THE PROTEIN AND SOLIDS-NOT-FAT CONTENT IN THE MILK OF JERSEY COWS

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THESIS

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THE PROTEIN AND SOLIDS-NOT-FAT CONTENT IN THE MILK OF JERSEY COWS

By

LAWRENCE W. SPECHT

AN ABSTRACT

Submitted to the School of Graduate Studies of Michigan State University of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

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ABSTRACT LAWRENCE W. SPECHT

The investigation was concerned with the protein and solids-not-fat content in the milk of individual cows. These components have assumed an increased importance in the milk pricing picture. The object of the study was to determine how these constituents vary and what factors cause them to fluctuate.

Two herds of Jersey cows were sampled. An inbred herd of twenty-three cows and a randomly-bred herd of twelve cows provided 475 and 259 samples respectively for analysis. The samples were drawn at bi-weekly intervals over a fifteen month period.

The fat content was determined by the Babcock method, the total solids by the Mojonnier, and the protein by the Pyne modification of the formol titration. The solids-not-fat value was obtained by difference.

Comparisons of the morning and evening samples from the randomly-bred herd showed no significant differences in the content of the fat, protein, total solids, and solids-not-fat. The morning milking yielded a significantly larger quantity of milk.

The inbred herd produced significantly more pounds of milk and protein per cow per day. Significant differences were found for the protein and solids-not-fat content in favor of the inbred herd. It could not be determined whether heredity or environment had the greater influence on these values.

Analysis of the data by seasons indicated that the highest values for fat, protein, total solids, and solids-not-fat were reached during the winter months and that the lowest values occurred in the summer months.

The second month of lactation yielded the highest values for milk production and the lowest figures for the milk solids studied. A gradual decline in milk production and a concurrent rise in the milk solids occurred from the second until the tenth month of lactation.

Individual lactation records of each cow's protein production were kept. Twelve complete lactations and twelve 180-day records (extended to 305 days) were available for study. The number of sires' daughters and dam-daughter comparisons were too small to justify any conclusions.

The effect of bi-weekly, monthly, and bi-monthly testing programs on the accuracy of the pounds of protein produced per cow in a single lactation was considered. The values obtained from the bi-weekly testing intervals were used as a basis for comparison. Values from the monthly and bi-monthly testing intervals were in excellent agreement with the figures obtained from the bi-weekly testing interval.

ABSTRACT LAWRENCE W. SPECHT

Regression and correlation values were calculated among the fat, protein, and solids-not-fat values for the two herds and for the pooled data. Although of limited value because of the small number of samples involved, these values indicated the herds studied were representative of the Jersey breed.

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INTRODUCTION

Milk is an excellent source of high quality protein. However, most milk has been purchased on the basis of its butterfat content with little regard for the value of its non-fat solids. The dairy industry is slowly changing its pricing system to pay on the basis of the solids-not-fat and fat content in milk. In order to give a more equitable share of the pricing load to the solids-not-fat portion, we must know more about the levels of protein and solids-not-fat produced by the individual cow. It should be determined how these levels vary and what factors cause them to fluctuate.

Occasionally, herds produce milk which falls below the legal limit for solids-not-fat. Until recently, this problem has received more attention in England than in this country. Ways of improving the solids-not-fat levels of such herds are being sought.

To avoid being penalized for milk low in the non-fat solids, the dairyman must either pay a premium for cows that produce at the higher levels for the non-fat solids and/or provide an environment that will encourage the ultimate in solids-not-fat production. In this respect, the information available from prior research studies is not useful to the dairyman. Most research work on the non-fat solids was collected before 1940 and was based either on an inadequate number of samples or was drawn from mixed herd milks.

For these reasons, this study is concerned with the protein portion of milk and its relationship to the non-fat solids. The assumption is made that protein is the most important of the non-fat solids and that it is a reliable indicator of the total solids-not-fat. Richardson (1952) stated that the protein percentage bears a definite relationship to the solids-not-fat percentage, and, that if the former is known, the latter may be calculated with a high degree of accuracy. Such a relationship makes it possible to increase the solids-not-fat level by manipulating the protein level.

The major purpose of this study is to obtain information on protein and solids-not-fat levels in the lactations of individual cows. Some of the points that will be considered are variations between night and morning milkings, herd differences within a breed, and variations due to season and stage of lactation. In addition, comparisons will be made of the accuracy of calculating the total protein production of a lactation from two-week, monthly, and bi-monthly testing periods. Interrelations among the non-fat solids, fat, and protein percentages will be calculated.

REVIEW OF LITERATURE

A large number of factors that influence the protein and solids-not-fat content of cow's milk have been reported in the literature. This review will discuss only those major factors likely to affect a cow's normal lactation. These may be divided into two groups:

(1) conditions due to the individual cow, arising from either her genetic or physiological make-up. Breed and strain within a breed are considered genetic factors, governed by heredity, in contrast to the physiological states of age and stage of lactation.

(2) conditions due to environmental factors. These may or may not be readily controlled by the dairyman. The plane of nutrition and the milking practices followed are easily adjustable by the dairyman, while it is more difficult to influence the effects of disease and season on protein and solids-not-fat production.

The factors listed above will be discussed separately, although they overlap in their effect on the protein and solids-not-fat levels of individual cows.

Heredity

A major portion of the variation found in the protein and solids-not-fat levels among individual cows is attributed to heredity. Bailey's review (1952) stated that there is little reliable information on the variation of the non-fat solids. He believed that the widely-held assumption that the level of the solids-not-fat fraction in milk tends to be similar for dams and their daughters depends primarily on the fact that different breeds tend to produce at different and characteristic levels.

However, Bonnier and Hansson (1946) statistically analyzed the data from 2,245 samples from 29 monozygotic twin pairs and reported the percentages of protein at fixed values of fat percentage are equal for two identical twins, not equal for two fraternal twins, and very unequal for two unrelated animals. This was also the case with lactose. It was concluded the relationships between the fat, protein, and lactose are determined largely by inheritance. Further work on this study reported by Hansson and Bonnier (1949) substantiated their earlier findings. These authors stated that the possibility of using this fact in practical breeding depended upon the feasibility of determining the protein and lactose components of the milk in the field. Richardson, Young, Dalal, Pearce, and Narula (1953) suggested the use of the formol titration for protein as a possible solution to this problem.

Moore and Keener (1942) believed "proven sires could be used to raise the percent of solids-not-fat in herds low in this respect. They suggested that by selecting bulls with the ability to transmit high solids-not-fat and by eliminating mastitis it would be possible to improve the compositional quality of herd milk. Rowland (1938) and Bailey (1952) made similar statements.

The workers cited above outlined the effect of heredity on the production of the non-fat solids, but they did not give heritability estimates for these constituents. The Swedish workers, with their monozygotic twin studies, are probably the most advanced in this area of study, and Hansson (1955) has suggested privately that the heritability value for protein is close to that of the fat percentage. The most used figure for the heritability of fat percentage is 0.4. This is sufficiently high to allow definite progress to be made in raising the protein and, therefore, the solids-not-fat levels by breeding procedures. These facts form a basis for much of the work that must be done on the influence of heredity.

Breed

The obvious examples of hereditary are the breed of cattle and the strains or individuals within a breed. In order to discuss variations of protein and solids-not-fat content, it is necessary to establish representative levels for the various breeds. The data on breed variation is voluminous and well-substantiated. A summary, Table I, published by Overman, Garrett, Wright, and Sanmann,

TABLE I

BREED VALUES FOR PERCENTAGES OF FAT, PROTEIN, AND SOLIDS-NOT-FAT

	Fat %			Prot. %			S.N.F. %		
N*	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Ayrshire									
208	2.92	5.66	4.14	2.92	4.58	3.58	7.20	10.38	8.94
Brown Swiss									
428	2.92	6.48	4.02	2.60	5.74	3.61	7.99	11.44	9.40
Guernsey									
321	3.65	7.66	5.19	2.65	5.45	4.02	8.19	11.10	9.68
Holstein									
268	2.60	6.00	3.55	2.44	6.48	3.42	7.82	11.90	8.97
Jersey									
199	3.28	8.37	5.18	2.93	5.83	3.86	7.68	11.07	9.51

* Number of samples

(1939) gives the minimum, maximum, and mean values for the five major breeds for the percentages of fat, protein, and solids-not-fat. These authors stated that the results, especially in regard to the relationships between the various components, are representative of the milk of each breed of cows studied. A discrepancy does exist in the values given for the Jersey and Guernsey fat percentages, when compared to what is considered normal.

