STUDIES ON THE VARIANCE OF THE COMPOSITION OF MILK

By

Yeikyo KIN, Shunrokuro ARIMA
and Yoshio HASHIMOTO

Faculty of Agriculture, Hokkaido University, Sapporo, Japan

Introduction

Milk is one of the few foodstuffs consumed in its natural state, and it is generally said that milk is a complete and sound or healthful and wholesome food, etc. That is because milk is a nutritionally valuable product, in that it was designed by nature to supply nourishment for the young animal.

Milk therefore is practically the only food stuff which contains all of the different substances known to be essential for human nutrition.

In fact, the dairy industry has contributed to the promotion of the optimum health and human welfare through adequate use of milk. This contribution has been made by the studies of many investigators, the efforts of producers and others being active in the field of dairy industry.

In the past, breeder and producer have measured the worth of the dairy cow on the fat of her milk. But in recent years, the dairy industry has placed increasing emphasis on the solids-not-fat (S-N.F) content of milk, because it has come to be regarded as of equal, or of greater, importance than the fat percentage. This change is the result of an increased awareness of the nutritive value of milk protein and the other-non-fatty constituents including vitamins and minerals.

In general, it is well known that the influence of many factors on the composition and total production of milk are breed, individuality, nutrition, locality, inheritance, seasonal effects, stage of lactation, and physiological factors which are age, exercise, gestation, yield, etc.

Many of these factors are inter-related, and for some the effect may be small, except under exceptional conditions.

The major factors influencing the main constituents of milk have been studied by many workers. That is because economists, nutritionists, regulatory officials of dairy products and others usually need to know the percentage of

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concentration of the main constituents in milk in order to evaluate it properly for any use and to improve it.

The purpose of this investigation was projected to study the variations between morning and evening milk, the effect of season and stage of lactation, herd's difference, and relationship between dams and daughters, on the constituents of milk from individual Holstein cows and herds.

Experimental Procedure

Animals used and method of milk sampling

Cows used in this experiment were individual Holstein cows obtained from 4 herds which were: Hokkaido University farm (A), NAGANO farm (B), the farm of Tsuki-samu school (C), and NOZAKI farm (D).

Samples were analyzed between May, 1961 and October, 1962. Somples of morning milk from 32 Holstein cows of 4 herds (9 animals from herd A, B, and C, respectively, and 5 animals from herd D) were obtained from May, 1961 to April, 1962. Samples of evening milk from 24 Holstein cows of 3 herds (8 animals from each herd A, B, and C, respectively) were obtained between May, and October, 1962. Consecutive morning and evening samples from individual cows were taken of the milk from each chosen cows one day each month. A milk sample of 200 ml was taken for each cow after complete milking.

Herd samples were taken of the bulked morning and evening milk of the whole herd from each 4 Holstein herds. In herd A, several Guernseys were included. Most cows used in this study were milked with milking machine. Samples of morning and evening milk produced during normal lactation period were analyzed, and initial milk for 20 days after calving and that produced in the last stage of lactation were avoided.

In general, feedings used in the 4 farms were mainly hay, straw, roots, oats, wheat meal, beer pulp, soybean meal, silage, etc.; and purchased concentrates were not used except for herd D. The cows used in this experiment were fed in the cow barns without grazing, D farm used purchased concentrates with roughage feedings, and cows were put out to graze in daytime between late spring and early autumn.

All samples used were treated by statistical analysis, means, standard errors, correlations and prediction equations.

Methods of analysis

The milk samples were warmed to a room temperature and gently inverted

several times to redisperse the fat equally. The milk samples were then taken for the determination of total solids, fat, protein, lactose, and ash. Total solids were measured gravimetrically by the official method for milk (10). Fat was determined by the BABCOCK method (10).

Solids-not-fat was calculated from difference between total solids and fat. Total nitrogen was determined by a micro-Kjeldahl method in milk diluted 1 to 5 with water, and this value was converted to crude protein by use of the factor 6.38.

Lactose was determined by BERTRAND method (28) with slight modification. First of all, 10 ml sample was taken into 200 ml volumetric flask and 100 ml H_2O, 7 ml of Bertraand A solution and 1 ml of N NaOH, were added in the order named. After mixing well, the flask was filled to 200 ml with water. Twenty milliliter filtrate was taken into 300 ml triangle flask with each 20 ml of BERTRAND A and B solution. It was filtrated with glass-filter after boiling for 3 minutes. Then Lactose content was determind with BERTRAND method.

