Nutrient Profiles of Commercial Goat Milk Cheeses Manufactured in the United States[1,2]

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ABSTRACT

Thirty varieties of commercial goat milk cheeses collected from 13 manufacturers in 11 states of the US were evaluated. Concentration profiles of basic nutrients, major and trace minerals, their correlations, and mineral ratios in the caprine cheeses were determined to compare nutritional parameters among the varieties. Mean percentage of moisture, fat, protein, and ash for plain soft, semi-soft, hard, pepper, garlic, and herb cheeses were 59.8, 22.5, 18.9, 1.74; 43.2, 28.5, 26.2, 2.83; 27.4, 32.3, 25.4, 3.58; 57.3, 22.9, 21.6, 1.32; 64.3, 18.3, 16.7, 1.34; 59.1, 21.8, 17.3, 1.60, respectively. Ranges of mean concentrations (mg/100 g wet basis) of S, P, K, Mg, Ca, Na, Cl, Fe, Al, Mn, Cu, and Zn were: 2.00 to 8.05; 192 to 785; 7.03 to 103; 10.3 to 78.0; 57.1 to 1035; 225 to 924; 96.0 to 1260; .52 to 8.73; .47 to 22.1; .08 to .40; .44 to 1.32; .49 to 4.13, respectively. Twenty of the 30 varieties were very high or high moisture cheeses, which would suggest slow coagulation as the major mode of fabrication. Wide variations in the concentrations of P, K, Ca, Na, Cl, Fe, Al, and Zn were found among and within varieties of the cheeses. High concentrations and variations in Fe and Al in the cheeses indicate a significant possibility of uptake of these elements into the products during farmstead manufacturing processes. Percentage of moisture was negatively and significantly ($P<.05$ or $P<.01$) correlated with the concentrations of ash, fat, protein, and most of the minerals. Percentage of ash was positively and significantly correlated with the concentrations of macrominerals but negatively and less correlated with concentrations of Fe, Al, Mn, and Cu. The Na:K ratio was the highest of the five mineral ratios. Differences were significant for Ca:P, Ca:Mg, and Na:K ratios among the six types of goat cheese tested.
(Key words: goat cheese, nutrient profiles, minerals)

INTRODUCTION

There has been a noteworthy increase in per capita consumption of cheeses in the United States during the last few decades (2). Goat milk cheese has gradually gained popularity among certain ethnic groups, health food lovers, and private goat farmers in the US. Moreover, the continued shift in consumer tastes to "exotic" foreign and specialty cheeses has led to the increased volume of goat cheese importation to the States. In 1988, the amount of imported goat cheese from France alone was 447 metric tons, which comprised approximately 80% total imported caprine cheeses (A. Bassier, 1989, Couturier U.S.A., Inc., Los Angeles, CA, personal communication).

The total volume of goat cheese produced by licensed dairies in the United States in 1980 was about 90 metric tons, and 31 metric tons of French goat cheese was sold in the same year (10).

The *Agricultural Handbook Number 54* of the USDA (22) describes over 400 varieties of

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[2]Mention of brand names does not constitute endorsement by Prairie View A&M University nor US Department of Agriculture over similar products that are equally suitable.

goat cheese and lists over 800 names of cheeses, many of which are made from goat milk or combinations of goat with other species milk such as cow, ewe, or buffalo.

Production of goat milk is seasonal, which causes significant variation in the chemical composition of its fluid milk and products. Goat cheese would be expected to vary in composition due to the high variation in the composition of milk, modifications of manufacturing procedures, and multitude of aging time and conditions (16). Much of the varietal differences among cheeses is attributed to the nature of physical and chemical changes during ripening (4, 5, 14), which are influenced by the cultures, chemicals, or flavor ingredients added to the curd during manufacturing (13, 14, 16).