Jersey Breed

This study deals specifically with the Jersey breed, hence a more detailed review of existing data is presented.

One of the earliest investigations was reported by Collier (1891). The average fat percent on 238 samples of Jersey milk was 5.61, while the solids-not-fat percent averaged 9.80. Collier did not list protein as such, thus its value cannot be compared with the figures given in later studies. A figure of 3.91 percent was given for casein content, although this makes the total protein figure rather high. Collier's values are higher for the average composition of fat and solids-not-fat than the Illinois data cited.

Sherman (1906) reported on a five year study on 600 grade and registered Jerseys. The data involved the analysis of 60 monthly samples. The samples were accurate composites of the milk, produced by the herd at a single evening's milking. The data were given as averages for each month, with the lowest values for all components of the milk occurring in July. The highest figures for the various constituents were found to occur in the months of December, January, and February. Table II gives the minimum, maximum, and average values reported by Sherman for fat, protein, and solids-not-fat.

Reder (1938) of Oklahoma gave protein percentages for normal Jersey milk, with a range of from 3.33 ± 0.04 (in the second month) to 3.85 ± 0.07 (in the eleventh month) for complete lactations. These data were compiled from a single herd, utilizing 290 samples. The mean protein percentage was 3.60 ± 0.02.

TABLE II

FAT, PROTEIN, AND SOLIDS-NOT-FAT VALUES
REPORTED BY SHERMAN

	Minimum	Maximum	Average
Fat %	5.24	5.57	5.42
Protein %	3.49	3.85	3.66
S.N.F. %	8.96	9.43	9.22

The Arizona study by Davis et al (1947) on two 30 cow Jersey herds gave a minimum value of 2.9 percent, a maximum value of 3.9 percent and an average of 3.5 percent for protein. These figures are lower than those shown in most other references. The authors suggested that the higher temperatures which exist in the Southwest could have had a depressing effect on the protein and solids-not-fat levels.

One of the most recent compilations is Richardson's summary (1953) of data reported by the California, Illinois, and Oregon Experiment Stations. For milk samples that tested from 4.0 to 7.0 percent butterfat, the comparable range in protein values was from 3.56 to 4.15 percent on 1,081 samples. Twenty-six samples of Jersey milk, testing below 4.0 percent, were omitted from the tables.

The minimum, maximum, and average protein percentages for Jersey milk reported for the work cited are summarized in Table III. These data suggest the mean protein percentage

TABLE III

SUMMARY OF JERSEY PROTEIN VALUES

Reference	Minimum	Maximum	Average
Sherman	3.49	3.85	3.66
Overman et al	2.93	5.83	3.86
Reder	3.33	3.85	3.60
Davis et al	2.90	3.90	3.50
Richardson	3.56	4.15	----

for normal Jersey milk is in the range of 3.5 to 4.0 percent, but individual values may vary considerably.

Individuals within the Breed

Variations between individual cows of the same breed, under the same environment, suggest that protein percentage is inherited separately from either milk yield or fat percentage.

There are reports in the literature of individuals and strains within a breed producing low levels of solids-not-fat. Davis et al (1947a) mentioned one "cow family" of four individuals, that persistently secreted milk lower in protein than the rest of the animals in a Jersey herd. Most of the reports have been concerned with the solids-not-fat portion of milk rather than specifically mentioning protein in relation to this problem. Rowland (1938) reported "families" within breeds producing low solids-not-fat milk. Richardson and Folger (1950) cited several other researchers who reported abnormally low levels of solids-not-fat that could not be traced to a pathological condition in the udder.

The discussion of abnormal levels of solids-not-fat secretion is centered in two schools of thought. One group believes the heredity factor is of major importance. Others believe that the majority of cows producing milk low in solids-not-fat have some type of udder infection.

Age

The question of changes in milk composition due to age is still unsettled. Bailey (1952) reviewed the work on this factor and reported that several workers found the second lactation yielded the highest quality milk. In this discussion, "quality" refers to the higher levels of non-fat solids. However, Bailey's own work (1952a) showed that the first lactation produced the highest non-fat solids values, and that the quality of milk declines slightly as the cow advances in age. This viewpoint is supported by the work of White and Drakely (1927) and Bartlett (1934). One might conclude that younger animals produce higher quality milk, and age does affect slightly the level of solids-not-fat. Rowland (1938) suggested that some of the decrease may be due to a higher incidence of udder infections (mastitis) in the older cows. While many older cows show no outward signs of infection, their milk is often lower in quality than the average for the herd. Foot and Shattock (1938) reported that often infection cannot be detected by casual examination on the farm. Laboratory methods are necessary to locate this "sub-clinical" infection. These findings would suggest that many more of our dairy cows are afflicted with some type of udder infection than we normally think of as having "mastitis."

Bonnier and Hansson's work (1946) with monozygotic twins is not in complete agreement with the work previously cited. These workers found that the differences between first and second lactations, in regard to percent of lactose and percent of protein (which make up the bulk of the solids-not-fat), were to a large extent due to random variations. They concluded, "If any differences in protein percentage between the first and second lactations did exist at all, they were so small that they could be ignored." These authors stated that by analogy the same conclusion could be drawn concerning differences between all lactations, and, therefore, all the lactations in their study were pooled for statistical treatment. It was also stated that most of the samples were drawn from first and second lactation cows. Therefore, their information on older cows was limited, and the study was not complicated by a high incidence of mastitis in these older individuals.

Stage of lactation

Protein and solids-not-fat content during a lactation period vary in the same direction as the fat percentage, but not necessarily in the same relationship. Azarme (1938) and Bailey (1952b) both showed a decreasing level of solids-not-fat for the first four to six weeks of the lactation. A gradual rise occurred from the second month until the late stages of lactation, when a sharp rise occurred in the solids-not-fat curve. Bailey and Azarme agreed that pregnancy is a major factor, affecting the time of the sharp rise of the curve.

Davis et al (1947b) stated that the protein content of the Jersey milk decreased 11.57 percent during the first month of lactation and increased 8.99 percent from the second month until the end of the lactation. Bailey (1952b) showed that the levels of solids-not-fat appear to be similar for both barren and pregnant cows for the interval from the middle of the second month to the middle of the sixth month of the lactation. However, he cautioned against using either end of the lactation curve for making repeated observations. When measuring individual differences, samples should be drawn from the first 180 days production in order to avoid the error induced by stage of gestation.

Nutrition

Perkins, Krauss, and Hayden (1932) reported little effect of the level of protein feeding on the composition of milk produced. Davis et al (1947c) observed that cows on marginal rations had essentially normal solids-not-fat. However, recent reviews by Bailey (1952) and Herrmann (1954) reported a number of investigations which showed a marked decline in the solids-not-fat level for cows on low levels of nutrition. English workers Rowland (1944), Bailey (1952c), and Baker and Cranfield (1933) all suggested that low rainfall and high temperatures combine to lower the amount and quality of roughage available for grazing in the summer months. This lowered nutrient intake is often serious enough to cause a decline in the solids-not-fat percentage. Cranfield, Griffiths, and Ling (1927) attributed this summer decline in solids-not-fat to lower lactose values and believed the lower values for solids-not-fat near the end of the winter feeding period were due to lowered protein percentages. Bailey (1952c) and Rowland (1944) also suggested that low levels of solids-not-fat in late winter were due to "low quality" feed. They believed wiser feeding practices and the practice of having a higher percentage of young cows in the late stages of lactation during this period would better enable the farmer to produce herd milk above the legal limit for non-fat solids.

Under normal barn feeding conditions or on good pasture, it is unlikely that nutrient intake would cause any significant change in the levels of protein and solids-not-fat secreted. There is considerable evidence that underfeeding, as, for example, when feed supplies are reduced by drought, reduces the solids-not-fat content of milk.

Milking practices

Variations in the protein and solids-not-fat content of milk due to milking practices have not been extensively investigated. Bartlett (1934) examined the first and last drawn milk at a milking, and found small difference in the protein and solids-not-fat. This is markedly different from the manner in which fat is drawn from the udder. Bailey (1952) cited Bartlett and Kay who investigated day to day variations and found them to be small.

