RESEARCH PAPERS

Composition of Milks of Dairy Cattle. I. Protein, Lactose, and Fat Contents and Distribution of Protein Fraction

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ABSTRACT

Milks from commercial dairy herds in Southeastern Pennsylvania were analyzed for total protein, casein, whey protein, β-lactoglobulin, nonprotein nitrogen, and lactose contents. Data for fat contents and milk yields were from Dairy Herd Improvement Association records for the same lactation. Milk samples were from a single milking of healthy cows (151) in midlactation. Since the remainder of the milk was returned to the bulk milk of the farm, the data represent market milk composition. The data were grouped and analyzed by breed and β-lactoglobulin phenotype; there were 18 to 33 cows per breed. In true protein percentage, the breeds ranked: Jersey 4.07 ± .49, Brown Swiss 3.84 ± .47, Guernsey 3.56 ± .53, Ayrshire 3.30 ± .52, Milking Shorthorn 3.17 ± .47, Holstein 3.07 ± .43. Breeds differed in all other components and in milk yield. Brown Swiss ranked highest in yield of protein. Only whey protein and β-lactoglobulin contents were influenced by the β-lactoglobulin genotype with β-lactoglobulin A > AB > B in whey protein content.

INTRODUCTION

For 100 yr, dairy cattle have been selected for yield and fat content of their milks. During this time, dairy farmers were paid for their milk on its fat content. However, in the last two decades, more attention has been paid to the economic value of the milk proteins. In Holland since 1957 milk supplied to the cheese industries has been paid for on both protein and fat content (14). Later Denmark, Poland, and Switzerland followed the Dutch example and paid for milk used in cheese factories on protein and fat content (16). In the future, as a result of these economic trends as well as predicted world protein shortages, selection goals for all cows should be toward milk with a higher protein content. For the purpose of fluid consumption, the distribution of milk proteins between the casein and whey fractions may not be an important factor. Milk used for cheese production, however, should have a high casein content but be low in its whey protein and lactose content because the whey fraction is an underutilized byproduct of the cheese industry.

With these trends information about composition of milks of common breeds from commercial dairy herds in the United States is desired. Much of the information provides only the average composition of bulk milk of each breed. In addition, adequate data on the distribution of the milk proteins between the whey and casein fractions are not available. Composition of milk has increased in fat and solids-not-fat content over the past 50-yr in the United States (1900 to 1950) (1) but not in England (8).

We obtained data for the average composition of the market milk for each of six common dairy breeds to assess variation of composition of milk within each breed, as well as the protein distribution between the casein and whey fractions.

EXPERIMENTAL METHODS

Milk Samples

Samples of milk were taken from each cow at the evening milking. All cows were in good health and in midlactation (2nd to 5th mo of lactation). Samples were frozen within 1 h, and were from: Grim Family,[2] Pottstown, PA (Holstein, Jersey, Brown Swiss); Norristown

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[1] Agricultural Research Service, U.S. Department of Agriculture.

[2] Reference to brand or firm name does not constitute endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned.

State Hospital, Norristown, PA (Holstein); Walebe Farm, Inc. Collegeville, PA (Jersey, Brown Swiss); Butterwoods Farms, Birchrunville, PA (Brown Swiss); Grater Brothers, Schwenksville, PA (Guernsey); Charles Gable, Elverson, PA (Ayrshire); and S. Yoder, Shoemakersville, PA (Milking Shorthorn). Samples were taken in October to December, 1972, when all animals were in dry lots. Feeding regimes were approximately the same on all farms: alfalfa, hay, corn silage and grain concentrate. All farms were members of the DHIA (Dairy Herd Improvement Association), with typical production per cow. Each farm regularly produced milk for commercial dairy industries. The DHIA records contained statements about the identity of the breed of each cow. Samples represented the contribution of each animal to the market milk composition for a given day. The data were from three analyses of each individual sample.

Reagents

All chemicals were of a reagent grade.