Worldwide, more people drink the milk of goats than the milk of any other single species (7, 19). Therefore, the nutritional and economical value of goat milk and its products have a significant impact on the well-being of mankind. However, there is little information on the nutritional and chemical compositions of commercial goat cheeses, and the scientific literature characterizing the nutritive value of commercially available goat cheeses manufactured and marketed in the US is almost nonexistent. Furthermore, *Agricultural Handbook Number 8-1* (20) lists little information on the chemical composition of goat cheeses.

The objectives of this study were 1) to determine the concentration of basic nutrients, and major and trace minerals in commercial goat cheeses produced in the US, 2) to compare differences in the levels of nutrients between varieties of goat cheese, and 3) to evaluate correlation coefficients between nutrient parameters and mineral ratios.

MATERIALS AND METHODS

Collection of Cheese Samples

Thirty varieties of commercially manufactured and marketed goat milk cheeses were collected from 13 manufacturers located in 11 states in the US. Samples were classified according to moisture content and type of spice added to the product. Plain type cheeses were divided into soft, semi-soft and hard varieties, using the classification by Webb and Johnson (25). Cheeses to which spice was added were characterized as garlic, pepper, and herb cheeses. Nearly all of the spice cheeses belonged to soft cheese varieties. Due to similarities of moisture content among soft and spice cheeses, the cheese samples were also categorized as plain soft and as soft with spice additives relative to hard cheeses.

Chemical Analysis of Nutrients

Three representative samples were taken from different packages of each variety of cheese for chemical analysis. Samples were assayed in triplicate for nutrients tested.

Moisture content was determined by oven drying at 105°C for 24 h (1). Total fat was assayed using the Babcock method, and total protein was analyzed by Kjeldahl procedure as described in *Standard Methods for the Examination of Dairy Products* (21). Ash content was determined by dry ashing the samples in a muffle furnace at 550°C for 24 h. For determination of mineral concentrations, 5 g of cheese samples were dry ashed in a porcelain crucible, solubilized with 10 ml of 6*N* HCl, quantitatively transferred into 25-ml volumetric flasks, and diluted to volume with double-deionized water (1). Concentration of major and trace minerals in the samples were determined by Inductively Coupled Argon Plasma Emission Spectroscopy (Jarrell-Ash Co., Model Number Atom-Comp-1100). The sample flow rate was .625 L/min, and the nebulizer pressure was set at 40 psi. The wavelengths used for the tested minerals were S, 182.0; P, 214.9; K, 766.2; Mg, 279.0 or 279.5; Ca, 315.8 or 317.9; Na 588.9 or 330.2; Fe, 271.4; Al, 308.2; Mn, 257.6; Cu, 324.7; Zn, 213.9 nm, respectively. Chloride concentration was quantified by a chloride analyzer (Corning Model Number 926, Medfield, MA).

Statistical Analysis

Analysis of variance, Duncan's multiple mean comparison of all nutrients among the tested cheese varieties, and correlation coefficients among the levels of nutrients were determined as described by Steel and Torrie (24). The unbalanced data due to missing observations were analyzed by the general linear model of the SAS program (23). Mineral ratios of Ca:P, Ca:Mg, Fe:Zn, Na:Cl, and Na:K were calculated for the six types (three plain and three

TABLE 1. Percentage of basic nutrients (wet basis) in selected varieties of commercial goat cheeses produced in the United States.