Davidson (1924) and Dicks, Eaton, and Carpenter (1951) reported that interrupted milking for several days did not appreciably affect the protein level of the milk.

Bailey (1952) and many other investigators stated that the morning milk contains a lower level of solids-not-fat than evening milk. It was suggested that this is due to the slightly longer milking interval, resulting in a higher milk yield of slightly lower quality.

In the literature previously cited, the changes due to various milking procedures were small. Many of these practices are not considered good management. It is not likely that proper milking practices would produce any long-term effect on the levels of protein and solids-not-fat secreted by individual cows.

Disease

The only reported work on the effect of disease on the solids-not-fat of milk is related to mastitis infections. It is well-known that acute mastitis drastically alters the composition of milk and makes it unfit for human consumption. This condition occurs less frequently in the well-managed herd and is not the major problem with regard to the long-term levels of protein and non-fat solids production. Rowland (1938) and Foot and Shattock (1938) stated that chronic low grade infections are the most serious dairy problem. These mild infections escape the notice of the dairyman and are detected only by microscopic examination. Rowland (1938) reported the levels of casein and lactose are abnormally low in mastitic milk. This would account for low solids-not-fat values. Rowland found that in seven samples out of nine, low solids-not-fat percentages were due to "subclinical" mastitis. The other two samples Rowland believed to be low in solids-not-fat for physiological rather than pathological reasons. Foot and Shattock (1938) studied 29 herds with over 900 cows in the winter of 1947-48 in England. Those cows secreting milk of less then 8.5 percent non-fat solids were examined closely for signs of mastitis. If the barn inspection did not show obvious signs of mastitis, the sample was sent to the laboratory for examination. Over 60 percent of the cows giving milk low in solids-not-fat had mastitis. There were twice as many cases of "subclinical" infection as there were of the readily apparent type. These authors stated that 60 percent was too conservative a figure and believed that the actual incidence of udder infections was close to 70 percent. The authors reported this conclusion agreed closely with the findings of Rowland and Zein-el-dine (1938). Richardson and Folger (1950) cited Kay, who reported that 80 percent of the English milks low in solids-not-fat could be traced to mastitis. The authors remarked that Kay's work conformed closely to their own unpublished data.

Season

Seasonal effects on protein and solids-not-fat refer to the particular combination of climatic variables which make up an animal's environment for any given period. The following references show that when any combination of climatic conditions exists that causes severe discomfort to the cow or a scarcity of nutrients, the levels of all major milk components will be affected. It is agreed that fat percentage and temperature have an inverse relationship. Protein and solids-not-fat vary in the same direction as the fat percentage, although not as markedly. Regan and Richardson (1938) reported that temperatures above 80-85 degrees Fahrenheit caused a decline in the casein and solids-not-fat values. Sherman (1906) noted that values for protein and solids-not-fat were lowest for the month of July and highest in the months of December, January, and February.

Bakalor of South Africa (1947) and Baker and Cranfield of England (1933) reported a positive correlation between the amount of rainfall and the level of solids-not-fat in milk.

The data suggests that the non-fat solids' values are lowest during the summer months and highest during December, January, and February. Rainfall, humidity, temperature, and the resultant crop of roughage exert a definite influence on milk quality.

EXPERIMENTAL PROCEDURE

The cows used in this study were from two purebred Jersey herds owned by Michigan State University. Twelve cows of a randomly-bred herd were used, primarily for comparison. All the milking animals of an inbred Jersey herd were sampled. Samples were taken for a period of fifteen months, at two-week intervals, alternating between the two herds. These data provided information about the changes which occurred in the composition of the milk with advancing lactation. To avoid the effects of colostrum, milk samples were not drawn during the first twelve days of a cow's lactation.

It was desired to obtain 305 day lactations on all cows. However, the individual calving dates were well distributed throughout the year, and only twelve of the cows had a complete ten month lactation record. The majority of the cows had portions of two lactations represented. It was possible in twenty-four cases to obtain information on the period from calving until the end of the sixth month. The first 180 days include the period Bailey (1953b) suggested for use in making repeated observations.

Most of the individuals of the inbred herd were the offspring of two sires. Ten of the cows in the randomly-bred herd were daughters of a third sire. Thus a comparison could be made of the protein production of the offspring of three sires.

The randomly-bred herd was utilized to obtain information on the variations between morning and evening milkings. The morning and evening samples from the randomly-bred herd were analyzed separately. The morning and evening samples from the inbred Jersey herd were mixed to give a one day "composite" before being analyzed.

Analytical Methods

Composition. Determinations were made of the percentages of butterfat, total solids, and protein. The solids-not-fat content was calculated by subtracting the fat content from the total solids content. The content of butterfat was determined by the Babcock method; the total solids content was determined by the Mojonnier method.

Formol Titration for Protein. Protein content was found by the Pyne modification of the formol titration, as outlined by Richardson et al (1953). "To 10 ml. of milk at a temperature of 20-25 degrees Centigrade, add 10 ml. distilled water, 0.4 ml. saturated aqueous potassium oxalate, and 1 ml. of 1.0 percent phenolphthalein. Allow to stand about two minutes. Neutralize to a faint but definite end point to compare exactly with a standard prepared by the addition of one to two drops of 0.01 percent aqueous rosaniline hydrochloride solution to

10 ml. of the milk plus 10 ml. water and 0.1 ml. potassium oxalate. The amount of dye to use varies with the natural color of the milk being used. Jersey and Guernsey milks require slightly more than those of the less highly pigmented milks. The color of the standard should correspond to a milk-phenolphthalein color at a pH of 8.3 .

To the neutralized milk, add 2 ml. of clear, well-preserved 40 percent formaldehyde. Neutralize to the same end point as before with 0.1 normal sodium hydroxide. Subtract from this latter titration, the titration of a blank containing 20 ml. water, 0.4 ml. oxalate, 1 ml. phenolphthalein, and 2 ml. formaldehyde. An experimentally determined factor of 1.83 is used to convert the remainder in terms of ml. of 0.1 normal sodium hydroxide to percent protein by weight."

In a number of samples from the randomly-bred herd and in a few samples from the inbred herd, the addition of the potassium oxalate was sufficient to cause these samples to produce the characteristic pink color, when phenolphthalein was added. Therefore, it must be assumed the end point of 8.3 was reached before the initial titration with 0.1 normal sodium hydroxide was begun. This was remedied by adding one or two drops of 10 percent acetic acid to the samples. This caused the pink color to disappear. Richardson (1954) observed a similar phenomenon for the milk of individual cows and stated that it was not necessarily associated with mastitic milk samples. He indicated in the same reference that the method of acidifying back to a pH of 7 before titrating would give a fair degree of accuracy in the formol titration.

For several of the cows, this reaction was consistant throughout their lactations, while with others it would appear and disappear from one test period to another. This is in agreement with the observations of Richardson, reported above.

Cows which gave the reaction described above did not show any visible signs of mastitis. An attempt was made to exclude the milk from any quarter that showed clinical mastitis on sampling day or that had been treated for same within the previous three day period.

Sampling procedure. A sample was taken from the total production of each cow at the morning and evening milkings. Immediately after weighing, the milk was thoroughly mixed and about 450 ml. were placed in a pint milk bottle and capped. All samples were refrigerated at about 40 degrees Fahrenheit until analyzed. Morning and evening samples from the randomly-bred herd were analyzed separately to obtain information on morning and evening variations. The butterfat and protein percentages were determined within the next twelve hours.

All samples were brought to room temperature in a water bath and thoroughly mixed before fifty ml. were removed from each, for use in the formol and Babcock tests.

Duplicate tests were run for the first five months on all formol titrations. The average of the duplicates was used as the protein figure for that particular sample. Repeatability between the two determinations seemed sufficiently good to permit discontinuing the duplicate work. This decreased by one-half the amount of titration work. The remainder of the sample (about 400 ml.) was preserved by adding one mercuric chloride tablet and refrigerating at about 40 degrees Fahrenheit until the total solids percentage was determined. The solids-not-fat percentage was calculated by subtracting the fat percentage from the total solids value (obtained by averaging duplicate samples from the Mojonnier.)

