RESEARCH PAPERS

Composition of the Milks of Dairy Cattle. II. Ash, Calcium, Magnesium, and Phosphorus

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ABSTRACT

Milks from commercial dairy herds in Southeastern Pennsylvania were analyzed for ash, calcium, magnesium, and phosphorus. Milk samples were from single milkings of 151 healthy purebred cows in midlactation. The data represent market milk composition. Average values for all animals were ash .78%, calcium 1.25 g/liter, magnesium .11 g/liter, and phosphorus 1.14 g/liter. The data also were grouped and analyzed by breed and β-lactoglobulin phenotype. Breeds differed in all inorganic components with 18 to 33 cows per breed. No differences in ash, calcium, magnesium, or phosphorus were significant when the data were grouped by β-lactoglobulin phenotype.

INTRODUCTION

In a previous paper (4), data concerning protein, lactose, and fat content of milks from six common dairy breeds were presented. The inorganic components of milk are important both in human nutrition and also as stabilizers of the milk system (3). Successful coagulation and precipitation of casein in the manufacture of cheese depend on the calcium ion concentration. The present study was undertaken to obtain data for the average composition of ash, calcium, magnesium, and phosphorus in the market milk of six common dairy breeds and to assess this variation within each breed.

EXPERIMENTAL PROCEDURE

Milk Samples

Aliquots of the same milk samples used in (4) were analyzed for inorganic constituents. Samples were taken from the full milking of healthy cows in midlactation and were frozen within 1 h of collection. Samples were collected from October to December 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, and samples represent the contribution of each animal to the market milk composition for a given day.

Reagents

All chemicals used were of reagent grade.

Ash, Calcium, and Magnesium

For ash determinations, 5 ml milk samples were evaporated to dryness on a steam bath and ignited in a muffle furnace at 525 C until the ash was carbon free. The ash was cooled in a desiccator, weighed, and calculated as percent ash (1). Calcium and magnesium in the ash were determined in an acidic aqueous solution containing 1% lanthanum chloride and 5% HCl by atomic absorption spectroscopy.

Total Phosphorus

For phosphorus determinations, 5 ml milk samples, containing 1 ml .4% magnesium acetate to chelate phosphate, were evaporated to dryness over a steam bath and ignited in a muffle furnace at 600 C. Phosphorus was then determined by a standard molybdenum blue micro method (2).

β-Lactoglobulin Phenotyping

Phenotyping of β-lactoglobulin was as described (4).

Statistical Analysis

Statistical analysis of the data was standard analysis of variance. In this analysis, breed and phenotypic differences in β-lactoglobulin were

TABLE 1. Means, standard deviations, and ranges of percent of ash, calcium, magnesium, and phosphorus in milk of six breeds.

		Holstein 26	Jersey 25	Guernsey 24	Ayrshire 25	Brown Swiss 33	Milking Shorthorn 18	Average 151	P (larger F) for breeds
Ash (%)	$\overline{X}$ SD	.741 .086	.826 .090	.801 .075	.752 .040	.781 .064	.743 .064	.776 .072	.0004
	range	.49 to .89	.67 to .98	.65 to .98	.66 to .85	.62 to .95	.62 to .91	.49 to .98	
Ca (g/liter)	$\overline{X}$ SD	1.21 .18	1.46 .14	1.31 .14	1.11 .08	1.25 .14	1.13 .09	1.25 .13	.0001
	range	.94 to 1.71	1.17 to 1.72	1.00 to 1.58	.98 to 1.40	1.00 to 1.59	1.01 to 1.37	.94 to 1.71	
Mg (g/liter)	$\overline{X}$ SD	.120 .040	.107 .012	.111 .016	.106 .013	.108 .017	.099 .011	.109 .021	.0722
	range	.082 to .268	.088 to .127	.081 to .150	.086 to .147	.084 to .146	.084 to .113	.081 to .268	
P (g/liter)	$\overline{X}$ SD	.985 .203	1.33 .17	1.16 .11	1.01 .10	1.24 .16	1.09 .16	1.14 .16	.0001
	range	.67 to 1.41	1.00 to 1.60	1.00 to 1.46	.88 to 1.27	.94 to 1.57	.80 to 1.40	.67 to 1.60	

TABLE 2. Mean and ranges of ratios of minerals in milk (g/g) for six breeds.