Goat cheese variety	No. Observ.	Moisture		Fat		Protein		Ash	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Fresh plain soft[1]	32	59.8	6.81	22.5	4.37	18.9	5.26	1.74	.97
Fresh soft, garlic[2]	6	64.3	5.55	18.3	3.15	16.7	2.34	1.34	.12
Fresh soft, pepper[3]	9	57.3	12.2	22.9	9.36	21.6	6.29	1.32	.185
Fresh soft, herb[4]	12	59.1	2.11	21.8	2.13	17.3	2.26	1.60	.605
Fresh chevre with chives	3	56.0	.55	24.5	.14	16.3	.14	1.45	.036
Fresh natural soft with herb and garlic	3	59.3	.23	21.1	.07	17.6	3.61	1.27	.089
Feta	3	52.3	1.21	25.3	1.06	25.1	1.56	4.30	.273
Aged green pepper cone	3	42.0	1.26	34.6	.21	29.6	.78	1.54	.03
Aged natural rind	3	47.6	3.40	29.5	1.41	28.5	.71	1.99	.04
Camembert capri	3	47.3	1.18	28.8	1.13	29.1	.35	1.67	.244
Blue capri, aged	3	44.0	.35	28.7	.28	29.5	.64	1.82	.113
Blue	3	25.9	1.62	31.8	1.06	20.2	.35	3.32	.357
Cheddar	3	41.7	1.76	26.6	1.13	30.3	.56	3.60	.134
Fromage de chevre, hard	3	28.1	1.53	29.3	.35	21.7	.64	3.66	.129
Shepherd's hard	3	31.6	1.82	33.1	1.20	28.9	.07	3.93	.145
Montasio's hard	3	25.9	1.29	36.8	1.06	31.9	.07	3.52	.021
Ancho chile, hard	3	42.3	.78	29.8	.35	22.2	.35	4.11	.028

[1]Mean of 10 varieties from 10 manufacturers.

[2]Mean of three varieties of garlic-added cheese.

[3]Mean of three varieties of pepper-added cheese.

[4]Mean of four varieties of herb-added cheese.

spice) of cheeses, and the differences between ratios were also compared.

RESULTS AND DISCUSSION

The mean moisture, fat, protein, and ash contents in selected varieties of commercially available goat cheeses in the US are shown in Table 1. Based on moisture content, the majority of the goat cheeses tested belonged to the soft cheese category. According to Webb and Johnson (25), cow cheeses are defined as hard, semi-soft, and soft, when the ranges for moisture are 30 to 40, 39 to 50, and 50 to 75%, respectively. However, Kosikowski (13) pointed out that a classification based on moisture is scarcely adequate because it tells little about the cheese. He classifies natural cheeses as "very high", "high ", "medium", and "low moisture"; the respective moisture ranges are 55 to 80, 45 to 55, 34 to 45; 13 to 34%.

Twenty of the 30 varieties tested in this study were very high and high moisture type cheeses when classified by the latter definition (13). Le Jaouen (15) indicated that the vast majority of goat cheeses are of the soft body type, and almost all French goat cheeses are of the natural drainage type associated with slow coagulation. Manufacture of goat cheeses by slow coagulation and natural acidification with lactic acid or possibly with a small amount of added rennet apparently leaves more moisture in the final products.

Few standards have been documented for classifying goat cheeses on the basis of moisture content. Even for cow cheeses, formal classifications based on rheology, or softness and hardness of body, use no objective measurements (13). Some cheeses classified as hard, such as Cheddar or Port Salut, are, in fact, softer in texture than those listed as soft, for example, Mysost and Block cottage (13).

The cheeses with added garlic had the highest mean moisture content (Table 1). Soft, spiced cheese varieties generally contained higher moisture than the other varieties. Feta and Camembert goat cheeses contained slightly less moisture than counterpart cheeses from cows reported in the *Agricultural Handbook Number 8-1* (20). However, the goat Cheddar cheese manufactured in our creamery had higher moisture than the cow Cheddar product

reported in the same handbook (20). *The Code of Federal Regulations,* Title 21: Parts 100 to 169 defines Cheddar cheese such that it cannot be made from goat milk (11). However, we were able to produce cheese of "similar" characteristics using goat milk in our creamery.

The percentage of fat in the goat cheese varieties increased as moisture decreased (Table 1). The same trend was also observed for protein content of the cheeses.

The ash content of the goat cheeses was higher in harder varieties than in soft varieties. However, the Camembert and Blue capri cheeses contained less ash than the other aged or hard varieties (Table 1). Concentrations of major minerals such as Ca, P, Na, and Cl in these cheeses were lower than for the other hard varieties (Table 2). Why concentrations of minerals vary among varieties is unknown. The difference, however, may have resulted from variation in mineral content of original milk or in processing methods of different manufacturers. Feta cheeses had the highest ash content, likely because of the high salt content of the brine solution.