The samples from the inbred herd were handled in the same way, excepting that 400 ml. from both the night and morning milkings were mixed. Fifty ml. of the resulting sample were drawn for the formol and Babcock tests. The remainder was used for the total solids test.

The night and morning samples were mixed without regard to the differences in milk production between the morning and evening milkings. Therefore, the daily averages for this herd are approximations of the true values for the total solids, fat, protein, and solids-not-fat percentages.

Table IV illustrates the comparisons made in this study.

TABLE IV

BREAKDOWN OF FACTORS COMPARED

Subject	Source of Data*	Lb. Milk	% Fat	% T.S.	% S.N.F.	% Prot.	Lb. Prot.
AM vs. PM	R	x	x	x	x	x	x
Herd dif.	I,R	x	x	x	x	x	x
Season	I,R,C	x	x	x	x	x	
Stage of lactation	I,R,C	x	x	x	x	x	
Individual lactations	C	x				x	x
Sires' daughters	C	x				x	x
Testing intervals	C						x
Regressions and correlations	I,R,C		x		x	x	

* R = Randomly-bred herd
I = Inbred herd
C = Combined herd data

RESULTS AND DISCUSSION

The sections concerned with the morning and evening variations, herd differences, and the effects of season and stage of lactation present the mean values calculated for the milk constituents. The differences between the various sample means were tested for significance using the "t" test. Dixon and Massey (1951)

Morning and evening variations

The morning and evening samples from the randomly-bred herd were analyzed separately in order to compare their compositional quality.

Pounds of milk. Two hundred fifty-nine comparisons were made over a fifteen month period with a mean of 12.52 ± 0.32 pounds for the morning samples and a mean of 11.45 ± 0.30 pounds for the evening samples. This difference between the sample means was significant.

Percent of fat. The morning milk samples averaged 5.28 ± 0.07 percent, while the evening samples averaged 5.23 ± 0.11 percent. This difference between sample means for 259 comparisons was not significant.

Percent of total solids. The 259 morning samples averaged 14.75 ± 0.09 percent and the comparable evening values averaged 14.95 ± 0.09 percent. The difference was not statistically significant.

Percent of solids-not-fat. The same number of morning values averaged 9.46 ± 0.04 percent, while the evening values averaged 9.52 ± 0.04 percent. This difference was not significant.

Percent of protein. Two hundred fifteen samples over a twelve month period averaged 4.15 ± 0.03 percent for the morning milk and averaged 4.15 ± 0.04 percent for the evening samples. There was no significant difference between the protein content of the evening and morning milks for individual cows of this herd.

Pounds of protein. Two hundred fifteen samples gave a morning mean value of 0.497 ± 0.013 pounds of protein produced per cow. The evening mean value was 0.455 ± 0.011 pounds. The difference between these means was significant. Since the protein percentage was the same for the night and morning samples, this significant difference in pounds of protein produced was due to the difference in the amount of milk produced at these periods.

Table V summarizes the values reported for morning and evening variations.

These data agree with the usual concept that morning's milk is slightly greater in quantity but lower in compositional quality. However, the lower fat percentage values for the evening samples are contrary to this accepted idea. There were a number of abnormally low butterfat

TABLE V

MORNING AND EVENING VARIATIONS

Factor	No. Comp.	Morning Samples	Evening Samples	"t" value
Lb. milk	259	12.52 ± 0.32	11.45 ± 0.30	2.43*
% fat	259	5.28 ± 0.07	5.23 ± 0.11	0.37
% tot. sol.	259	14.76 ± 0.09	14.95 ± 0.09	1.52
% s.n.f.	259	9.46 ± 0.04	9.52 ± 0.04	1.11
% protein	215	4.15 ± 0.03	4.15 ± 0.04	0.00
Lb. protein	215	0.497 ± 0.013	0.455 ± 0.011	2.35*

* Significant

tests among the evening samples. The milker often was unable to get a complete let down from several members of the herd. A similar behavior occurred in the morning, although not as frequently. Therefore, the lower evening value for fat percentage could reflect the effect of these low testing samples. This observation supports the contention of Richardson and Folger (1950), who stated that milk samples should not be drawn from physiologically disturbed cows.

It can be seen that the protein and solids-not-fat values vary less than do the values for fat and total solids. Since the protein values were nearly alike for this experiment, it must be assumed that lactose was responsible for the difference in the solids-not-fat values.

Differences between herds

The fifteen month test period was divided into five periods: April-June 1954, July-September 1954, October-December 1954, January-March 1955, and April-June 1955. Morning and evening values for the randomly-bred herd, discussed above, were averaged to provide a figure that could be used for comparison with the "composite" values from the inbred herd. The comparisons between the two herds were made by periods, which roughly approximated the seasons of the year. Table VI summarizes the values found for the milk constituents by these three-month intervals for each of the herds.

Period I. The mean value for the percent of butterfat was significantly larger for the randomly-bred herd. The mean percentages of total solids and solids-not-fat were significantly higher in the randomly-bred herd. The inbred herd averaged 2.67 pounds of milk per cow per day more than the individuals of the randomly-bred herd. The figures presented in Table VI for these milk constituents are in agreement with the usual concept that larger quantities of milk contain slightly lower amounts of milk solids. No protein values were available for this period.

Period II. Highly significant values were obtained for the pounds of milk and pounds of protein per cow per day in favor of the inbred herd. The significance of the pounds of protein figure is a result of the difference

TABLE VI

HERD DIFFERENCES BY SEASON

Factor	Randomly-bred Herd		Inbred Herd		"t"
	No.[a]	Mean	No.[a]	Mean	value
Period I April-June 1954					
Lb. milk	44	26.36 ± 1.23	83	29.03 ± 1.16	1.58
% fat	44	5.72 ± 0.14	83	5.35 ± 0.09	2.26*
% t. sol.	44	15.57 ± 0.17	79	14.98 ± 0.11	2.94**
% s.n.f.	44	9.86 ± 0.06	79	9.59 ± 0.03	3.80**
Period II July-September 1954					
Lb. milk	63	21.63 ± 1.16	95	28.82 ± 1.28	4.16**
% fat	63	5.09 ± 0.09	95	5.25 ± 0.08	1.33
% t. sol.	63	14.26 ± 0.18	95	14.68 ± 0.10	2.10*
% s.n.f.	63	9.37 ± 0.07	95	9.43 ± 0.04	.70
% prot.	63	3.89 ± 0.06	95	3.83 ± 0.03	.94
Lb. prot.	63	0.81 ± 0.04	95	1.09 ± 0.05	4.69**
Period III October-December 1954					
Lb. milk	42	23.58 ± 1.45	90	26.25 ± 1.22	1.41
% fat	42	5.14 ± 0.12	90	5.82 ± 0.07	4.89**
% t. sol.	42	14.49 ± 0.18	90	15.50 ± 0.09	4.98**
% s.n.f.	42	9.36 ± 0.09	90	9.68 ± 0.06	3.08**
% prot.	42	4.34 ± 0.09	90	4.47 ± 0.05	1.97*
Lb. prot.	42	1.00 ± 0.05	90	1.14 ± 0.05	2.04*
Period IV January-March 1955					
Lb. milk	55	27.16 ± 1.19	90	24.38 ± 0.82	1.93
% fat	55	5.53 ± 0.10	90	5.93 ± 0.07	3.17**
% t. sol.	55	15.05 ± 0.14	90	15.38 ± 0.08	2.04*
% s.n.f.	55	9.56 ± 0.05	90	9.46 ± 0.03	1.67
% prot.	55	4.22 ± 0.05	90	4.49 ± 0.04	3.91**
Lb. prot.	55	1.13 ± 0.04	90	1.07 ± 0.03	1.16
Period V April-June 1955					
Lb. milk	55	22.03 ± 1.37	117	25.84 ± 0.82	2.38*
% fat	55	5.46 ± 0.17	117	5.54 ± 0.07	.44
% t. sol.	55	14.82 ± 0.19	117	14.90 ± 0.08	.38
% s.n.f.	55	9.38 ± 0.08	117	9.37 ± 0.03	.13
% prot.	55	4.26 ± 0.05	117	4.27 ± 0.04	.14
Lb. prot.	55	0.91 ± 0.05	117	1.08 ± 0.03	3.06**
All Periods April 1954 - June 1955					
Lb. milk	259	23.97 ± 0.59	475	27.09 ± 0.48	4.02**
% fat	259	5.26 ± 0.06	475	5.57 ± 0.04	2.96**
% t. sol.	259	14.86 ± 0.08	471	15.07 ± 0.04	2.90**
% s.n.f.	259	9.49 ± 0.03	471	9.51 ± 0.02	.54
% prot.	215	4.15 ± 0.03	392	4.26 ± 0.03	2.36*
Lb. prot.	215	0.95 ± 0.02	392	1.09 ± 0.02	4.56**

* Significant

** Highly significant

[a] Number of samples

in pounds of milk produced between the two herds, since the difference between the protein percentage values favored the randomly-bred herd but did not approach significance. The inbred herd had slightly higher butterfat, total solids, and solids-not-fat means, but these were significant only for the total solids figure.