Results

Individual milk. Samples of morning milk from 32 cows and evening milk from 24 cows were analyzed. The results presented in Table 1 consist of 521 samples of total solids, solids-not-fat, and protein content and 126 samples of lactose and ash content. The percentage of lactose and ash content were obtained only from morning milk analyzed between January and April, 1962. Milk yield was the mean value per day per cow from 24 cows. The

TABLE 1. Maximum, minimum and average values for milk constituents of individual cows

Constituent	No. of cows	No. of samples	Max.	Min.	Means and standard errors
Milk yield (kg)	56	521	34.20	3.84	12.73±0.23
Total solids (%)	56	521	15.99	9.50	11.54±0.046
Solids-not-fat(%)	56	521	10.31	6.30	8.02±0.028
Fat (%)	56	521	6.50	2.10	3.52±0.032
Protein (%)	56	521	5.60	2.29	3.14±0.018
Lactose (%)	32	126	4.76	3.65	4.08±0.023
Ash (%)	32	126	0.77	0.66	0.70±0.002

Max.: Maximum
Min.: Minimum

cows were milked twice daily at almost equal intervals.

The values presented in Table 1 show the most widely variable constituent of milk to be the fat content, followed in order by protein, total solids and solids-not-fat content. The maximum percentage of fat content is 3.09 times the minimum value; the corresponding values for protein, total solids, and solids-not-fat content are 2.44, 1.68, and 1.64, respectively. The maximum and minimum values in Table 1 included samples which were abnormally low in solids-not-fat content. Such widely variable values of milk composition occurred both above and below the breed average.

Mixed milk. Samples were obtained from the bulked evening and morning milk of the whole herd. The total number of cows in 4 herds was usually 75 and in that several Guernseys were included. Lactose and ash content of the bulked milk were analyzed for 4 months between January and April, 1962. The results are shown in Table 2.

TABLE 2. Maximum, minimum and average values for the constituents of the mixed milk

Constituent	No. of herds	No. of samples	Max.	Min.	Means and standard errors
Total solids (%)	4	48	13.70	9.93	11.70±0.130
Solids-not-fat (%)	4	48	8.87	7.50	8.08±0.070
Fat (%)	4	48	4.90	2.82	3.62±0.093
Protein (%)	4	48	4.20	2.50	3.17±0.041
Lactose (%)	4	16	4.40	3.75	4.12±0.050
Ash (%)	4	16	0.75	0.69	0.71±0.019

Generally, the values of milk composition were slightly higher than those from individual cows. Minimum and maximum values for the total solids, solids-not-fat, fat, protein, and lactose content of milk from Holstein herds reported by DAVIS et al. (16) ranged from 11.1%, 7.7%, 3.0%, 2.2%, and 4.1%, respectively, in minimum to 12.9%, 9.1%, 4.4%, 3.2%, and 5.3%, respectively, in maximum. They also showed that the mean values for total solids, solids-not-fat, fat, protein, and lactose content of milk from Holstein herds were 12.0%, 8.5%, 3.5%, 2.9%, and 4.7%, respectively. EISSES (5) reported that the percentage of solids-not-fat and protein content of market milk in the Netherlands were 8.74% and 3.34%, respectively. The maximum percentage of fat content is 1.73 times the minimum value; the corresponding values for protein, total solids, and solids-not-fat content are 1.68, 1.38, 1.16, respectively.

Variations in morning and evening milk

Samples of morning milk from 27 Holstin cows of 3 herds were analyzed between May and October, 1961 and Samples of evening milk from 24 Holstein cows of the some herds were taken between May and October, 1962. The results are shown in Table 3.

TABLE 3. Compositional variations between morning and evening milk

Constituent	Morning samples		Evening samples	
	No. of samples	Means and standard errors	No. of samples	Means and standard errors
Total solids (%)	158	11.33±0.080	142	11.52±0.083*
Solids-not-fat (%)	158	7.96±0.048	142	8.02±0.050
Fat (%)	158	3.37±0.051	142	3.50±0.055
Protein (%)	158	3.12±0.025	142	3.13±0.025

* Difference (morning vs. evening) significant at 5% probability level.

The data given here show values a little higher in evening milk constituents than the values in morning milk constituents. Data show statistically significant difference in total solids content of morning and evening milks. But no significant differences were obtained in the solids-not-fat, fat and protein content of morning and evening milks. In this study, samples of morning and evening were not obtained during the same year, so it was thought likely that several factors, such as environments, management practices, age, lactation, etc., probably did not influence equally both constituents of morning and evening milk.

Percentage of changes of constituents of individual milk from summer to winter

The constituents of milk produced during the summer and winter months by calendar month were compared. The results are shown in Table 4. All 96 samples from 32 cows of 4 herds during the summer and winter months were analyzed.

Mean values obtained for the total solids, solids-not-fat, fat, and protein content of milk produced in the winter months were significantly higher than those produced in the summer months. Data given here show the highest

TABLE 4. Percentage of change of constituents of milk from summer to winter

Constituent	No. of samples	Compositional difference between winter and summer (%)	Percentage of change from summer to winter (%)
Total solids	96	1.12	9.69**
Solids-not-fat	96	0.57	7.12**
Fat	96	0.56	15.82**
Protein	96	0.13	4.13*

* Difference between winter and summer significant at 5% probability level.
** Difference between winter and summer significant at 1% probability level.

difference in the fat content between the summer and winter months with the total solids content; next followed by the solids-not-fat content and protein content, in the order named.