		Holstein 26	Jersey 25	Guernsey 24	Ayrshire 25	Brown Swiss 33	Milking Shorthorn 18	Average 151
Ca:P	$\overline{X}$	1.20:1	1.10:1	1.13:1	1.10:1	1.01:1	1.04:1	1.09:1
	range	.80:1 to 1.92:1	.98:1 to 1.31:1	.94:1 to 1.35:1	.86:1 to 1.43:1	.80:1 to 1.18:1	.79:1 to 1.27:1	.79:1 to 1.92:1
Mg:P	$\overline{X}$	.12:1	.08:1	.09:1	.10:1	.09:1	.09:1	.095:1
	range	.08:1 to .32:1	.06:1 to .10:1	.08:1 to .12:1	.08:1 to .12:1	.07:1 to .11:1	.07:1 to .11:1	.06:1 to .32:1
Ca:Mg	$\overline{X}$	10.11:1	13.74:1	11.99:1	10.49:1	11.59:1	11.44:1	11.56:1
	range	5.38:1 to 15.88:1	11.54:1 to 17.54:1	10.28:1 to 13.58:1	7.39:1 to 12.47:1	8.70:1 to 15.70:1	9.83:1 to 14.16:1	5.38:1 to 17.54:1
Ca + Mg:P	$\overline{X}$	1.32:1	1.18:1	1.23:1	1.20:1	1.10:1	1.13:1	1.19:1

treated independently, and their interaction was the error term.

RESULTS AND DISCUSSION

Total ash, calcium, magnesium, and phosphorus of the milks showed significant differences between breeds as well as a wide range of values within each breed. Table 1 shows a summary of the data, and the last column indicates the significance of the results derived from the analysis of variance.

Ash Content

The average ash content of the milks of the breeds (Table 1) varied from .74% for Holstein and Milking Shorthorn to .83% for the Jersey breed. The average amount of ash in the milks of all breeds tested was .78%. The lowest value (.49%) was in the milk from a Holstein cow and the highest (.98%) in milks from Jersey and Guernsey cows.

Ash was higher than the average pooled plant milk received by dairies in New York State during 1959 to 1961 which contained .73% ash (5). However, the cattle in this latter study were predominantly Holstein, and the Holstein milk in this report had an average ash of .74%. Ash of pooled dairy milk in Sweden, 1969, was .73% (8), and the cattle were predominantly Swedish Red and White and Swedish Friesian.

Calcium

Average calcium of the milks of the breeds (Table 1) varied from 1.11 g/liter for Ayrshire to 1.46 g/liter for Jersey. The average calcium content in the milks of all breeds was 1.25 g/liter. The lowest value (.94 g/liter) was for a Holstein cow and highest (1.72 g/liter) for a Jersey cow. The average pooled plant milk in New York State, 1959 to 1961, contained 1.11 g/liter calcium, varying from .61 to 1.34 g/liter (5). Pooled plant milk in California, 1960, (7) had average calcium of 1.37 g/1000 g milk, while pooled dairy milk in Sweden, 1969, had an average calcium content of 1. 24 g/liter (8).

Magnesium

Average magnesium of the milks of the breeds (Table 1) varied from .099 g/liter for Milking Shorthorns to .120 g/liter for Holstein. The average magnesium content in milks of all breeds was .108 g/liter. The highest value (.268 g/liter) was for a Holstein cow while the lowest value (.081 g/liter) was for a Guernsey. Pooled dairy plant milks reportedly contained magnesium as follows: in New York State, 1959 to 1961, average .164 g/liter (varying from .038 to .484 g/liter) (5); in California, 1960, average .085 g/1000 g milk (7); and in Sweden, 1969, average .13 g/liter (8). The variation of magnesium between individual milk samples was considerable: .081 to .268 g/liter as shown in Table 1, but .038 to .484 g/liter was reported for New York State pooled milk (5). It seems that the wide variation of magnesium in milk could be related to the magnesium in feeds of the animals. Calcium and phosphorus did not show such variations. There is a possible relationship between low magnesium in milk and a cow's sensitivity to grass tetany. Grass tetany in cows usually results from low magnesium and calcium in the blood (10).