Concentrations of major minerals, such as P, K, Ca, Na, and Cl, varied widely among and within varieties of cheese and relatively less variation in S and Mg content of the goat cheeses (Table 2). For the fresh plain soft cheeses manufactured by 10 different producers, concentrations of the five major minerals varied widely (Table 2). These results suggest that manufacturing procedures vary significantly among manufacturers. The mineral composition of cheese depends on the conditions of coagulation, wheying, and salting (17). Rapid acidification by lactic fermentation, followed by efficient wheying, favors curd demineralization, whereas rapid coagulation avoiding or retarding acidification retains the mineral elements of the milk (6).

Martin-Hernandez and Juarez (17) observed that concentrations of Ca, P, and Mg in fresh, semi-hard, and Majorero goat cheese were increased compared with those in the original milk. Those results were supported by this study in which concentrations of S, P, Mg, Ca, and Na for all tested varieties were higher than in those of goat milk shown in the previous reports (8, 18). The authors (17) also reported that Ca concentration was highest, followed by P and Mg. In the present study, Ca was higher than P only for semi-soft or hard varieties, whereas the opposite phenomenon was seen in the high moisture, soft cheese varieties (Table 2). Potassium content of the cheeses apparently had lower retention and greater variation in the products. The aged varieties contained considerably lower Ca and P than other varieties with similar moisture, which resulted in lower ash contents (Table 1 and 2). Mineral content of cheese is affected by the coagulation and ripening conditions (17). The reduction in Ca and P is attributed to the loss of calcium phosphate from the whey when it changes from a colloidal to a soluble state during coagulation (curd pH, 4.45) (6). The high loss of Ca and P in those varieties are also supported by reports that curd grain size exerts considerable influence on the retention of Ca, P, Fe, and Zn in cottage cheese (26, 27) and Manchego cheese (9).

Martin-Hernandez and Juarez (17) reported 80 to 90% of the Na in milk is lost in whey. In that report, Na concentrations were lower than the present study, in which high levels of Na in these varieties were probably due to added salt. Wong et al. (28) also found that Na values in 21 varieties of commercial cow cheeses differed widely from previously published values.

Variability in the concentrations of Mn and Cu was less than for Fe, Al, and Zn (Table 3). The concentrations of the five trace minerals in this study were higher than those reported by Martin-Hernandez and Juarez (17).

Most goat cheese varieties evaluated in this study had significantly higher concentrations of Fe when compared with concentrations of Fe reported for cow cheeses in *Handbook Number 8-1* (20) and of goat cheeses investigated by Martin-Hernandez and Juarez (17). Furthermore, there were marked variations in Fe and Al within and among the varieties of goat cheeses in this study. High Fe and Al values indicate a possibility of contamination by these minerals from processing utensils and containers during manufacturing of the cheeses. The production of most goat cheeses is performed predominantly by farmstead cheese producers using manual procedures, unlike the commercial, automated production of cow cheese. In fact, several samples of goat cheese we tested had extremely high values of Fe, Al, and Zn (Table 3).

Brule and Fauquant (3) found that the high retention rate for trace elements in cheeses was attributable to 95% of Zn and Mn and 50 to

TABLE 2. Concentrations (mg/100 g, wet basis) of major minerals in selected varieties of goat cheeses produced in the United States.