The lower figures for both pounds of milk and the percentages of most of the solids calculated for the randomly-bred herd can be assumed to be due at least partially to the number of low fat and low solids-not-fat samples obtained from those cows which did not let down their milk completely.

Period III. The figures for the inbred herd were larger than the figures for the randomly-bred herd for all factors considered, although the difference in pounds of milk produced per cow per day was not significant. Highly significant values were obtained for the percentages of fat, total solids, and solids-not-fat. Significant differences were obtained for the percentage of protein and pounds of protein. It is suggested that lower temperatures contributed to the increased values reported for all of the milk solids, since the inbred herd was housed in a pen-type barn, where the inside temperatures were only slightly above the outdoor temperature. The randomly-bred herd was housed in a conventional stanchion type barn, where the temperature seldom fell below 45 degrees Fahrenheit.

Period IV. The fat, total solids, and protein content again favored the inbred herd. The fat and protein concentrations were highly significant, while the total solids figure was significant. However, the percentage value for solids-not-fat favored the randomly-bred herd, although not significantly. A possible explanation is that the randomly-bred herd samples contained a higher percentage of lactose. This higher lactose content could have been sufficient to overcome the differences between the protein values and to cause the higher solids-not-fat values observed for the randomly-bred herd. Such an explanation is in agreement with the inverse relationship between lactose and protein, shown by Overman, Sanmann, and Wright (1929) and many other research workers. The randomly-bred herd also had higher values for daily milk production and for pounds of protein produced per cow per day, but these values were not significantly different from those of the inbred herd. The lower milk production level for the inbreds is attributed to poorer quality hay and silage fed during the latter part of the winter.

Period V. This period gave herd figures more nearly alike than any of the other test periods. The milk production figure was significantly higher for the inbreds and this contributed to the highly significant value obtained for the pounds of protein produced per cow per day. All other mean values were nearly equal. The "t" values for these constituents were very small. It should be mentioned that both herds were under the same climatic conditions during periods I, II, and V.

All periods. The overall comparisons on 259 samples from the randomly-bred herd and 475 samples from the inbred herd reveal the following points of interest.

The mean value for pounds of milk produced per cow per day by the inbreds was 3.12 pounds greater than the randomly-bred herd value. The figures of 23.97 ± 0.59 pounds for the randomly-bred herd and 27.09 ± 0.48 pounds for the inbred herd refer only to cows in milk. These mean values are not herd averages per cow per day, since dry cows are not included. Any cow giving less than 4 pounds of milk per day was considered dry and not sampled. The difference between the herds is statistically highly significant. These data agree with prior milk production records available on both herds. There is little doubt that the inbred herd members were better producers than the individuals of the randomly-bred herd. In addition, they were more carefully milked and managed.

The inbred herd averaged 5.57 ± 0.04 percent on all butterfat samples. The randomly-bred herd samples averaged 5.26 ± 0.06 percent. This is a highly significant difference and may be accounted for partly by the combination of lower environmental temperatures to which the inbreds were exposed during the winter feeding period and by the large number of abnormally low fat samples produced by the randomly-bred herd.

The mean percentage of total solids for the inbred herd was 15.07 ± 0.04, while the value for the randomly-bred herd was 14.86 ± 0.08. This difference can be accounted for by the difference in the mean fat percentage values. Therefore, for the reasons given above, most of the difference in the total solids values, although statistically highly significant, is likely due to environment rather than to heredity.

The solids-not-fat mean value was 9.51 ± 0.02 for the inbred herd. The mean value for the randomly-bred herd was 9.49 ± 0.03. The difference between the herd means for solids-not-fat did not approach significance. It is not possible to say from the data whether the herds are genetically similar for levels of solids-not-fat or whether the lactose and protein fractions balance one another to give nearly identical solids-not-fat values.

Two hundred fifteen samples from the randomly-bred herd gave a mean of 4.15 ± 0.03 percent for protein, while 392 inbred herd values gave a mean of 4.26 ± 0.03 percent. Statistically this difference is significant. As previously pointed out, differences in protein percentage were greatest during the two cold weather periods (Periods III and IV). The protein values did not show the wide variation found in the fat and total solids values during any of the periods.

The inbred herd produced significantly more protein per cow per day during Periods II, III, and V. The randomly-bred herd produced more during Period IV. A comparison of the 215 samples gave a mean value of 0.95 ± 0.02 for pounds of protein for the randomly-bred herd and a figure of 1.09 ± 0.02 pounds for the inbred herd. This is highly significant and due principally to the difference in milk production.

In this study, the non-genetic factors were not adequately controlled. Therefore, it cannot be stated definitely that the differences in milk composition between the herds were due chiefly to environment. Both herds would have to be housed and managed under the same conditions in order to eliminate the influence of environment.

Season

Much of the data concerned with season have been presented in the discussion on the differences between the herds. Seasonal values by three months' periods are given in Table VI for each herd. In this section of the discussion, the data were combined to give a larger number of samples per season. Table VII presents the means and standard errors for all factors considered by season.

The amount of milk produced per cow per day was highest during the April-June 1954 season, with a mean value of 28.10 ± 0.88 pounds. All other seasonal values were within the narrow range of 24.62 ± 0.72 pounds to

TABLE VII

POOLED SEASONAL VALUES

	Lb. Milk	% Fat	% Protein	% T. Solids	% S.N.F.	Lb. Protein
Apr-Jun 1954						
Samples	127	127	---	123	123	---
Mean	28.10 ± 0.88	5.48 ± 0.67		15.19 ± 0.09	9.69 ± 0.03	
Jul-Sept 1954						
Samples	158	158	158	158	158	158
Mean	25.95 ± 0.97	5.19 ± 0.07	3.85 ± 0.03	14.51 ± 0.09	9.41 ± 0.04	0.98 ± 0.03
Oct-Dec 1954						
Samples	132	132	132	132	132	132
Mean	25.40 ± 0.96	5.60 ± 0.07	4.43 ± 0.04	15.18 ± 0.09	9.58 ± 0.05	1.09 ± 0.04
Jan-Mar 1955						
Samples	145	145	145	145	145	145
Mean	25.44 ± 0.69	5.78 ± 0.06	4.39 ± 0.04	15.25 ± 0.08	9.50 ± 0.03	1.09 ± 0.02
Apr-Jun 1955						
Samples	172	172	172	172	172	172
Mean	24.62 ± 0.72	5.51 ± 0.07	4.26 ± 0.04	14.87 ± 0.08	9.37 ± 0.03	1.03 ± 0.03
Apr 1954-Jun 1955						
Samples	734	734	607	730	730	607
Mean	25.99 ± 0.38	5.46 ± 0.03	4.22 ± 0.02	15.00 ± 0.04	9.50 ± 0.02	1.04 ± 0.02

25.95 ± 0.97 pounds. The differences between these latter values are not considered to be significantly different.

The fat concentration mean value was 5.48 ± 0.07 percent for the April-June 1954 period. The mean value for fat content dropped to 5.19 ± 0.07 for the summer months of July, August, and September. It rose to 5.60 ± 0.07 in the October-December period and increased again during the January-March 1955 period to 5.78 ± 0.06. Most of these two increases were due to the large increase in fat concentration encountered in the inbred herd and discussed in the section concerned with differences between the herds. The average pooled value was 5.46 ± 0.03.