Influence of season on yield and milk composition from indvidual cows (stage of lactation eliminated).

The results presented Fig. 1 show the influence of season on the major constituents of milk and milk yield. Milk yield was highest in May and fell slightly to June and then fell sharply to the lowest value in October. After that milk yield rose gradually to January, and again fell slowly till April. The maximum and minimum milk yields (day/cow) were 17.08 kg, and 10.21 kg, respectively.

The total solids and solids-not-fat content showed a small peak in June and fell rapidly from June to August, when the minimum value appeared and then increased remarkably reaching the highest value during winter months. The maximum values in the total solids and solids-not-fat content were in February and March, respectively. The fat content of milk was a lower value from May to November, except October, and then increased, reaching the maximum value in February and fell gradually till April. The influence of season on the protein content was not so remarkable compared with the other constituents. The protein content was lowest in July and highest in February.

Mean values of difference between the maximum and minimum values for the total solids, solids-not-fat, fat, and protein content were 1.86%, 1.39%, 0.87%, and 0.42%, respectively. The fall in the solids.not-fat in February may be due to the sudden increase of the fat content in that month.

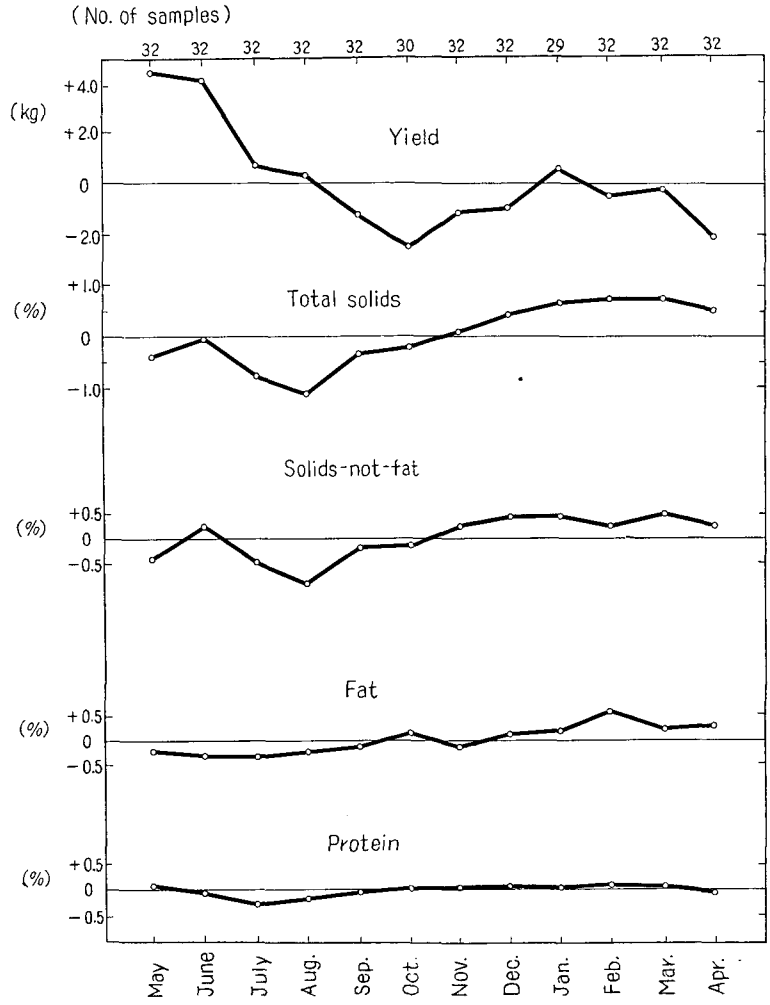

Fig. 1. The effect of season on yield and milk composition from individual cows (stage of lactation eliminated).

Influence of season on yield and milk composition from herds (stage of lactation eliminated)

It is apparent from Fig. 2 that the trend of variances of the bulked milk composition was nearly the same trend as that of individual milk composition. Both the values of constituents of the individual and bulked herd milk were clearly of a lower level in the late summer and higher in the late winter. Mean values of difference between the maximum and minimum percentage

