.6– 82.6 45	—.414	—.144	—.103	—.666
Stage of lactation (days)	16–376 360	16–466 450	16–466 450	16–466 450	—1.080	.720	—.076	.072
Stage of gestation (days)	0–248 248	0–263 263	0–263 263	0–263 263	1.438	.684	.421	.289
Milk production (pounds)	1.6– 55.6 54	1.6– 37.6 36	1.6– 61.6 60	1.6– 31.6 30	.108	—.256	—.008	.051

percent from winter to summer. With the Ayrshires, inside temperature seemed to be the more important factor in effecting a change in the butterfat test.

With the Guernseys, outside temperature appeared to be the more important factor. Outside temperature thru its extreme range had a possible effect of changing the butterfat test .824 percent. Inside temperature had a possible effect of .144 percent, and the sum of the two in the way of a seasonal influence had a possible effect of .968 percent.

Outside temperature again seemed to have more influence with Holsteins where thru its extreme range it caused a change of .504 percent and inside temperature a change of .103 percent. The seasonal effect of the two together made a possible variation of .607 percent.

The two temperatures had an approximately equal influence with the Jerseys. The range of outside temperature changes caused a variation of .528 percent and the range of inside temperature changes caused a variation of .666 percent. The total seasonal effect was a variation of 1.194 percent.

Total seasonal effect, as measured by the influence of the extreme variations in outside and inside temperatures, is compared in table VII to the actual seasonal variations cited in table III.

TABLE VII. POSSIBLE EFFECT OF SEASONAL CHANGES UPON THE BUTTERFAT TEST

	Seasonal difference from table III (percent)	Difference due to range of outside and inside temperature variation (percent)
Ayrshires	.60	.550
Guernseys	1.05	.968
Holsteins	.61	.607
Jerseys	1.10	1.194

The extreme seasonal variation in the butterfat test, due to the influence of temperatures, amounted to 14.4 percent of the mean fat test for the year for the Ayrshires, 20.1 percent for the Guernseys ,19 percent for the Holsteins and 23.1 percent for the Jerseys. In considering the seasonal variation from this angle, it may be concluded that there is practically no difference in the manner in which variations in environmental temperature affect the percentage of fat in the milk of different breeds.

The stage of lactation and stage of gestation are shown in table VI to have a considerable influence upon the butterfat test. However, it is unfortunate for the possible reliability of the use of the terms for the effect of the stage of lactation that some coefficients are negative. The regression coefficients give the quantity of milk production in itself little influence upon the butterfat test. Evidently milk production and butterfat test are associated, principally thru their common relationship to the factors of stage of lactation and stage of gestation.

LITERATURE CITED

(1). DOANE, C. J.
1904. The Character of Milk during the Period of Heat (Oestrum). Bul. Md. Agr. Exp. Sta. 68.

(2). ECKLES, C. H.
1924. Dairy Cattle and Milk Production. 406-427.

(3). ECKLES, C. H.
1912. Influence of Fatness of Cow on Fat in Milk. Bul. Mo. Agr. Exp. Sta. 100.

(4). ECKLES, C. H. and PALMER, L. S.
1916. Influence of the Plane of Nutrition of the Cow upon the Composition and Properties of Milk—Influence of Overfeeding. Res. Bul. Mo. Agr. Exp. Sta. 24.

(5). ECKLES, C. H. and PALMER, L. S.
1916. The Influence of the Plane of Nutrition of the Cow upon the Composition and Properties of Milk and Butterfat—Influence of Underfeeding. Res. Bul. Mo. Agr. Exp. Sta. 25.

(6). GAINES, W. L. and DAVIDSON, F. A.
1926. Rate of Milk Secretion as Affected by Advance in Lactation and Gestation. Bul. Ill. Agr. Exp. Sta. 272.

(7). GOWEN, J. W.
1923. The Effect of Age on the Milk Yield and Butterfat Percentage of Guernsey A. R. Cattle. Bul. Me. Agr. Exp. Sta. 311.

(8). GRADY, R. I.
1917. Stage of Lactation Affects Milk Yield. Mo. Bul. Ohio Agr. Exp. Sta. 2:401-406.

(9). HAYS, W. P.
1926. Effect of Environmental Temperature on the Percentage of Fat in Cows' Milk. Jour. Dairy Sci. 9:219-235.

(10). HILLS, J. L.
1892. The Effect of Weather upon the Quality and Quantity of Milk. Ann. Rpt. Vt. Agr. Exp. Sta. 1892, 128.

(11). HOOPER, J. J. and BACON, P. E.
1921. Influence of Oestrum or Heat on the Production of Milk and Butterfat. Bul. Ky. Agr. Exp. Sta. 234.

(12). RAGSDALE, A. C. and BRODY, SAM
1922. The Effect of Temperature on the Percentage of Fat in Milk—First Report. Jour. Dairy Sci. 5:212-215.

(13). RAGSDALE, A. C. and TURNER, C. W.
1922. The Stage of Lactation as a Factor in the Variation of the Percent of Fat in Cows' Milk. Jour. Dairy Sci. 5:22-26.

(14). RAGSDALE, A. C. and TURNER, C. W.
1922. The Seasonal Variations of the Percentage of Fat in Cows' Milk. Jour. Dairy Sci. 5:544-554.

(15). TURNER, C. W.
1924. Factors Affecting the Percentage of Fat in Cows' Milk. Bul. Mo. Agr. Exp. Sta. 222.

(16). WALLACE, H. A. and SNEDECOR, G. W.
1925. Correlation and Machine Calculation. Official Publication Iowa State College 23:35.

(17). WHITE, G. C. and JUDKINS, H. J.
1918 Variations in the Fat, Solids-not-Fat, and Total Solids in Cows' Milk. Bul. Conn. (Storrs) Agr. Exp. Sta. 94.

(18). WOODWARD, T. E.
1923. Factors Influencing Percentage of Fat in Milk. Jour. Dairy Sci. 6:466-478.

(19). WYLIE, C. E.
1925. The Effect of Season on the Milk and Fat Production of Jersey Cows. Jour. Dairy Sci. 8:127-131.