The total solids mean value was highest during the January-March period, averaging 15.25 ± 0.08 and was lowest for the July-September period, averaging 14.51 ± 0.09. This is good agreement with the literature. The pooled mean value was 15.00 ± 0.04 percent.

The solids-not-fat values followed the same overall pattern as the fat and total solids, but did not exhibit as much variation. These values ranged from 9.37 ± 0.03 in the April-June 1955 period to 9.58 ± 0.05 in the October-December 1954 period. The pooled mean value was 9.50 ± 0.02. This agrees closely with the value of 9.49 ± 0.47 found by Combs (1954). The values reported by Overman et al (1939), Davis et al (1947), and Richardson and Folger (1950) are also in good agreement.

The lowest protein values were found in the July-

September 1954 period. Their mean value was 3.85 ± 0.03. This figure agrees closely with the data presented in the literature review. The highest protein values were obtained in the October-December period with a mean of 4.43 ± 0.04. The January-March 1955 period gave a mean percentage of 4.39 ± 0.04. The value for the April-June 1955 period was 4.25 ± 0.04. The pooled value was 4.22 ± 0.02. This value is somewhat higher than the figures cited in the literature review. The range in values was from 2.87 percent to 5.89 percent. The lower figure resulted from a sample drawn in July from a three year old inbred Jersey cow, which was in the second month of lactation. The high value was from a randomly-bred five year old cow in late lactation. This range of values agrees very closely with the one given by Overman et al (1939). Since these values were not obtained from true composites, they are higher than would be expected for mixed herd milk samples.

The pounds of protein produced per cow per day depends mainly upon the cow's daily milk production, rather than on the percent of protein in the milk. In this instance, the daily average values for milk production were nearly identical in all periods, thus, the pounds of protein produced followed closely the changes in the protein percentage. The pooled values averaged approximately a pound of protein per cow per day. No other animal can approach the dairy cow's ability to produce this valuable nutrient.

Stage of lactation

Samples drawn between the twelfth and 365th days of the lactation were sorted into twelve intervals. The first interval included only the samples from the twelfth through the thirtieth day. Ten thirty-day intervals followed. The last interval included samples from the 331st to the 365th day of lactation. A small number of samples from cows in production more than 365 days were omitted from the calculations. Table VIII gives the mean values by stage of lactation for each of the herds and for the pooled data.

The second month of lactation generally gave the lowest values for the milk solids and the highest figures for milk production. A gradual rise occurred in all milk solids percentages from the second month until the tenth month of lactation, while milk production declined slowly. The values for the last two intervals were somewhat irregular because of the small numbers. In addition, some cows were still several months from calving but producing well during the eleventh and twelfth months of their lactation. These cows' samples lowered the percentages for milk solids, but increased the pounds of milk produced per cow per day during the last two intervals.

TABLE VIII

AVERAGE DAILY COMPOSITION OF MILK BY STAGE OF LACTATION

	Days in Lactation											
	12 to 30	31 to 60	61 to 90	91 to 120	121 to 150	151 to 180	181 to 210	211 to 240	241 to 270	271 to 300	301 to 330	331 to 355
Randomly-bred herd												
No.*	14-16	25-26	24-28	23-30	24-32	23-30	22-27	24-26	20-22	11-12	6-8	1-2
Lb. milk	35.2	35.2	32.0	28.2	25.9	21.0	20.5	16.4	13.2	14.0	10.2	9.2
% fat	5.46	5.40	5.29	5.16	5.33	5.36	5.43	5.34	5.39	5.62	5.25	5.70
% prot.	3.83	3.67	3.97	4.19	4.14	4.23	4.24	4.35	4.41	4.71	4.68	4.28
% t. sol.	14.85	14.57	14.55	14.63	14.86	14.77	14.99	14.80	14.71	15.62	14.99	15.60
% s.n.f.	9.41	9.23	9.29	9.52	9.53	9.46	9.67	9.47	9.48	10.03	9.75	9.95
Inbred herd												
No.*	25-30	42-46	40-47	42-51	34-44	35-47	36-47	36-43	37-42	29-34	17-24	10-11
Lb. milk	38.8	39.9	36.4	30.7	27.0	25.5	22.7	21.4	19.0	17.8	16.3	17.1
% fat	5.34	5.12	5.24	5.47	5.49	5.56	5.65	5.92	5.92	5.90	5.76	5.93
% prot.	3.99	3.79	4.04	4.17	4.32	4.37	4.38	4.47	4.54	4.42	4.53	4.45
% t. sol.	14.87	14.41	14.63	14.84	15.02	15.11	15.22	15.51	15.56	15.30	15.53	15.52
% s.n.f.	9.50	9.30	9.36	9.37	9.52	9.55	9.59	9.59	9.64	9.61	9.74	9.64
Pooled data												
No.*	39-46	67-72	64-75	65-81	58-76	58-77	58-74	60-69	57-64	40-46	23-32	11-13
Lb. milk	37.9	38.2	34.8	29.8	26.5	23.7	21.9	19.5	17.0	16.8	14.8	15.9
% fat	5.38	5.22	5.26	5.35	5.44	5.48	5.57	5.70	5.74	5.83	5.63	5.89
% prot.	3.93	3.74	4.01	4.18	4.25	4.32	4.33	4.42	4.49	4.50	4.57	4.43
% t. sol.	14.86	14.46	14.59	14.76	14.95	14.97	15.13	15.24	15.27	15.38	15.39	15.53
% s.n.f.	9.46	9.28	9.33	9.42	9.53	9.51	9.60	9.55	9.58	9.72	9.74	9.69

* First figure refers to the number of samples analyzed for protein percentage.
Second figure refers to the total number of samples analyzed.

Individual lactations

The combined data for this study represents 51 partial or complete lactations from 35 cows. There were 24 lactations that included the first 180 days in milk. Twelve of these were complete lactations, between 275 and 305 days in length. The remaining 12 lactations were cut off at 180 days and factored by 1.43 to allow more comparisons to be made. This is the standard Dairy Herd Improvement Association factor used to extend butterfat records. Eleven cows did not calve so as to allow a sampling of their first six months in milk. Table IX gives the breakdown on all lactations of at least two months' duration.

TABLE IX

NUMBER OF LACTATION FOR HERD MEMBERS

	Lactation Number							
	1	2	3	4	5	6	7	Total
Complete lactations	0	4	2	1	1	2	2	12
180 days (extended to 305)	1	1	4	4	1	0	1	12
All-partial or complete	8	12	12	9	4	3	3	51

The breakdown by lactation number gives an indication of the range in age for the herd members. The majority of the cows were in their second, third, or fourth lactation. Age at calving ranged from one year and nine months to nine years and two months. There were not sufficient numbers within the sub-classes to allow an analysis of the data for the effect of age.

Table X gives a comparison of the 180 and 305 day values for the pounds of milk and protein produced and for the percentage of protein in a lactation. The cows are grouped by sires.

In most cases where 180 and 305 day actual production figures were available for comparison, the percentage of protein for the sampling period increased approximately 0.2 percent. The extension factor of 1.43 does not allow for this increase in protein percentage. Therefore, no values are given for protein content on those lactations extended from 180 to 305 days. For this reason, the values given for pounds of protein on the twelve extended records are low.