Analytical Methods Used for Milk Protein Fractions

Nitrogen was determined by the standard micro-Kjeldahl method of the AOAC (4). A nitrogen conversion factor of 6.38 was used for calculation of protein contents of milk samples and various fractions. To obtain total nitrogen content, whole milk was used for digestion. The nonprotein nitrogen content (NPN) was determined on the supernatants produced by either of two methods: (a) 10 ml milk + 40 ml 15% trichloroacetic acid (18); or (b) solid trichloroacetic acid was added to whey to 12% concentration. Both methods gave identical results. The true protein nitrogen was calculated as follows: true protein N = total N − NPN. Whey nitrogen was determined by 16.041 Method I of AOAC (5). Whey protein nitrogen was calculated as follows: whey protein N = whey N − NPN. The value of the casein nitrogen was calculated from the total and whey nitrogen values: casein N = total N − whey N. β-Lactoglobulin N was determined by the method of Aschaffenburg and Drewry (2) except that β-lactoglobulin was precipitated in the last step with trichloroacetic acid instead of $(NH_4)_2SO_4$. Other whey protein N (α-lactalbumin, proteose-peptone, etc.) was taken to be equal to whey protein N − β-lactoglobulin N.

Lactose Determinations

Lactose was determined by the method of Marier and Boulet (12).

Milk Yield and Fat Contents

Milk yield, percent fat, and fat yield were obtained from DHIA records for the total lactation during which the samples were taken. These data were analyzed by the Pennsylvania State University, University Park.

β-Lactoglobulin Phenotyping

Phenotypes of β-lactoglobulins of the milk samples were identified by gel electrophoresis of whole whey (13) obtained by centrifugation at 50,000 × *g* for 1 h.

Statistical Analysis

Statistical analysis of the data was by the Statistical Analysis System (SAS) program. In this program, breed and β-lactoglobulin were treated independently and their interaction was the error term.

RESULTS

Nitrogen Distribution in Milk

Nitrogen distribution (mg nitrogen/100 ml) is in Table 1. The nitrogen content is subdivided into NPN, total protein, casein, total whey nitrogen, whey protein, β-lactoglobulin, and other whey protein. These same data are in Table 2 as percentages of total nitrogen in the milk of each breed.

True Protein Distribution in Milk

From data in Table 1, percent distribution of true protein nitrogen among casein, total whey protein, β-lactoglobulin, and other whey protein fractions was calculated (Table 3).

Distribution of Nitrogen Content of Whey

Table 4 gives the nitrogen distribution of the whey fraction for each breed, while Table 5 shows the distribution of the whey proteins between β-lactoglobulin and other whey proteins for each breed.

TABLE 1. Nitrogen distribution in milk, mg N 100 ml milk, mean/range.

	Holstein 26[a]	Jersey 25	Guernsey 24	Ayrshire 25	Brown Swiss 33	Milking Shorthorn 18	Average 151
Total N	505.1	661.5	580.0	543.4	634.8	535.7	582.9
(Mean-range)	303.4-641.6	531.5-801.3	425.8-742.4	407.1-787.2	493.1-734.0	409.0-731.2	303.4-801.3
NPN	24.4	23.3	22.5	26.2	34.0	39.6	28.1
(Mean-range)	16.4-38.9	19.3-28.0	17.1-35.0	17.6-37.7	22.0-45.2	28.1-46.5	16.4-46.5
Protein N	480.7	638.2	557.5	517.2	600.8	496.1	554.8
(Mean-range)	286.1-617.8	511.4-775.9	408.5-720.2	381.5-749.5	464.6-698.9	369.7-685.9	286.1-775.9
Casein N	395.8	530.9	451.0	427.6	492.4	401.5	455.1
(Mean-range)	240.0-516.8	419.5-650.0	324.6-589.5	329.5-626.2	371.1-595.3	283.0-528.2	240.0-650.0
Whey N	109.2	130.6	129.0	115.8	142.4	134.2	127.9
(Mean-range)	63.3-159.7	104.5-164.1	97.4-163.1	77.5-163.8	100.2-177.8	103.4-203.0	63.3-203.0
Whey protein N	84.9	107.3	106.5	89.6	108.4	94.5	99.7
(Mean-range)	46.0-128.4	78.0-138.8	74.5-136.5	51.9-131.4	66.8-142.5	69.8-157.7	46.0-157.7
β-lactoglobulin N	28.9	44.0	34.5	25.5	36.1	26.4	33.1
(Mean-range)	10.3-45.5	27.1-71.6	22.4-49.2	15.4-44.1	18.3-54.3	15.9-35.3	10.3-71.6
Other whey protein N	56.0	63.3	72.0	64.1	72.3	68.1	66.7
(Mean-range)	35.7-93.1	43.8-101.1	52.1-93.1	27.6-100.7	50.3-97.4	45.1-122.4	27.6-122.4

[a]Number of cows.

