Evaluation of Formulas for Predicting Various Components of Mixed Herd Milk

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J. B. Mickle, E. R. Egermeier, S. D. Musgrave,
R. D. Morrison, F. A. Graybill, and R. MacVicar

Departments of Dairying, Mathematics,
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The fat content of milk has been the basis for the development of a number of formulas for predicting the amounts of certain constituents of herd milk. Many of these formulas have been based on 2- to 4-day composite samples and/or on samples taken biweekly, or at longer intervals. Composite samples tend to minimize daily variations.

This bulletin reports results of a study designed to re-evaluate certain of these formulas using data taken from fresh daily samples. The variability of daily samples was evaluated to determine the precision of formulas based on daily samples, and to compare these formulas with those in the literature.

MATERIALS AND METHODS

Daily samples of mixed herd milk representing the night and morning milkings of the Oklahoma State University herd were collected an average of six days per week, every other week, from November 1955 to November 1956.

These samples were analysed for milk fat content by the Mojonnier procedure. Casein was precipitated according to the procedure outlined in A.O.A.C. "Methods of Analysis" (1). Nitrogen content was determined on the casein filtrate as well as on the whole milk by the Kjeldahl procedure (1) and protein was calculated as nitrogen times 6.38. Lactose was determined by the picric acid procedure of Perry and Doan (14). Ash was determined by the method outlined in A.O.A.C. "Methods of Analysis" (1), and specific gravity was determined at 25°C. with pycnometer bottle. Titratable acidity was measured without being diluted with water (1) and pH was measured with a Beckman model H-2 instrument using a glass electrode. Total solids were calculated as the sum of fat, total protein, lactose, and ash.

RESULTS AND DISCUSSION

Monthly averages for the herd milk data are shown in Figure 1. These data show the seasonal trends which would be expected. The 95% confidence limits of the yearly averages for these data are similar to the 95% confidence limits of the literature data (4, 6, 7). Averages of each week's data are shown in Figures 2 and 3. These data show the relatively large week-to-week variations which occurred in the composition of this milk, particularly in the fat and lactose content. Azarme (2) reported