Cheese varieties	No. observations	S		P		K		Mg		Ca		Na		Cl	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Fresh plain soft[1]	32	3.54	2.89	275	107	25.8	27.6	14.6	4.22	172	179	416	187	293	322
Fresh soft, garlic[2]	6	4.10	2.40	247	98.0	15.2	7.84	17.2	8.39	117	58.2	331	81.3	145	1.89
Fresh soft, pepper[3]	9	4.13	1.79	236	32	27.8	31.1	17.9	2.72	107	23.1	298	62.7	201	61.8
Fresh soft, herb[4]	12	2.99	1.02	225	31.2	35.0	29.3	15.3	3.91	112	33.6	336	137	165	73
Fresh chevre with chives	3	2.13	.22	226	5.32	14.0	8.96	14.7	.21	108	2.70	313	17.8	156	18.0
Fresh natural soft with herb and garlic	3	4.20	2.05	292	131	20.6	8.16	19.0	12.7	139	82	368	105	145	.71
Feta	3	3.49	1.91	544	22.9	62.2	33.6	17.6	1.12	639	8.08	916	105	1260	35.0
Aged green pepper cone	3	5.21	1.96	250	33.5	8.91	1.82	19.2	2.01	110	41.1	358	19.2	278	3.50
Aged natural rind	3	6.03	3.66	303	50.5	30.3	19.7	23.6	5.13	101	31.7	429	33.8	397	2.83
Camembert capri, aged	3	2.37	.37	264	4.36	7.03	4.08	21.8	1.30	229	38.4	279	47.2	301	4.24
Blue capri, aged	3	3.24	2.02	304	1.05	91.6	5.98	27.2	1.66	130	39.5	240	25.5	168	2.83
Blue	3	8.05	3.24	575	10.9	88.8	26.3	34.9	.12	841	89.6	924	68.4	398	17.0
Cheddar	3	7.80	3.39	526	12.4	11.0	5.40	42.0	1.60	599	25.2	361	24.5	1030	42.4
Fromage de chevre, hard	3	4.68	.55	548	71.1	26.5	15.3	37.5	2.45	756	85.2	345	65.6	174	8.49
Shepherd's hard	3	4.13	.23	737	14.4	54.4	56.1	61.7	.98	1035	12.9	285	44.4	114	59.4
Montasio, hard	3	4.87	.46	720	8.09	42.0	18.2	55.3	3.06	990	8.78	260	9.50	96	17.0
Ancho chile, hard	3	3.17	.74	688	21.1	53.3	12.0	70.5	.84	939	18.0	464	14.8	162	42.4

[1]Mean of 10 varieties from 10 manufacturers.

[2]Mean of three varieties of garlic-added cheese.

[3]Mean of three varieties of pepper-added cheese.

[4]Mean of four varieties of herb-added cheese.

TABLE 3. Concentrations (ppm; wet basis) of trace minerals in selected varieties of goat cheeses produced in the United States.

Cheese varieties	No observations	Fe		Al		Mn		Cu		Zn	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Fresh plain soft[1]	32	17.8	17.5	14.8	14.7	.955	.106	7.40	3.09	9.05	5.75
Fresh soft, garlic[2]	6	13.0	14.7	38.4	63.6	.879	.072	8.08	5.69	14.4	19.0
Fresh soft, pepper[3]	9	28.5	37.7	44.5	58.6	1.222	.493	6.50	1.87	8.76	3.46
Fresh soft, herb[4]	12	17.7	10.3	9.05	4.20	1.056	.327	6.68	1.86	7.75	2.33
Fresh chevre with chives	3	18.4	6.12	5.45	1.70	.973	.076	6.01	1.08	7.19	1.15
Fresh natural soft with herb and garlic	3	20.1	19.7	68.0	86.6	.914	.041	11.3	6.95	16.0	2.25
Feta	3	6.1	.88	14.9	2.52	.971	.043	6.46	.29	15.5	2.02
Aged green pepper cone	3	20.2	9.13	27.9	9.06	1.241	.441	7.83	2.48	11.6	3.33
Aged natural rind	3	18.5	8.05	40.2	28.5	.911	.070	10.9	3.03	13.0	3.97
Camembert capri, aged	3	8.88	5.47	12.7	4.96	.897	.081	5.38	.37	16.3	2.71
Blue capri, aged	3	87.3[5]	48.6	156.5[5]	126.6	.804	.031	5.56	.75	31.4[6]	6.61
Blue	3	15.2	8.18	36.2	27.4	.933	.023	5.60	.83	6.89	3.79
Cheddar	3	7.68	1.66	14.9	3.02	.928	.041	4.93	.33	6.53	5.72
Formage de chevre, hard	3	12.3	10.9	23.4	22.0	.927	.006	5.25	1.08	7.10	1.94
Shephard's hard	3	26.7	23.7	12.3	1.24	3.98	5.15	6.56	.56	18.7	11.9
Montasio, hard	3	11.0	2.84	15.9	4.38	1.057	.015	5.99	1.14	41.3[6]	11.1
Ancho chile, hard	3	24.8	18.6	16.1	1.27	1.07	.014	6.44	.11	9.13	.92