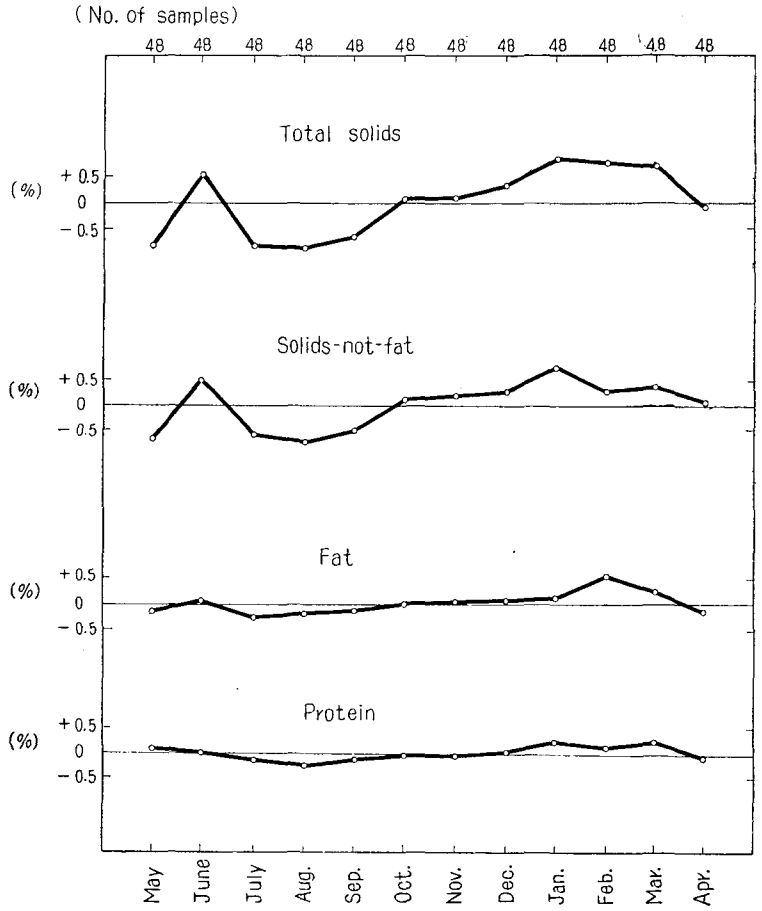

Fig. 2. The effect of season on milk composition from herds (stage of lactation eliminated).

for the total solids, solids-not-fat, fat and protein content from the bulked milk were 1.77%, 1.46%, 0.8%, and 0.53%, respectively.

As described previously, the cows from three herds (the cows of the herd D were grazed during from the late spring to early autumn) were not grazed to the pasture throughout the year and they were fed in the cow sheds, except the times of exercise. However seasons had a marked effect on the major constituents of milk. It is thought likely that seasonal variations may be the results of several factors operating at the same time. These problems are discussed later.

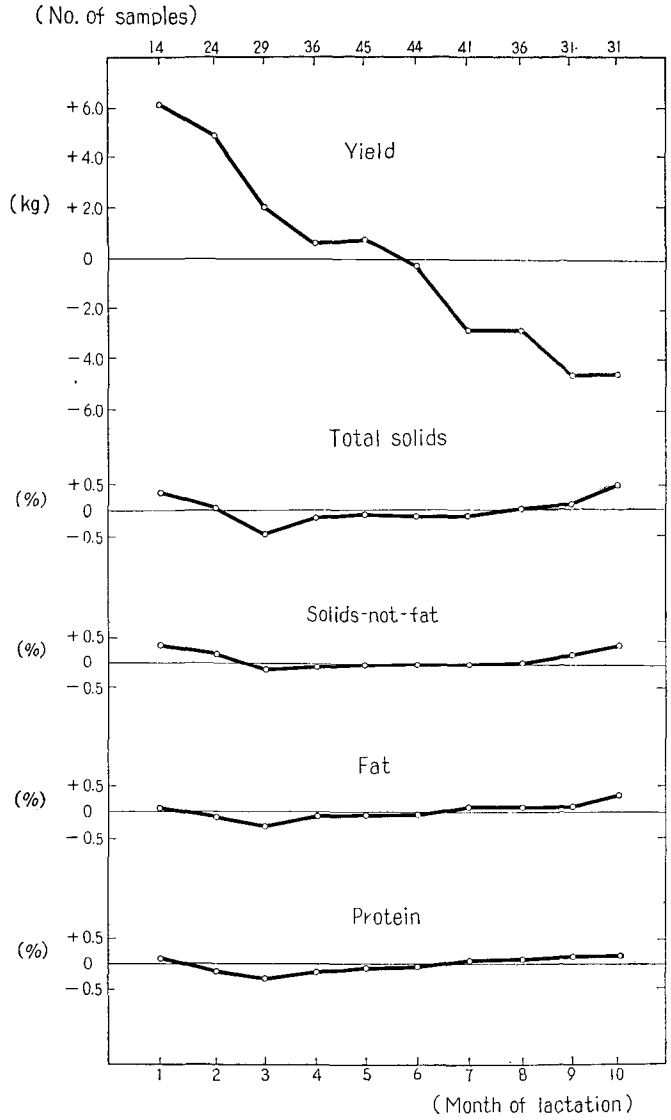

Fig. 3. The effect of stage of lactation on yield and milk composition from individual cows (season eliminated).