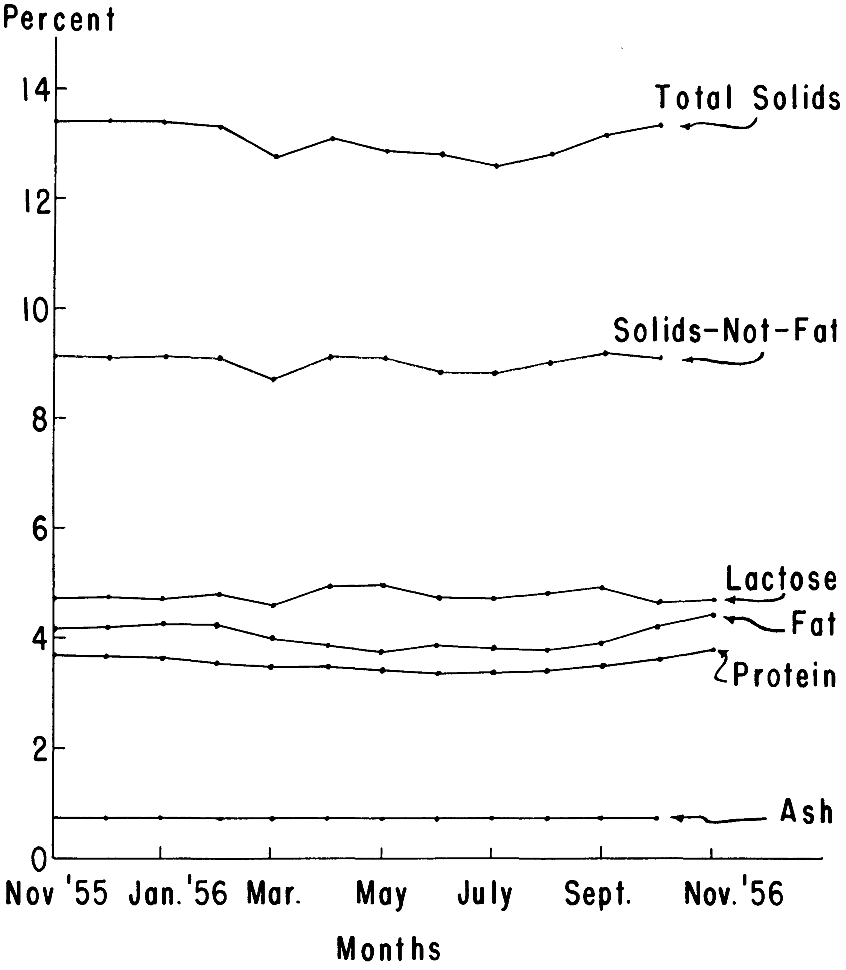

Figure 1.—Monthly herd milk averages.

similar findings. The daily variations were even greater than the variations in the weekly averages, and it appears that these daily variations are often greater than the seasonal changes.

Simple correlation coefficients were calculated, and these, with the number of observations for each calculation, are shown in Table I. The total range within which the total solids content of this milk could be predicted can be reduced 62% by knowing the fat content, as indicated by the square of the correlation coefficient. Similarly, the variation in the protein content could be reduced 58%, the ash content reduced 40%,

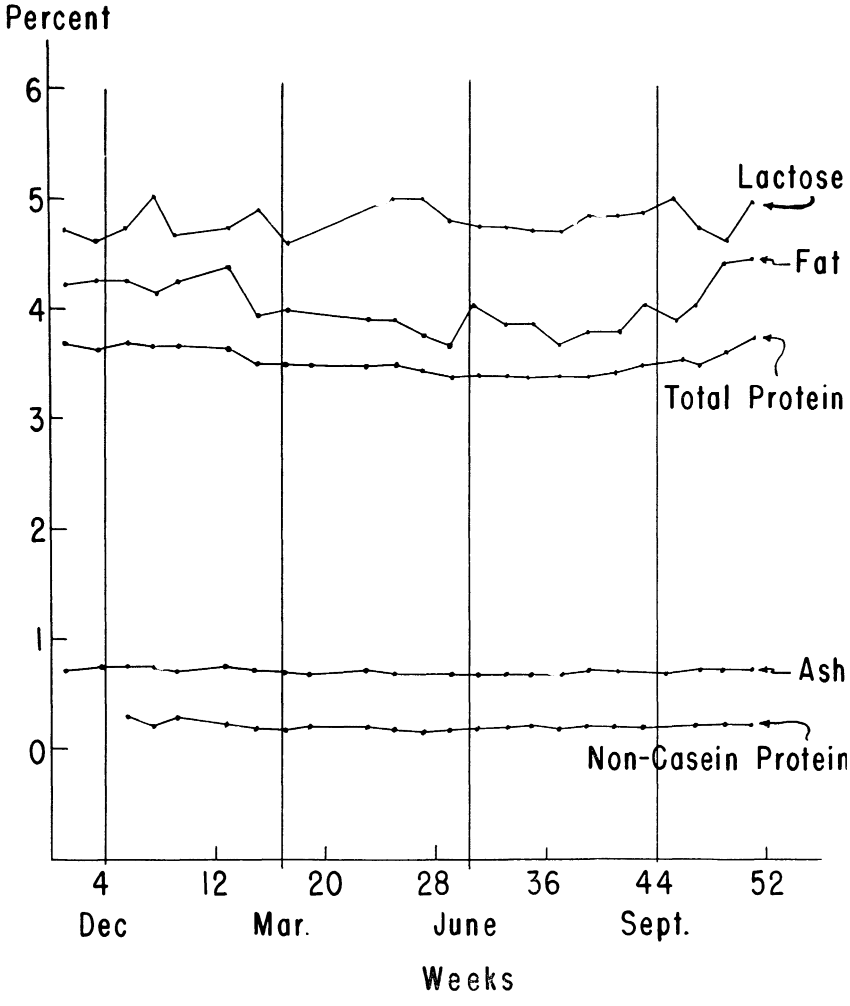

Figure 2.—Weekly herd milk averages for total solids and solids-not-fat.

and the variation in the lactose content reduced only 7%, if the fat content of the milk were known. There are values in the literature which are similar to these, and some workers have indicated that the various milk components occur almost independently of each other (4, 6, 8, 11, 13). Another author has indicated that there is a higher correlation between fat and protein than there is between fat and various other components of milk (7).