Daughter comparisons by sires

Sires I and II were inbred bulls. Sire III was the randomly-bred sire. The individual daughter values are listed in Table X. Sire I had two daughters that completed a lactation and two with 180 day production figures that were extended to 305 days. These four animals averaged 8,281 pounds milk, 338 pounds of protein and 4.08 percent protein. Sire II had four daughters that completed a 305 day lactation and three others that had 180 days in milk. These latter three records were extended to 305 days and the resultant seven lactations averaged 8,747 pounds milk,

TABLE X

MILK AND PROTEIN PRODUCTION IN INDIVIDUAL LACTATIONS

	180 days in milk			Complete lactations			
Cow	Lb. milk	Lb. protein	% prot.	Days	Lb. milk	Lb. protein	% prot.
Sire I							
3	7,585.4	299.0	3.94	305	9,531.4	395.6	4.15
5	6,328.7	258.7	4.09	305*	9,050.0	370.0	-
13	7,277.3	275.2	3.78	275	8,728.1	346.5	3.97
15	4,064.7	168.0	4.13	305*	5,812.5	240.2	-
Sire II							
8	6,651.8	262.5	3.95	305	9,965.4	411.1	4.13
10	4,396.9	201.8	4.59	305*	6,287.6	288.6	-
14	5,581.9	230.6	4.13	305*	7,982.1	329.8	-
16	4,708.6	197.1	4.19	305*	6,730.7	281.9	-
18	6,074.8	234.8	3.87	305	8,174.1	334.4	4.09
19	8,178.8	311.1	3.80	305	10,911.0	437.7	4.01
21	7,258.2	286.2	3.94	305	11,177.0	448.9	4.02
Sire III							
101	5,154.3	224.1	4.35	305*	7,370.6	320.5	-
193	4,766.0	182.6	3.83	305*	6,815.4	261.1	-
196	6,017.1	231.5	3.85	305*	8,604.5	331.1	-
1107	4,365.8	191.8	4.39	284	5,364.0	241.2	4.50
1108	5,361.3	205.7	3.84	286	7,629.0	308.2	4.04
1109	4,942.3	194.9	3.94	305*	7,067.5	278.7	-
1111	5,181.8	214.8	4.14	305*	7,410.0	307.1	-
Various other sires							
2	6,427.8	263.3	4.10	305	8,101.7	347.8	4.29
7	6,713.8	267.9	3.99	305	8,881.0	373.3	4.20
22	4,957.2	204.7	4.13	305*	7,088.8	292.7	-
23	4,974.8	218.2	4.39	305*	7,114.0	312.1	-
176	5,492.7	211.3	3.85	305	7,886.1	315.7	4.00
184	5,670.3	200.3	3.53	305	8,349.1	301.7	3.61

* Extended from 180 days to 305 days with the DHIA factor

362 pounds of protein, and 4.14 percent protein. The small numbers involved prevent drawing any conclusions as to which sire is the more prepotent for high protein production. However, this method could be adopted for proving sires on the basis of the protein production of their daughters.

Sire III had seven daughters in the randomly-bred herd with at least 180 days in milk. Only two of these had a completed production record. It was necessary to extend the 180 day records for the other five daughters. The seven lactations averaged 7,180 pounds milk, 293 pounds of protein, and 4.07 percent of protein.

These data from eighteen daughters with single records (ten of which are extended) are not sufficient to postulate any real differences among the three sires.

The dam-daughter comparisons are given in Table XI.

Testing intervals

The twelve completed lactations and the twelve 180 day lactations which were extended to 305 days were pooled for use in this section. It is realized that the most accurate estimate of a cow's protein production for a lactation results from daily milk weights and daily determinations of the protein percentage. This is not a practical testing procedure for field use. An effort was made to compare the results from a two-week testing interval with those from monthly and bi-monthly intervals. The bi-weekly interval was considered to be the standard, since it

TABLE XI

DAM-DAUGHTER COMPARISONS

Dam	Dau.	Sire	Days milked	Pounds milk	Pounds prot.	Percent prot.
3		I	305	9,531	396	4.15
	8	II	305	9,965	411	4.13
5		I	180*	9,050	370	4.09
	13	I	275	8,728	347	3.97
	21	II	305	11,177	449	4.02
15		I	180*	5,813	240	4.13
	22	IV	180*	7,089	293	4.13
176		V	305	7,886	316	4.00
	1109	III	180*	7,068	279	3.94
184		V	305	8,349	302	3.61
	1108	III	286	7,629	308	4.04

* Extended to 305 days

involved the largest number of samples. The monthly period was considered because of its universal use by Dairy Herd Improvement Associations. The bi-monthly period was used in the hope of saving labor in a large scale sampling program, taking advantage of the small variation shown by the protein percentage. Standard Dairy Herd Improvement Association rules were followed regarding centering dates, days in milk, and the use of back credit. Table XII gives the total pounds of protein for the three testing intervals and the percent of deviation from the two-week values for the monthly and bi-monthly values.

The monthly testing interval gave excellent agreement with the bi-weekly interval method. The range of deviations for the monthly figures from the bi-weekly values was

TABLE XII

POUNDS OF PROTEIN PRODUCED IN SINGLE LACTATIONS
WITH THREE TESTING INTERVALS

Cow	X^a	Y^b	Z^c	% dev. of Y on X	% dev. of Z on X
2	347.84	350.24	342.90	+0.69	-1.42
3	395.58	406.96	407.51	+2.88	+3.02
7	373.32	374.49	386.11	+0.31	+3.43
8	411.08	406.53	405.32	-1.11	-1.40
13	346.53	339.50	337.15	-2.03	-2.71
18	334.37	339.22	345.45	+1.45	+3.31
19	437.67	445.87	438.97	+1.87	+0.30
21	448.91	457.97	456.80	+2.02	+1.76
176	315.73	322.07	331.90	+2.01	+5.12
184	301.73	295.09	313.05	-2.20	+3.75
1107	241.20	242.45	229.44	+0.52	-4.88
1108	308.20	307.83	308.51	-0.12	+0.10
5*	369.96	374.49	377.99	+1.22	+2.17
10*	288.57	285.93	299.54	-0.91	+3.80
14*	329.79	329.47	330.86	-0.10	+0.32
15*	240.17	238.70	248.16	-0.61	+3.33
16*	281.90	287.47	286.40	+1.98	+1.60
22*	292.68	298.34	313.01	+1.93	+6.95
23*	312.07	309.24	313.84	-0.91	+0.57
101*	320.46	312.61	313.86	-2.45	-2.05
193*	261.13	259.66	267.45	-0.56	+2.42
196*	331.10	322.44	344.47	-2.62	+4.04
1109*	278.71	268.71	268.58	-3.59	-3.60
1111*	307.14	293.49	292.25	-4.44	-4.85

* Cows with records extended from 180 to 305 days

[a] Bi-weekly testing intervals

[b] Monthly testing intervals

[c] Bi-monthly testing intervals

from -4.44 percent to a +2.88 percent. The mean percent deviation for the monthly method was + 0.20 percent. The correlation between the two sets of values was .995 . Comparison of the individual values indicates there is no real difference between these two methods. Therefore, the monthly testing interval would be preferred, since it would save labor and the cows could be sampled for protein in conjunction with the butterfat sampling procedure.

Comparison of the bi-monthly interval with the bi-weekly interval gave surprisingly good results. The range in deviations was from -4.88 percent to +6.95 percent. The mean percent deviation was +1.04 percent. The correlation for these two sets of values was .986 .

The bi-monthly method is not as convenient to calculate as the monthly method, but it saves a considerable amount of time and labor in sampling. The fewer the number of samples available on any single lactation, the greater the chance of distortion of the final value by abnormal tests, sickness of the cow, errors of calculation, and other chance factors. As long as the Dairy Herd Improvement program tests on a monthly basis, it will be most convenient to sample cows for protein at the same time the butterfat sample is taken. This is especially true in cases where the cows are milked with a pipeline milker and buckets are used only on the testing day.

Regression and correlation values

The regression and correlation values were determined for the solids-not-fat, fat, and protein percentages in order to compare these figures with the results from other studies. These values were calculated on each of the two herds and also on the pooled data. Table XIII gives the regression and correlation values.

The regression value calculated for the estimation of the protein percentage from the fat percentage from the randomly-bred herd data was Y = 3.27 + 0.890 X, for the inbred herd Y = 2.08 + 0.388 X, and for the pooled data Y = 2.67 + 0.281 X. The corresponding simple correlations were +0.34, +0.61, and + 0.50. Overman et al (1939) gave a regression value of Y = 2.40 + 0.282 X for protein on fat from Jersey milk samples and a correlation of +0.53.

The regression value of the solids-not-fat percentage on the fat percentage was Z = 8.33 + 0.216 X for the randomly-bred herd, Z = 6.91 + 0.465 X for the inbred herd, and Z = 7.80 + 0.307 X for the pooled data. The correlations were +0.40, +0.68, and +0.50 respectively.