Phosphorus

Phosphorus occurs in protein, lipid, and inorganic fractions in milk (6). The average phosphorus of milks of breeds tested (Table 1) varied from 1.01 g/liter for Holstein to 1.33 g/liter for Jersey. The average total phosphorus con-

TABLE 3. Relationship between β-lactoglobulin phenotypes and inorganic milk components (means).

β-Lactoglobulin phenotypes	Ash	Ca	Mg	P	Ca/P
	(%)		(g/liter)		(ratio)
A-31[a]	.78	1.26	.115	1.12	1.11:1
B-63	.77	1.21	.108	1.12	1.08:1
AB-57	.78	1.28	.106	1.17	1.09:1
Average-151	.78	1.25	.108	1.15	1.09:1

[a]Number of cows.

TABLE 4. Coefficients of correlation for milk components[a].

	% Casein	Total whey	β-Lg	Other whey	% Total protein	Milk yield	% fat	% Lactose	% Ash	Calcium	Magnesium
Total whey protein (g/100 ml)	.55										
β-Lactoglobulin (g/100 ml)	.62	.62									
Other whey protein (g/100 ml)	.35	.67	.16								
Percent total protein	.98	.65	.67	.49							
Milk yield (kg)	-.19	-.20	-.37	.04	-.20						
Percent fat	.60	.36	.51	.05	.58	-.45					
Percent lactose	.15	-.07	.07	-.15	.11	.04	.07				
Percent ash	.55	.44	.51	.20	.56	-.12	.42	.06			
Calcium (g/liter)	.62	.40	.56	.11	.61	-.27	.56	.11	.63		
Magnesium (g/liter)	.29	.20	.16	.16	.29	.08	.04	-.04	.30	.35	
Phosphorus (g/liter)	.74	.37	.51	.15	.71	-.32	.56	.22	.57	.60	.15

[a]Probability $<.01$ of $r>.2$ for hypothesis $r = 0$.

tent of the milks of all breeds was 1.15 g/liter. The highest value (1.60 g/liter) was for a Jersey cow while the lowest value (.67 g/liter) was for a Holstein cow. Pooled plant milk in California, 1960, contained an average of .970 g/1000 g milk (7) and in Sweden, 1969, .95 g/liter (8). The Swedish data (8) show that during the 30 yr, 1937 to 1969, the phosphorus content in pooled plant milk decreased from 1.04 g/liter to .95 g/liter. Also whey protein content decreased. However, calcium, magnesium, total solids, fat, total protein, casein, and lactose content increased.

Calcium to Phosphorus Ratios

Milk is the major source of calcium in the human diet, and proper calcium to phosphorus ratios are important for nutrition and development. The mean calcium and phosphorus ratio (by weight) in milk from all breeds was 1.09:1. The ratios according to breed varied from 1.01 to 1.20:1 (Table 2). The lowest ratio (1.01:1) was for Brown Swiss, and the highest (1.20:1) was for Holstein. The ratio for Milking Shorthorn was similar (1.04:1) to Brown Swiss while the Jersey, Guernsey, and Ayrshire breeds (1.10:1, 1.13:1, 1.10:1) were close to each other.

Magnesium to phosphorus and calcium to magnesium ratios also were calculated (Table 2). Milks from Holstein cows showed the widest variations in ratios of inorganic components.

β-Lactoglobulin Phenotypes and Their Relationship to Inorganic Milk Components

The data were grouped according to β-lactoglobulin phenotype (Table 3). Although means differed, when variance was analyzed none of these differences by β-lactoglobulin phenotype was significant.

Relationship of Milk Constituents to Each Other

The analytical results of the organic (4) and the inorganic fractions of milk were compared by correlation coefficients. These results are in Table 4. Correlations among true protein, casein, β-lactoglobulin, fat, ash, calcium, and phosphorus were larger than .5. Lactose and magnesium showed no significant correlations. The lack of correlation between ash and lactose appeared to be inconsistent with the theory (9) that the mineral and lactose contents maintain a constant osmotic pressure in milk. Since calcium, magnesium, and phosphorus occur primarily in the colloidal complexes of milk and do not contribute to the osmotic pressure, their contribution to the ash content was subtracted. This residual ash content (representing primarily sodium, potassium, and chloride) was correlated −.027 with lactose content. No correlations between milk yield and any components were significant, in fact, most correlations were negative. When the data were grouped by breed, the coefficients changed but no breed specific correlations were outstanding.

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