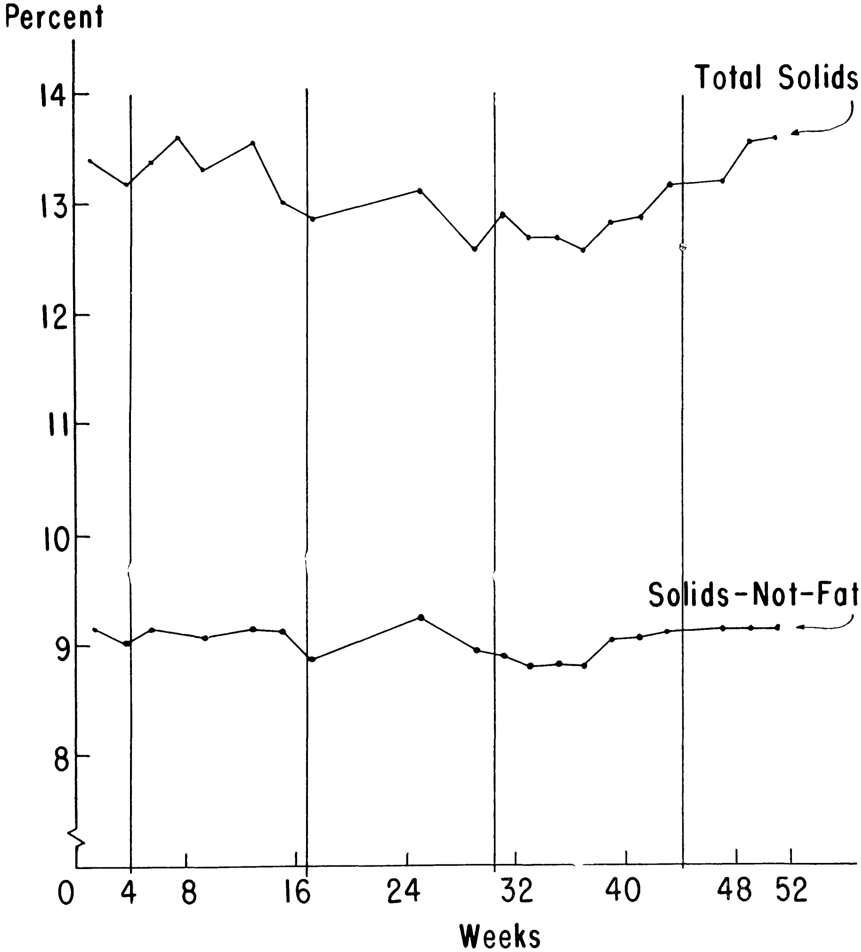

Figure 3.—Weekly herd milk averages for lactose, fat, protein, and ash.

Table 1.—Correlation Coefficients and Number of Observations for Daily Herd Milk Samples

	TS*	SNF	F	L	P	NCP	A	pH	TA	SG
TS	--	.783 (101)**	.790 (101)	.356 (101)	.760 (101)	.473 (71)	.640 (101)	.452 (96)	—.057 (101)	—.534 (64)
SNF		—	.237 (101)	.808 (101)	.437 (101)	.294 (71)	.360 (101)	.270 (96)	— 030 (101)	—.395 (64)
F			--	—.268 (123)	.763 (129)	.476 (99)	.632 (111)	.448 (127)	.215 (132)	—.342 (90)
L				--	—.176 (122)	—.113 (96)	—.150 (104)	—116 (121)	.057 (126)	— 088 (86)
P					--	.643 (105)	.732 (119)	.442 (133)	.155 (138)	—.340 (96)
NCP						--	.486 (87)	.371 (109)	.263 (109)	—.163 (86)
A							--	.418 (115)	—.064 (120)	—.454 (80)
pH								--	—.208 (137)	—.371 (99)
TA									--	.153 (99)
SG										--

*TS:	Total Solids	NCP:	Non-Casein Protein
SNF:	Solids—Not-Fat	A:	Ash
F:	Fat	pH:	pH
L:	Lactose	TA:	Titratable Acidity
P:	Total Protein	SG:	Specific Gravity

**Number of observations.

Means for the values measured in this study and the standard deviations of the means are shown in Table II.