TABLE 2. Nitrogen distribution in milk. Milk total N = 100%.

	Holstein 26[a]	Jersey 25	Guernsey 24	Ayrshire 25	Brown Swiss 33	Milking Shorthorn 18	Average 151
NPN	4.9	3.6	3.9	4.9	5.4	7.5	4.9
(Mean-range)	3.1-7.5	2.9-4.9	2.8-5.9	3.3-6.3	3.1-8.2	5.3-10.6	2.8-10.6
Protein N	95.1	96.4	96.1	95.1	94.6	92.5	95.1
(Mean-range)	92.5-96.9	95.1-97.1	94.1-97.2	93.7-96.7	91.8-96.9	89.4-94.7	89.4-97.2
Casein N (Casein number)	78.2	80.2	77.7	78.7	77.4	74.8	77.9
(Mean-range)	68.7-83.7	78.4-82.2	74.0-81.4	74.0-82.6	71.2-81.5	64.3-79.7	64.3-83.7
Whey N (total)	21.8	19.8	22.3	21.3	22.6	25.2	22.1
(Mean-range)	16.3-31.3	17.8-21.6	18.6-26.2	17.4-26.0	18.5-28.8	20.3-35.7	16.3-35.7
Whey protein N	16.9	16.2	18.4	16.4	17.1	17.7	17.2
(Mean-range)	12.4-26.3	14.5-18.1	15.0-22.7	12.7-20.8	12.3-23.5	13.1-25.7	12.3-26.3
β-lactoglobulin N	5.8	6.6	6.0	4.6	5.5	4.9	5.6
(Mean-range)	3.0-10.6	4.3-10.4	3.8-8.1	3.3-7.0	2.4-8.3	3.6-6.0	2.4-10.6
Other whey protein N	11.1	9.6	12.4	11.8	11.7	12.8	11.6
(Mean-range)	7.7-19.1	7.2-13.2	9.4-16.3	6.3-14.3	8.2-16.4	8.2-22.1	6.3-22.1

[a]Number of cows.

TABLE 3. True protein distribution in milk. Total true protein N = 100%, mean/range.

	Holstein 26[a]	Jersey 25	Guernsey 24	Ayrshire 25	Brown Swiss 33	Milking Shorthorn 18	Average 151
Casein N	82.2	83.2	80.9	82.7	81.9	80.9	82.0
(Mean-range)	72.3-87.1	81.3-84.7	76.6-84.4	78.0-86.5	75.1-86.9	71.4-85.9	71.4-87.1
Whey protein N	17.8	16.8	19.1	17.3	18.1	19.1	18.0
(Mean-range)	12.9-27.7	15.3-18.7	15.6-23.4	13.5-22.0	13.1-24.9	14.1-28.6	12.9-28.6
β-lactoglobulin N	6.1	6.9	6.2	4.9	5.8	5.3	5.9
(Mean range)	3.1-11.3	4.5-10.8	4.0-8.5	3.5-7.4	2.5-8.7	4.0-6.6	2.5-11.3
Other whey protein N	11.7	9.9	12.9	12.4	12.3	13.8	12.1
(Mean-range)	8.0-20.1	7.4-13.6	9.7-16.8	6.5-15.0	8.7-17.3	8.8-24.6	6.5-24.6

[a]Number of cows.

TABLE 4. Distribution of nitrogen in whey. Total whey N = 100%, mean/range.