Influence of stage of lactation on yield and milk composition (season eliminated)

Samples of initial stage after calving and last stage of lactation were avoided, so that sharp changes in concentration of the milk constituents associated with very early and last stage of lactation are not shown in the figure. In the samples obtained 7 days after calving the fat content was 0.8% above the mean, the protein content was 0.6% above, and the lactose content was 0.4% below the respective mean values (17).

It is clear from Fig. 3 that advancing stage of lactation, gave a smaller influence on the major constituents of milk than that of the influence of season. The milk production from cows throughout the lactation was highest in the first month of lactation and then it gradually decreased to the end of the lactation. The values of maximum and minimum milk yield were 20.17 kg and 9.4 kg (day/cow), respectively. The general tendency for the total solids, solids-not-fat, fat, and protein content decreased for three months after calving and then increased slightly with abvancing lactation, rising more rapidly after about 9 months. The actual ranges of advancing lactation for the total solids, solids-not-fat, fat, and protein content of milk were 1.11%, 0.56%, 0.61%, and 0.37%, respectively.

Coefficient of correlation for the constituents of milk

The relationship between the constituents of milk was studied and the coefficient of correlation was statistically computed. The results were shown in Table 5. The values of the coefficient of correlation presented in Table 5 were all positive and obtaind a signiffcant relationship between the constituents of milk. These results revealed that the major constituent of milk had a relationship among each other, and it was generally clear the solids-not-fat content

TABLE 5. Coefficient of correlation for individual cows' milk

Relationship	No. of samples	Coefficient of correlation
Fat~Solids-not-fat	521	r = +0.27**
Fat~Total solids	521	r = +0.71**
Fat~Protein	521	r = +0.31**
Protein~Solids-not-fat	521	r = +0.48**
Protein~Total solids	521	r = +0.59**
Solids-not-fat~Total solids	521	r = +0.79**

** Positive significant at 1% probability level.

of milk increased with the increase of the protein and fat content.

Prediction equations for Individual cows' milk

The use of fat or protein content to predict the solids-not-fat and total solids content of milk was studied. The prediction equations were computed from these data and are presented in Table 6. Such prediction equations have been considered by workers (21, 22).

The solids-not-fat contents predicted from equations developed from Jersey cows' milk were reported by Specht et al. (21) The prediction equations were: S-N-F = 8.33 + 0.216 Fat (Herd A), S-N-F = 6.97 + 0.465 Fat (Herd B), S-N-F = 6.92 + 0.602 Protein (Herd A), and S-N-F = 6.96 + 0.589 Protein (Herd B).

TABLE 6. Prediction equations for individual cows' milk

Relationship	No. of samples	Equation
Fat~Solids-not-fat	521	Solids-not-fat = 7.00 + 0.291 F.
Fat~Total solids	521	Total solids = 7.524 + 1.141 F.
Fat~Protein	521	Protein = 2.352 + 0.224 F.
Protein~Solids-not-fat	521	Solids-not-fat = 5.445 + 0.820 P.
Protein~Total solids	521	Total solids = 7.006 + 1.444 P.

F. = Fat. P. = Protein.

The average composition of milk from 4 herds

Samples of morning milk from 4 herds were obtained between May, 1961 and April, 1962. All four farms are around the Sapporo area, and two of them are managed by schools, and the others are owned by farmers. So environmental conditions were almost the same, but management practices were a little different among them. The cows of A, B, and C herd were fed in the cow sheds, and herd D were grazed to the pasture in the daytime during late spring, summer and autumn. Feedings used in the four herds were mainly hay, straw, roots, oat wheat-bran, beer-pulp, soybean meal, silage, etc. The purchased concentrates were only used in D farm, but the other farms almost did not use it.

As presented in Table 7, the values of milk constituents were significantly different among the four herds. Especially, the values of the total solids, solids-not-fat, and protein content produced in herd C and the solids-not-fat in herd A were lower than those produced in the other herds. It is suggested that feedings and managements may affect significantly the compsition of milk.

TABLE 7. The average composition of milk from 4 herds (means and standard errors)

Herd name	No. of cows	No. of samples	Milk yield (kg)	Total solids (%)	S-N-F (%)	Fat (%)	Protein (%)	Lactose (%)	Ash (%)
A	9	103 (34)	9.57	11.39± 0.105	7.89± 0.068	3.50± 0.056	3.05± 0.049	4.04± 0.022	0.70± 0.002
B	9	108 (36)	16.12	11.64± 0.103	8.20± 0.056	3.44± 0.063	3.24± 0.055	4.12± 0.025	0.71± 0.002
C	9	108 (36)	12.42	11.14± 0.171	7.69± 0.087	3.45± 0.065	2.91± 0.032	4.03± 0.020	0.70± 0.002
D	5	60 (20)	—	12.06± 0.233	8.27± 0.126	3.79± 0.153	3.39± 0.059	4.08± 0.025	0.71± 0.003

( )=No. of samples for lactose and ash.