The regression most often mentioned in the literature is the one calculated by Jack, Roessler, Abbott, and Irwin (1951), which is Z = 7.11 + 0.444 X or the percent of solids-not-fat equals 7.11 plus 0.444 times the percent of fat. This value was calculated from mixed herd milk without regard to breed. The widely quoted equation of

TABLE XIII

REGRESSION AND CORRELATION VALUES
AMONG FAT, PROTEIN, AND SOLIDS-NOT-FAT PERCENTAGES

	Regression	Correlation
Randomly-bred herd	Y = 3.27 + 0.890 X	+0.34
	Z = 8.33 + 0.216 X	+0.40
	Z = 6.92 + 0.602 Y	+0.56
Inbred herd	Y = 2.08 + 0.388 X	+0.61
	Z = 6.91 + 0.465 X	+0.68
	Z = 6.96 + 0.589 Y	+0.67
Combined herds	Y = 2.67 + 0.281 X	+0.50
	Z = 7.80 + 0.307 X	+0.50
	Z = 6.95 + 0.594 Y	+0.62

X = percent of fat
Y = percent of protein
Z = percent of solids-not-fat

Jacobson (1936), which was also on mixed milks, is Z = 7.07 + 0.40 X. Jack et al (1951) also gave a regression equation for estimating the percent of solids-not-fat from the fat percent for mixed Jersey milk samples. This was Z = 8.08 + 0.253 X. Overman et al (1939) gave a similar equation, Z = 8.23 + 0.247 X.

The regression values for the solids-not-fat percent on the protein percentage were as follows: for the randomly-bred herd, Z = 6.92 + 0.602 Y; for the inbred herd,

$Z = 6.95 + 0.589\ Y$; and for the pooled data, $Z = 6.95 + 0.594\ Y$. The correlation coefficients were +0.56, +0.67, and +0.62 respectively. Richardson et al (1953) gave a regression equation for the solids-not-fat percentage on the protein percentage of $Z = 5.85 + 0.99\ Y$ for Jersey herd samples, while Overman et al (1939) gave a value of $Z = 6.61 + 0.749\ Y$. Overman's correlation value was +0.67.

The values obtained in this study compare favorably with those cited from other sources. No attempt was made to obtain all the regression values available in the literature. Only those reported by recent workers in the field were cited.

One might conclude that a similar equation would be suitable for estimating the solids-not-fat content of milk from the protein percentage. The protein percentage could be obtained from the formol titration test. Whether the formol titration test is sufficiently rapid and simple for routine field use is still questionable. Such a question must be resolved before this test could be seriously considered as an addition to our Dairy Herd Improvement Program. The determination of the pounds of protein produced per cow for each lactation, and, subsequently, their conversion into energy units might provide a better basis than our present system supplies for the evaluation of the individual cow's efficiency.

SUMMARY

Two herds of Jersey cattle provided 734 samples of milk for the analysis of the fat, protein, total solids, and solids-not-fat percentages. The study was most concerned with the protein and non-fat solids values because of the increased emphasis on the economic and nutritional aspects of these two constituents.

A randomly-bred herd of 12 cows yielded a total of 259 samples. The samples were taken at two-week intervals over a fifteen month period to ascertain the variations in the percentages of the fat, protein, total solids, and solids-not-fat components between night and morning milkings. The morning milkings averaged 12.52 ± 0.32 pounds per cow, while the evening milkings averaged 11.45 ± 0.30 pounds of milk per cow. This difference was statistically significant. The morning values for the content of fat, total solids, and solids-not-fat were 5.28 ± 0.07 percent, 14.75 ± 0.09 percent, and 9.46 ± 0.04 percent respectively. The comparable evening values were 5.23 ± 0.11 percent, 14.95 ± 0.09 percent, and 9.52 ± 0.04 percent. None of these differences were significant. Two hundred fifteen morning samples analyzed for protein gave values of 4.15 ± 0.03 percent and 0.497 pounds of protein produced

per cow. The same number of evening samples yielded values of 4.15 ± 0.04 percent and 0.455 pounds of protein produced per cow. In summary, the morning milk was slightly greater in quantity, but contained slightly lower amounts of the total solids and solids-not-fat.

The data from the randomly-bred herd were also utilized for the purpose of comparison with the 475 samples obtained from an inbred Jersey herd. The average daily values for the two herds are given below:

	Randomly-bred herd	Inbred herd
Lb. milk	23.97 ± 0.59	27.09 ± 0.48
% fat	5.26 ± 0.06	5.57 ± 0.04
% protein	4.15 ± 0.03	4.26 ± 0.03
% total solids	14.86 ± 0.08	15.07 ± 0.04
% solids-not-fat	9.49 ± 0.03	9.51 ± 0.02
Lb. protein	.95 ± 0.02	1.09 ± 0.02

A highly significant difference existed between the two herds for milk production with the inbred herd averaging about three pounds more milk per cow per day. It is believed that the inbred herd was genetically superior for milk production, but the erratic response of several members of the randomly-bred herd to the milking procedure also contributed to this difference. The larger inbred herd values were statistically significant for the protein content and highly significant for the fat and total solids content. During the October-December and January-March periods, the inbred herd was exposed to the lower temperatures of a loose housing barn. A marked increase was observed in the solids content of the milk from this herd during that time. Herd mean values for the percentages of fat, protein, and solids-not-fat were more nearly alike during the spring and summer periods. The protein and solids-not-fat values showed less variability than the fat and total solids' values.

The samples from both herds were pooled to observe the differences due to season. The average amount of milk produced per cow per day ranged from 24.62 ± 0.72 pounds to 28.10 ± 0.88 pounds. In general, the solids content of the milk varied inversely with the temperature of the seasons. The lowest values for the fat content were observed in the July-September period, when 158 samples averaged 5.19 ± 0.07 percent. The highest values appeared in the January-March period with 145 samples averaging 5.78 ± 0.06 percent. The low values for the protein and total solids content also occurred in the July-September period. These values were 3.85 ± 0.03 percent and 14.51 ± 0.09 percent. The lowest average value for the solids-not-fat was 9.37 ± 0.03 percent, which occurred in the April-June 1955 samples. The highest values for the protein content were found in the October-December 1954 period and averaged 4.43 ± 0.04 percent. The highest average total solids value was 15.35 ± 0.08 in the January-March 1955 period. The highest solids-not-fat average value was 9.59 ± 0.03, obtained during the April-June 1954 period

The stage of lactation values exhibited characteristic variations for milk production and the percentages of milk solids. The mean value for the daily milk production was highest during the second month of lactation, when it averaged 38.2 pounds, and then it declined slowly until the tenth month of lactation, when it averaged 16.8 pounds. The lowest milk solids values were evident during the second month, and a gradual rise occurred from the second to the tenth month of lactation for both the fat and non-fat solids. The second and tenth month pooled mean values were as follows: fat percentage, 5.22 and 5.83 percent; protein percentage, 3.74 and 4.50 percent: total solids percentage, 14.46 and 15.38 percent; solids-not-fat, 9.28 and 9.72 percent.

Limited information was obtained in regard to the protein production of individual cows in a single lactation. Only twelve complete lactations were available for comparison. Twelve other lactations were extended from 180 to 305 days to increase the amount of information. Most of the lactations were from young cows in their second, third, or fourth lactation. Mastitis was not a complicating factor in this study.

Grouping the cows by sires allowed a comparison of the protein production of the offspring of three bulls. No difference in transmitting ability for protein production could be postulated between the two inbred sires. The inbred sires' daughter averages for pounds of protein and milk production were markedly higher than the averages for the daughters of the randomly-bred bull. There was little difference among the bulls for the percentage of protein produced by their daughters.

A few dam-daughter comparisons are presented. No conclusions can be drawn from these small numbers.

There is virtually no difference in the accuracy of the bi-weekly, monthly, and bi-monthly testing periods for protein production per cow lactation. It is suggested that the monthly testing interval in connection with the Standard Dairy Herd Improvement testing program is the most convenient method of sampling to use in a long term study to obtain information on the protein and solids-not-fat values.

Regression values and correlation coefficients were determined for the relationships among the fat, protein, and solids-not-fat percentages. The regression equations calculated from the pooled data were:

Percent of protein = 2.67 + 0.281 x fat percentage

Percent of solids-not-fat = 7.80 + 0.307 x fat percentage

Percent of solids-not-fat = 6.95 + 0.594 x protein percentage

Although their usefulness is limited due to the small number of samples involved, the values are in good agreement with the literature.

Any project involving the sampling of individual cows for any of the milk solids must be a long time study in order to test the milk of a single cow over several lactations, before many of the causes of variation can be fully evaluated.

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