Simple regression equations were calculated for some of these variables. These equations and the 95% confidence limits on single observations of Y at $\bar{X}$ are shown in Table III. The values used to calculate these equations and their confidence limits are shown in Table IV.

Equations 1, 3, 6, and 7 are similar to those appearing in the literature (7, 8, 9, 10, 12, 13). Equations 2 and 4 do not appear often in the

Table II.—Means, Standard Deviations, and Number of Observations for Daily Herd Milk Samples

Variable	n	Mean	Standard Deviation	Variable	n	Mean	Standard Deviation
		%	%			%	%
TS	101	13.13	0.39	NCP	109	0.23	0.03
SNF	101	9.06	0.25	A	120	0.73	0.02
F	132	4.04	0.25	pH	137	6.67[a]	0.60[a]
L	126	4.79	0.23	TA	138	0.168	0.007
P	138	3 55	0 13	SG	99	1.0320[a]	0.0020[a]

[a] Not expressed as percent.

literature, but were calculated from these data since the correlation coefficients of the variables involved were relatively high.

Table III.—Simple Regression Equations and 95% Confidence Limits on Single Observations

	Equation(*a*)	Confidence Limits at $\bar{X}$
(1)	$\hat{TS} = 8.106+1.234\ F$	±0.48
(2)	$\hat{TS} = 10.179+0.618\ L$	±0.73
(3)	$\hat{P} = 1.974+0.389\ F$	±0.17
(4)	$\hat{P} = 0.325+4.426\ A$	±0.17
(5)	$\widehat{P\text{-}NCP} = 1.985+0.329\ F$	±0.15
(6)	$\hat{L} = 5.747-0.235\ F$	±0.43
(7)	$\hat{A} = 0.508+0.054\ F$	±0.032

a The variables used in these equations are expressed in percent.

Table IV.—Values Used to Calculate Simple Regression Equations and Confidence Limits

	Variables								
	Y	X	n	$\bar{Y}$	$\bar{X}$	Sy^2	Sx^2	Sxy	$s^2_{y.x}$
(1)	TS	F	101	13.131	4.073	15.271	6.259	7.721	0.0581
(2)	TS	L	101	13.131	4.777	15.271	5.058	3.125	0.1348
(3)	P	F	129	3.548	4.046	2.100	8.072	3.139	0.00692
(4)	P	A	119	3.546	0.728	1.834	0.050	0.222	0.00728
(5)	P-NCP	F	96	3.311	4.032	1.201	6.353	2.089	0.00547
(6)	L	F	123	4.797	4.049	6.120	8.010	—1.879	0.04694
(7)	A	F	111	0.728	4.062	0.048	6.488	0.352	0.000262

Equation 5 relating casein and fat appears to be different from those reported by Babcock (3) and Van Slyke and Price (15).

Multiple regression equations and their 95% confidence limits were calculated to predict total solids, protein, lactose, or ash from fat and specific gravity. These are shown in Table V.

Since the equations predicting total solids measured as the sum of the solid milk components and as determined on the Mojonnier apparatus are somewhat different, the results of both methods are shown. The values used in calculating these equations are given in Table VI.

Table V.—Multiple Regression Equations and 95% Confidence Limits on Single Observations

			Equation					Confidence Limits at X_1, X_2
(8)	[a]$\hat{TS}_a$	=	51.396	+	1.185F	—	41.762SG	±0.455
(9)	[a]$\hat{TS}_m$	=	25.408	+	0.691F	—	14.924SG	±0.316
(10)	$\hat{P}$	=	12.537	+	0.358F	—	10.121SG	±0.169
(11)	$\hat{L}$	=	30.044		0.225F	—	23.569SG	±0.342
(12)	$\hat{A}$	=	4.033	+	0.042F	—	3.370SG	±0.032

[a]TS_a = Total Solids as the sum of Fat, Protein, Lactose and Ash.
[a]TS_m = Total Solids measured by the Mojonnier method.