Milk composition for dams and daughters

Samples of morning milk from dam-daughter pairs fed in the same farms were analyzed. One dam-daughter pair was obtained from herd C and two other dam-daughter pairs were obtained from herd A. The effect of season was eliminated, and Samples were analyzed during one period of lactation, respectively. Mean values of the constituents of milk are shown in Table 8.

TABLE 8. Average composition of milk for dams and daughters

	No. of cows	Total solids (%)	S-N-F (%)	Fat (%)	Protein (%)
Dams	3	10.38	7.46	2.92	2.68
Daughters	3	10.60	7.54	3.06	2.85

It is clear from the results of Table 8 that both values of the milk constituents produced from dams and daughters were lower than the mean values of herds. It is thought likely that there is some relationship between dams and daughters on the composition of milk. The results presented in Table 8 were obtained only from three dam-daughter pairs, so it was not made clear whether there is a significant relationship between dams and daughters or not. It would be desirable that further investigation of inheritance of the milk composition between dams and daughters be continued.

Discussion

Many factors are known to influence milk composition, such as cattle

breeds, seasons of a year, feedings and management practices.

It is thought that hereditary variation is due to the genetic make-up of the breed and individual, and such factors as seasons of the year, feedings and management practices are due to physiological changes. In this paper, the causes of these variations, with regard to the total solids, solids-not-fat, fat and protein content of milk, have been discussed.

As data indicated in Table 1 and 2 the ranges of variances between the maximum and midimum values of the milk composition for the main constituents of milk are remarkably wide. Especially the percentage of the solids-not-fat content is low, and the minimum values for the solids-not-fat content of certain individual cows of each of the 4 herds were lower than the existing legal requirement of 8.0 per cent. This reason is thought to be caused by differences of the capacity among individual cows. It is evident from Table 1 and 7 that there is a significant difference of individuality among cows even if conditions of environment, feeding and management practices are identical. Therefore, individuality is more properly thought of as the result of genetic factors. This is in agreement with another worker (1) reported. NICHOLSON (18) reported that differences among individual cows for pounds of milk, fat, solids-not-fat, and total solids were highly significant at the 1% level, and for the percentage of fat, solids-not-fat, and total solids content were also highly significant. NAKANISHI (3) reported that the percentage of the solids-not-fat content of raw milk produced in Japan was lower than that produced in foreign countries. The mean values of total solids, solids-not-fat, fat, protein, and lactose content analyzed from individual Holstein cows reported by DAVIS et al. (16) were 12.1%, 8.6%, 3.5%, 3.0%, and 4.8%, respectively. These values of the total solids, solids-not-fat, and lactose content of milk given by them were higher than those indicated in Table 1, but conversely the values of fat and protein content were slightly lower.

From Table 2, the mean values of the composition of the bulk milk were generally of a higher level than those of individual cows. This because the samples of the bulk milk were obtained from whole herds, in which several Guernsey cows were included, and some of them were produced in abnormal lactation periods over tenth months after calving. But mean differences obtained for the totol solids, solids-not-fat, fat and protein, loctose, and ash content of morning and evening samples were not significant statistically. The differences between maximum and minimum values of each constituents of the bulk milk were less than corresponding values for milk of individual cows presented in Table 1.

Data presented in Table 3 showed a significant difference at the 5% level

in the total solids content of morning and evening milks. No significant differences were observed in the solids-not-fat, fat, and protein content of morning and evening milks. BAILEY (6) reported that morning milk usually contained a lower level of solids-not-fat than evening milk with a mean difference of 0.07%. SPECHT et al. (21) reported that when individual cows from two Jersey herds were sampled bi-weekly for a 15-month period to obtain values of the compositional quality of their milk, mean differences obtained for the fat, protein, total solids, and solids-not-fat content of morning and evening samples from one of the herds were not significant. BARTLETT (7) reported that little difference was obtained for the solids-not-fat content of morning and evening milks. NICHOLSON et al. (18) reported that mean differences obtained for pounds of milk, fat, solids-not-fat, and total solids of morning and evening samples were significant at 1% probability level, respectively.

DAVIS et al. (16) showed that the percentage of change of the total solids, solids-not-fat, fat, lactose, and protein content of Holstein cow's milk from summer to winter was 3.88%, 1.42%, 9.51%, 9.30%, and 4.22%, respectively. The highest variance occurred in the fat content as well as the result indicated in Table 1. It is thought that the variance of the milk composition from summer to winter was due to the effect of environmental temperature. RAGSDAL-et al. (8)and HAYS (9) reported that there was an increase of approximately 0.2 per cent fat in cow's milk for each 10° F. lowering of the temperature within the limits of 70° and 30° F.. MERITAN and BOWER (12) reported that when the effect of environmental temperature cycles on the composition of milk from Holstein and Jersey cows was investigated by analyzing milk samples from animal exposed to controlled diurnal temperature rhythms, the percentage of fat and solids-not-fat increased during both the high (70 to 100° F.) and low (10 to 40° F.) temperature cycles. The protein content of milk from both breeds was increased during the low temperature cycles.