	Holstein 26[a]	Jersey 25	Guernsey 24	Ayrshire 25	Brown Swiss 33	Milking Shorthorn 18	Average 151
NPN	22.6	18.1	17.6	23.0	24.1	30.1	22.3
(Mean-range)	15.4-28.0	14.0-25.3	12.7-24.0	17.5-33.0	16.3-34.7	22.3-40.0	12.7-40.0
Whey protein N	77.4	81.9	82.4	77.0	75.9	69.9	77.7
(Mean-range)	72.0-84.6	74.7-86.0	76.0-87.3	67.0-82.5	65.3-83.7	60.0-77.7	65.3-87.3
β-lactoglobulin N	26.6	33.6	26.9	22.0	24.4	19.9	25.8
(Mean-range)	15.3-38.0	25.5-50.4	17.5-36.2	16.0-35.0	11.8-32.7	10.0-24.7	10.0-50.4
Other whey protein N	50.8	48.3	55.5	55.0	51.5	50.0	51.9
(Mean-range)	38.4-65.6	34.8-61.6	44.4-64.9	33.2-65.7	38.9-62.0	40.5-62.0	33.2-65.7

[a]Number of cows.

TABLE 5. Distribution of the whey proteins. Percent of the total whey proteins, mean/range.

	Holstein 26[a]	Jersey 25	Guernsey 24	Ayrshire 25	Brown Swiss 33	Milking Shorthorn 18	Average 151
β-lactoglobulin	34.1	41.0	32.7	28.7	31.9	28.7	33.0
(Mean-range)	18.9-49.7	27.1-59.1	21.2-44.8	19.6-51.3	17.7-43.4	13.9-37.4	13.9-59.1
Other proteins	65.9	59.0	67.3	71.3	68.1	71.3	67.0
(Mean-range)	50.3-81.1	40.9-72.9	55.2-78.8	48.7-80.4	56.6-82.3	62.6-86.1	40.9-86.1

[a]Number of cows.

TABLE 6. Composition of the milks, g/100 ml milk.

		Holstein 26[a]	Jersey 25	Guernsey 24	Ayrshire 25	Brown Swiss 33	Milking Shorthorn 18	Average 151
Crude protein	$\bar{X} \pm S$	3.22 ± .45	4.22 ± .51	3.70 ± .55	3.47 ± .55	4.05 ± .50	3.42 ± .51	3.72 ± .63
	range	1.94-4.09	3.41-5.11	2.72-4.74	2.60-5.02	3.15-4.68	2.61-4.67	1.94-5.11
True proteins	$\bar{X} \pm S$	3.07 ± .43	4.07 ± .49	3.56 ± .53	3.30 ± .52	3.84 ± .47	3.17 ± .47	3.54 ± .60
	range	1.83-3.94	3.26-4.95	2.61-4.59	2.43-4.78	2.96-4.46	2.36-4.38	1.83-4.95
Casein	$\bar{X} \pm S$	2.53 ± .40	3.39 ± .40	2.88 ± .44	2.73 ± .43	3.14 ± .42	2.56 ± .40	2.89 ± .51
	range	1.53-3.30	2.68-4.15	2.07-3.60	2.10-3.99	2.37-3.80	1.81-3.37	1.53-4.15
True whey proteins	$\bar{X} \pm S$	.541 ± .111	.684 ± .094	.681 ± .121	.571 ± .127	.691 ± .117	.600 ± .143	.632 ± .132
	range	.29-.82	.50-.89	.48-.87	.33-.79	.43-.91	.45-1.01	.29-1.01
β-lactoglobulin	$\bar{X} \pm S$	.184 ± .051	.281 ± .074	.222 ± .047	.163 ± .051	.222 ± .062	.168 ± .034	.208 ± .068
	range	.07-.29	.19-.46	.14-.31	.10-.30	.08-.35	.10-.23	.07-.46
Other whey proteins	$\bar{X} \pm S$	.361 ± .091	.404 ± .053	.459 ± .095	.410 ± .096	.470 ± .089	.432 ± .130	.424 ± .102
	range	.23-.59	.28-.65	.33-.59	.18-.56	.32-.62	.29-.78	.18-.78
Fat	$\bar{X} \pm S$	3.73 ± .32	5.42 ± .53	4.76 ± .44	4.12 ± .22	4.28 ± .39	3.58 ± .26	4.34 ± .71
	range	3.4-4.6	4.0-6.6	4.0-5.4	3.7-4.8	3.3-4.9	3.2-3.9	3.2-6.6
Lactose	$\bar{X} \pm S$	4.93 ± .61	4.99 ± .34	4.66 ± .34	4.67 ± .34	5.15 ± .46	4.80 ± .31	4.89 ± .45
	range	3.51-6.22	4.25-5.79	3.82-5.29	4.12-5.52	3.96-5.89	4.32-5.35	3.51-6.22

[a]Number of cows.