Table VI.—Corrected Sums of Squares, Cross Products and Means for Multiple Regression Equations

Equations 8 and 9, Total Solids (n = 64)

	F	SG	TS_a	TS_m	Means
F	4.341	—0.0140	5.728	3.207	4.036
SG	- ---	0.000199	—0.0249	—0.0126	1.0323
TS_a	- ---	--- ----	10.932	--- ----	13.068
TS_m	- ---	--- ----	--- ----	3.903	12.789

Equation 10, Protein (n = 88)

	F	SG	P	Means
F	5.771	—0.0135	2.205	4.013
SG	- ---	0.000253	—0.00739	1.0321
P	- ---	- ------	1.473	3.529

Equation 11, Lactose (n = 83)

	F	SG	L	Means
F	5.690	—0.0140	—0.949	4.018
SG	- ---	0.000242	—0.00255	1.0322
L	- ---	- ------	3.615	4 812

Equation 12, Ash (n = 72)

	F	SG	A	Means
F	4.462	—0.0130	0.230	4.025
SG	- ---	0.000218	—0.00128	1.0321
A	- ---	- ------	0 03101	0.724

Lately there has been increased interest in using the lactometer and other methods of measuring specific gravity to predict the total solids content of milk. Because of this interest, the added precision gained by knowing specific gravity in addition to the fat content was calculated for these equations. These results are shown in Table VII. Listed are the multiple correlation coefficients, (R), for equations 8 through 12, the simple correlation coefficients, (r), for fat, (F), and the Y variable, and the percent sum of squares (ss), removed by specific gravity after the sum of squares due to fat has been removed. It appears that knowing specific gravity in addition to fat adds very little to the amount that the variation can be reduced when predicting total solids, protein, lactose, or ash. This is indicated by a comparison of the R^2 values to the r^2 values for fat and Y.

Table VII.—Correlation Coefficients and Sum of Squares Removed by Specific Gravity After Fat

	Y	n	Simple Correlation Coefficients Y vs F	Multiple Coefficients Correlation Y vs F and SG	% SS(a) Removed by SG after F
			r	R	$(R^2–r^2)100$
(8)	TS_a	64	0.8315	0.8461	2.45
(9)	TS_m	64	0.7792	0.7847	0.87
(10)	P	88	0.7562	0.7663	1.54
(11)	L	83	−0.2093	0.2751	3.19
(12)	A	72	0.6196	0.6707	6.60

a Sum of squares

Differences between these equations and those reported by others might be due to the sampling procedures used. As already mentioned, daily samples were used in this work, but most of the literature reports are based on samples taken biweekly or at longer intervals. In addition, some of the samples used for the work reported by others were 2 to 4 day composites (4, 6, 8, 9, 10, 12, 13). It is the authors' opinion that this daily sampling procedure gave results which better describe the composition of herd milk than did other sampling procedures reported in the literature.

Another possible cause of differences between this work and that of others is the cows in the herd from which the milk was taken. The Oklahoma State University dairy herd was composed of approximately 41% Holstein, 24% Ayrshire, 18% Jersey and 19% Guernsey cattle during the time this study was in progress. Walton (16) has shown that there are large variations in the composition of the milk of individual cows.

The correlation coefficients obtained in this study, for the most part, were rather low. This, the graphs of the data, and the confidence limits on the simple regression equations, indicate that daily variations are relatively large, and that sizeable errors could occur if single observations were the basis for standardizing large volumes of milk; for example, when standardizing the casein—fat ratio for a vat of cheese on the basis of a single Babcock test. In view of these errors, the best procedure may be to determine directly the milk constituent in which one is interested.

SUMMARY AND CONCLUSIONS

Daily samples of herd milk were taken an average of six days per week, every other week, for one year. Total solids, solids-not-fat, fat, total protein, non-casein protein, lactose, ash, specific gravity, titratable acidity, and pH were determined from these samples.

The seasonal trends of these data were similar to the reports in the literature. However, daily and weekly variations in the composition of this milk were quite large when compared to the changes in the monthly and seasonal averages.

Simple correlation coefficients indicate that there was little relation between most of the milk constituents determined. Simple regression equations were calculated for some of the variables. Confidence limits on these equations indicated that sizeable errors could occur if a single observation were the basis for standardizing a large volume of milk.

Multiple regression equations were calculated to predict certain milk constituents on the basis of the fat content and specific gravity of the milk sample. Correlation coefficients for these data indicate that knowing both specific gravity and fat does little more to reduce the variance of the predicted variable than does knowing fat alone.

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