As showed in Fig. 1 and 2, seasonal factors had a more marked effect on the major constituents of milk than that of advancing lactation. The range of variation of the mean value for each constituent caused by seasonal factors (Fig. 1) and advancing lactation (Fig. 3) was: total solids, 1.86 and 1.11%; solids-not-fat, 1.39 and 0.56%; fat, 0.87 and 0.61%; protein, 0.42 and 0.37%, respectively. BROOKS (11) and DAVIS et al. (16) reported that the effect of season on the milk composition was greater than that of advancing lactation, but WAIITE et al (17) reported that seasonal effect was of smaller magnitude than that arising from advancing lactation.

The milk production decreased 6.63 kg from June to October and then increased 3.11 kg to January and showed irregular decrease until April. There

was little difference of milk production between May and June. DIX ARNOLD and BECKER (15) reported that the seasonal influence on milk yield, irrespective of advancing lactation, resulted in the maximum rate of milk production during June, and the minimum during November and December. It is thought that the variance of milk production is due to the effect of the calving month of cows, feeding, and environmental temperature. Most cows used in this study calved during the spring months and the others calved during the autumn. Few cows were found to calve during the summer months.

Advancing lactation had much more marked effect on milk production than that of seasonal factors. The increase of the total solids and solids-not-fat content in June is most likely the result of a temporary change due to the effect of feeding and suitable climate for cows. On the other hand, little variance in the fat and protein content was observed in June. The decrease in the total solids, solids-not-fat, fat and protein content during the summer months may be caused by the effect of high temperature. BECKER and ARNOLD (14) reported that, in general, higher fat contents were associated with the cooler months of the year, and the lower fat contents with the warm summer months. SPECHT et al. (21) reported that the low values for fat, protein, and total solids content occurred during the summer months. These differences were presumed to be due mainly to the higher environmental temperature of the summer months.

As the temperature rises the blood vessls of the skin become dilated, and heat is radiated from the skin. Evaporation of water from the body is also promoted. If the environmental temperature becomes so high, that physical regulation will not cool the body sufficiently, and metabolism of the body will slow down. Such metabolism of cow's body will influence the variance of the milk composition.

The increase of the major constituents of milk occurring during the winter months may be also due to the influence of environmental temperature, with feeding.

HAYS (9) reported that, above 70°F., there was an actual increase in the fat test. The reason for this is not known, but it is believed to have been due to incrersed metabolism, induced by higher temperature or the result of disturbing the animals by the sudden changes from one temperature to another (9). He concluded that temperature was a major factor in the seasonal variation of the per cent of fat in cows milk. WAITE et al. (17) reported that the most important seasonal factor was the relatively abrupt change of feeding and mode of living which occured when the cows went out to grass in the spring and when they returned for the winter to the barn. It was reported

that when the starch equivalent (S. E.) of the concentrate was raised milk yield and milk composition were increased (25, 26, 27), but the others (2, 20) did not find any noticeable increase. On the other hand, RAGSDALE et al. (24) reported that when the ration fed to dairy cows was reduced 50 per cent the per cent of fat of milk increased, and the peak of the increase in the per cent of fat was reached about the third day. Then the per cent of fat remained abnormally high as long as the reduced ration was continued. But, when the ration was brought back to normal the percent of fat decreased. Therefore, the effect of feeding on the composition of milk has not been known exactly. The major seasonal variance is probably the effect of both environmental temperature and feeding.

As reported previously, no samples were analyzed during the first 20 days and last stage of lactation, in order to avoid the effect of colostrum and milk of last stage of lactation. Milk production decreased markedly with advancing lactation by a decrease from 20.17 kg in the first month to 9.40 kg in the last month of lactation. It is well known that the maximum milk production is usually reached during the first or second month of lactation, and milk secretion after reaching maximum production decreases with advancing lactation.

TURNER et al. (23) reported that the decline of milk production with the advance of the period of lactation was shown to be fairly constant, and a slightly greater percentage decreased during the last two or three months of lactation was shown to be due to advanced pregnancy. WYLIE (13) reported that the season of freshening as well as the period of lactation affected the richness of milk from a cow. The richest milk may be produced at some time before the end of the lactation period depending on the month in which the cow freshened. The cows milked twice per day reached their peak of production on the fifteenth and sixteenth days after calving, and the cows milked three times per day reached a peak on the eighteenth day (23).