Total Organic Composition of the Milk

The total organic composition of milks of each breed is in Table 6. Protein distributions were from Table 1, lactose and fat data were obtained as stated in the experimental section.

β-Lactoglobulin and Composition

The relationship between the composition of milks and the various β-lactoglobulin phenotypes is in Table 7.

Yields of Milk and Its Constituents

Table 8 gives the milk and fat yields for each breed from DHIA records while true protein, casein, and lactose yields are from our data.

DISCUSSION

Crude Protein and True Protein Content

Reports (1, 8) have ignored the NPN content of milk, and total nitrogen of milk multiplied by 6.38 represented the protein content in milk. An average of 4.9% (2.8 to 10.6%) of total N in milk is in NPN fraction (Table 2). This means that NPN in milk is equivalent to .18 g protein/100 g of milk (Table 6). In milk from Jersey and Guernsey cows, NPN accounts for only 3.6% (2.9 to 4.9%) and 3.9% (2.8 to 5.9%) of the total N. However, in Milking Shorthorns NPN was higher at 7.5% (5.3 to 10.6%) of total N. Results for NPN were similar (21) for pooled plant milk in Ontario (5.5%) and for other studies (19, 20). The biological value of NPN is still unknown.

The largest true protein content was in milk from Jerseys (4.07%) and Brown Swiss (3.84%) and the lowest in milk from Holstein (3.07%) and Milking Shorthorn (3.17%) (Table 6). With respect to true protein content, as well as average composition of protein fractions of milk, Holstein and Milking Shorthorns were similar. Breed differences in protein content were significant at $P < .001$.

Casein Fraction

Casein is the principal protein component of bovine milk, as well as the principal protein component of cheese; hence, the yield of cheese depends directly on the amount of casein in milk.

The average amount of casein in the milks was 2.89% ± .51 (varying from 1.53 to 4.15% for individual samples). The amount of casein (Table 6) was in a close correlation with the true protein contents of the milk of which it is a part. Casein contents varied from 2.53% for Holstein to 3.39% for Jersey (Table 6). Casein comprises 82% of the true protein fraction in all milks, varying 71.4 to 87.1% for individual samples (Table 3).

The percent of total N of milk as casein is called the casein number (22), and it characterizes the suitability of milk for cheese production. The average casein number was 77.9 with individuals varying from 64.3 to 83.7 (Table 2). For the cheese industry, milk from Jersey cows

TABLE 7. Relationship between β-lactoglobulin phenotypes and other milk components.[a]

β-lactoglobulin phenotypes	Milk	Fat	True proteins	Casein	Whey protein	β-lacto-globulin	Lactose
	(kg)[c]	(%)					
A – 31[b]	5100	4.39	3.67	2.98	.68	.26	4.89
B – 63	5244	4.24	3.46	2.85	.59	.17	4.86
AB – 57	4786	4.43	3.60	2.91	.65	.22	4.92
Average – 151	5042	4.34	3.54	2.91	.64	.21	4.89

[a]While trends in composition occur, only the differences in β-lactoglobulin and whey protein contents are statistically significant.

[b]Number of cows.

[c]Yield in the lactation (305 days) when milk samples were taken.

TABLE 8. Yields of milk and its constituents for the lactation when milk samples were taken (305 days), kg, mean/range.