The mean value of the total solids, solids-not-fat, fat, and protein content decreased from the first month to the third month of lactation, respectively, then gradually increased to the last month of lactation. The values of the decrease from the first month to the third month of lactation for the total solids, solids-not-fat, fat, and protein content were 0.77%, 0.52%, 0.26%, and 0.34%, respectively, and those of the increase from the third month to the tenth month of lactation for each of them were 1.11%, 0.54%, 0.61%, and 0.37%, respectively. The tendency of these variance with advancing lactation is in close agreement with the reports of considerable workers (4, 14, 15, 16, 17, 23). TURNER et al. (23) reported that highly developed dairy cows often continued to produce milk for several years, while beef cows and animals of

inferior daily qualities dried up within a few months even furnished with an abundance of feed. LARSON (19) mentioned that an appreciation of the influence of the stage of lactation was necessary in considering the productive capacity of an individual cow during the entire lactation.

From Table 5, there is a significant relationship between the constituents of milk. BROOKS (11) reported that the coefficient of correlation for this relationship between milk production and percentage of fat content was: $r = -0.167 \pm 0.190$. DAVIS et al. (16) reported that when the fat content increased a corresponding rise was shown in the total solids, solids-not-fat, and protein content of milk, except in some cases. Such exceptional cases were found in this study. Especially some cases in the samples were abnormally high in the fat content and abnormaly low in the solids-not-fat content. The variance of the protein content was smaller than that of the other constituents.

From the data presented in Table 5, it is clear that relationship between the protein and the solids-not-fat content was of more significant positive value than that between the fat and the solids-not-fat content of milk. Therefore, it is desirable to increase the protein and lactose content in order to increase the solids-not-fat content.

The solids-not-fat content predicted from equations computed from this study (Table 6) are not quite in close agreement with the other equations (21) for the fat content encountered. Though the correlation between fat and solids-not-fat is only slight ($r = 0.27$), it is significant, but it is insufficiently high to make a reliable estimation of solids-not-fat content on the basis of the fat content of milk. RICHARDSON and FOLGER (22) showed the prediction equations for calculating the solids-not-fat percentage from the fat percentage, within practical limits of fat concentration.

The percentages of the total solids, solids-not-fat, fat, and protein from each of the 4 herds were different from each other (Table 7), and significant difference was obtained among herds. The values of the constituents of milk produced in herd D were highest and those produced in herd C were lowest among them. It is thought that such diffeence between herds is caused by management practices, including feedings, individuality and heritability.

It is more clear from Table 8 that both the constituents of milk from the dams and daughters are lower than the mean value of herds in spite of being kept in the same conditions. WAITE et al. (17) reported that the high heritability between the dam and daughter correlation within herds obtained. These values in the neighbourhood of 0.5 were obtained for solids-not-fat, protein, and ash, about 0.35 for fat and lactose, 0.25 for milk yield.

It is, therefore, thought that there is a significant relationship between

the genetic factors and the composition of milk. In order to improve the qualities of milk composition, further investigation of inheritance is desirable.

Summary

1. During May, 1961-April, 1962 the samples of morning milk from 32 Holstein cows were obtained from each cow one day each month during the normal lactation. The samples of evening milk from 24 Holstein cows were obtained during May, 1962-October, 1962, and the method of milk sampling was the same as morning milk sampling. The samples of mixed milk from the 4 herds were from the bulked milk of the whole herd.

2. The average values of the milk constituents for the total solids, solids-not-fat, fat, protein, lactose and ash content from individual cows were 11.54%, 8.02%, 3.52%, 3.14%, 4.08%, and 0.70%, respectively. Those of the constituents of the mixed milk for the total solids, solids-not-fat, fat, protein, lactose, and ash content were 11.70%, 8.08%, 3.62%, 3.17%, 4.12%, and 0.71%, respectively. The average milk yield per cow per day was 12.73 kg.

3. Mean differences obtained for fat, protein, and solids-not-fat content of morning and evening samples were not significant, but the total solids content showed a significant difference.

4. Significant differences among herds were obtained in quantities of milk and percentage of total solids, solids-not-fat, fat, and protein contents.

5. Seasonal effects on milk composition were greater than those of advancing lactation and caused the following changes in milk composition:

a) Milk yield was highest in May, and then fell to a minimum in October. That increased steadily from October to January, and then fell to April.

b) Total solids and solids-not-fat contents increased from May to June and fell to a minimum in August, and then both gradually increased to a maximum during the winter months.

c) Both fat and protein contents were lower during the summer months and higher during the winter months and their ranges of variance throughout the year were smaller than those of total solids and solids-not-fat content.

6. Advancing lactation caused the following changes in milk composition:

a) Milk yield was highest during the first month of lactation and fell markedly with advancing lactation.

b) Total solids, solids-not-fat, fat, and protein contents fell rapidly from the first month to the third month of lactation and then increased slightly for the remainder of lactation, rising more rapidly after about the ninth month of lactation.

7. Coefficient of correlation for the major constituents of milk was calculated from individual cows.

8. Equations were presented for predicting total solids and solids-not-fat contents from protein or fat content.

9. The mean values of milk composition produced from dams and daughters were both lower than those of the mean value of herds.

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