	Holstein 26[a]	Jersey 25	Guernsey 24	Ayrshire 25	Brown Swiss 33	Milking Shorthorn 18	Average (all breeds) 151
Milk[b]	5956	3476	4022	5668	6064	4510	5042
(Mean-range)	3240-9115	2229-5846	2639-5813	3730-7397	3137-9463	3350-6238	2229-9115
Fat[b]	221	188	191	234	258	161	214
(Mean-range)	125-351	121-298	143-283	157-307	117-441	116-236	116-441
True protein	184	141	148	184	233	144	177
(Mean-range)	107-359	92-229	96-212	154-255	110-365	85-273	92-365
Casein	152	117	115	153	191	116	145
(Mean-range)	85-253	77-190	75-165	122-213	88-302	65-210	65-302
Lactose	294	173	187	265	312	216	248

[a]Number of cows.

[b]Obtained from the DHIA Records.

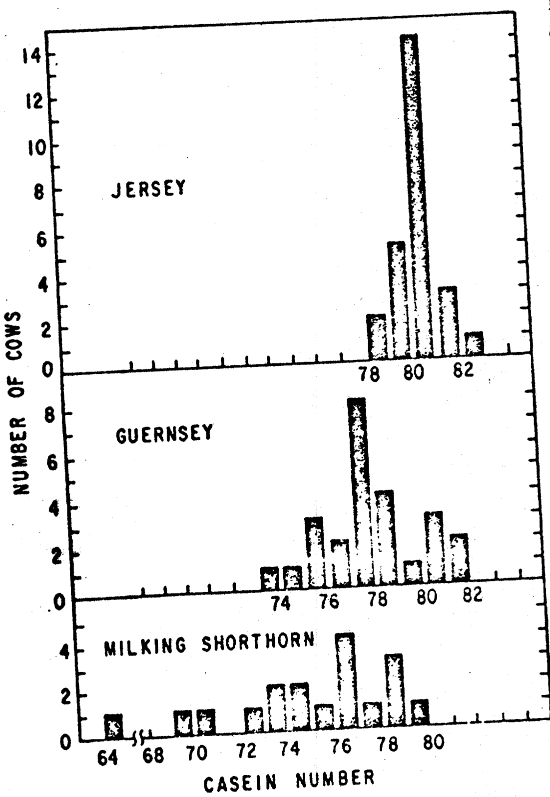
would be best suited for manufacturing of cheese while milk from Milking Shorthorn would be least suited (Table 2). There would be little change in the ranking of the various breeds in this respect if NPN is subtracted as can be seen by comparing casein number with casein as percent of true protein value (Table 3). However, variations of casein number in each breed (Fig. 1) show that some cows in each breed secrete milk with high casein content. Fig. 1 shows that range of the casein fraction of Jersey milk is narrow and comprises 80.2% of milk nitrogen (Table 2). No other breed shows a similar narrow distribution of casein number. Breed differences in casein content were significant at $P < .001$.

Whey Fraction

The whey fraction, including NPN, comprises 22.1% of the total milk nitrogen (Table 2). Milk of Jersey cattle contained 19.8% whey fraction nitrogen, and milk of Milking Shorthorns contained 25.2% whey nitrogen (Table 2). In Ontario, Szijarto et al. (21) found 23.5% of the nitrogen of pooled plant milk was in the whey fraction. The breed population in Ontario was 80% Holstein. The total true whey protein fraction, in all milks, averaged .64 g/100 ml of milk (Table 6). Brown Swiss, Jersey, and Guernsey were highest in whey protein while Holstein was lowest ($P < .01$).

The whey protein fraction accounts for 18% of the true milk proteins (Table 3). The NPN fraction in whey comprises 22.3% of the total whey nitrogen, but variations were considerable (Table 4). Milking Shorthorn milk contained highest NPN, 30.1% of the whey nitrogen. Commercial whey products have contained an average of 25% NPN (6).

The β-lactoglobulin fraction comprised 33% of the whey proteins (Table 5), 5.9% of the true proteins (Table 3), and 5.6% of the total N in milk (Table 2). These results agree with other reports (10, 15) which utilized chemical procedures for the separation of whey proteins. Results were different for Rolleri et al. (17) and Davies (7), who used electrophoretic and gel chromatographic procedures, respectively. Pre-



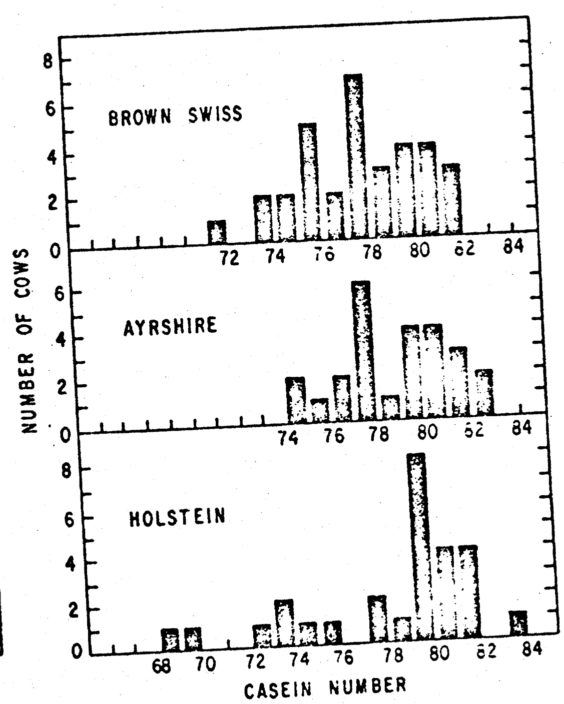


FIG. 1. Bar graphs of casein number of milks of individual cows; each breed is plotted separately. The casein number represents percent of total N of milk as casein.

liminary studies showed that absolute values for whey samples depend upon the method of fractionation.

The biological value of the whey protein is the highest among the milk proteins. From the nutritional standpoint, it would be desirable to increase whey protein content in milk intended for fluid consumption. However, for the cheese industry, the opposite is true since the whey fraction is an undesirable component, that is, a major problem in pollution control (6).

Lactose and Fat Contents

The highest lactose content (Table 6) occurred in Brown Swiss (5.15%) while Guernseys had the lowest at 4.66%. This represents a difference of 6%; however, individuals within each of these breeds exhibited a range equal to 30% of the mean. Breed differences in lactose content were significant ($P < .001$).

Jerseys (Table 6) exhibited the highest fat content (5.42%) while Milking Shorthorn (3.58%) had the lowest fat content; these differences by breed were significant at $P < .001$. The average fat content for all breeds was 4.34%.

β-Lactoglobulin Phenotypes and Their Relationship with Other Milk Components

Aschaffenburg and Drewry (3) suggested some form of quantitative relationship between β-lactoglobulin and casein synthesis. Given equal yields of milk of comparable casein content, an animal homozygous for the Lg^A-allele will produce almost twice as much β-lactoglobulin as the B homozygote while the output of the heterozygote falls about halfway between that of the two homozygotes.

Table 7 shows that on a percentage basis milks containing β-lactoglobulin A have not only more casein but also more true protein, whey protein, and β-lactoglobulin than milks containing β-lactoglobulin B. This appears to confirm the finding of Aschaffenburg and Drewry (3). However, only two of these differences were statistically significant. True whey protein and β-lactoglobulin contents were correlated with the β-lactoglobulin phenotype in Table 7 ($P < .004$).

Milks from cows homozygous for β-lactoglobulin A would be suited for consumption as fluid milk (higher total whey protein content). On the other hand, the casein number of milks from β-lactoglobulin B cows is highest at 78.6 (77.7 for A type and 77.4 for AB type β-lactoglobulin). Hence, for casein/whey ratio, this means that in cheese making, β-lactoglobulin B type milk would leave less protein nitrogen in whey.

Differences in average milk yield, lactose content, and fat content of three types of milk, based on β-lactoglobulin phenotype, were not significant.

Yields of Milk and Its Constituents During the Lactation

Table 8 shows the yields for each breed for the lactation (305 days) when the milk samples were taken. Variations of yields are considerable within each breed but between breeds differences in total milk yield were significant. True protein and casein yields (Table 8) were slightly lower than actual total yields for lactation, since the protein content in milk increases slightly at the end of lactation (effect of stage of lactation) (14, 23). The lactose content in milk slightly decreases at the end of lactation (14). Breeds could be placed into two groups: high yielding breeds (Holstein, Ayrshire, Brown Swiss) and low yielding breeds (Jersey, Guernsey, Milking Shorthorn).

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