[1]Mean of 10 varieties from 10 manufacturers.

[2]Mean of three varieties of garlic-added cheese.

[3]Mean of three varieties of pepper-added cheese.

[4]Mean of four varieties of herb-added cheese.

[5]Extremely high Fe and Al values.

[6]Very high Zn values.

75% of the Cu and Fe being bound to casein. Other reports on Fe retention for cottage cheese and Spanish goat cheeses were 39% (27) and 79.4 to 86.3% (17), respectively. The broad variations in Fe and Zn content were also found in different types of cheeses in previous reports (6, 28).

Correlation coefficients (r) between the levels of all tested nutrient parameters are shown in Table 4. Moisture content of the goat cheeses negatively and significantly ($P<.05$ or $P<.01$) correlated with percentage of ash, protein, fat, and the concentration of most of the minerals. Ash concentration had positive and significant r ($P < .05$ or $P<.01$) with the concentrations of protein, fat, and all of the macrominerals; ash concentration had negative and lower r with the concentration of trace minerals (Table 4). Sulfur contents revealed minimal r with all minerals except P. Calcium, P, and Mg concentrations showed positive and highly significant ($P<.01$) correlation with those of basic nutrients and macrominerals except, in certain cases, for S, Na, and Cl. The correlation (r = .977) between the concentrations of Ca and P in goat cheeses is noteworthy, which is in agreement with the previous report by Kindstedt and Kosikowski (12) in cow Cheddar cheese. The concentrations of Cl were poorly correlated with the concentration of other minerals except Na. The content of Fe was significantly ($P<.01$) and positively correlated with the concentration of Al, indicating strong evidence for crosscontamination of the two minerals from equipment during manufacture of the products. The Mn content was poorly correlated with all parameters except Mg content. The concentration of Cu was negatively and poorly correlated with most nutrients, but the concentration of Zn was positively and highly correlated with nutrients other than Na, Cl, and Mn.

When the 30 varieties of goat cheeses were divided into two groups, plain and spice cheeses, and further subdivided into three categories within each group, then analyzed statistically, there were significant ($P<.05$ or $P<.01$) differences in the concentrations of basic nutrients, P, Mg, Ca, and Zn among the six

TABLE 4. Correlation coefficients (r) between nutrients in commercial goat cheeses produced in the United States.

	Ash	Protein	Fat	S	P	K	Mg	Ca	Na	Cl	Fe	Al	Mn	Cu	Zn
H_2O	-.758**	-.608**	-.877**	-.350**	-.835**	-.299**	-.790**	-.841**	-.220*	-.121	-.127	-.226*	-.156	.118	-.410*
Ash		.515*	.612**	.246*	.886**	.427**	.745*	.903**	.475**	.418**	-.068	.042	.174	-.238*	-.260*
Protein			.638**	.276*	.600**	.119	.520**	.537**	.059	.307*	.028	.130	.152	-.023	.381*
Fat				.335*	.669**	.203	.622**	.669**	.127	.151	.099	.132	.220	-.034	.394**
S					.287**	.010	.195	.285	.223	.053	-.106	.005	.024	-.001	.154
P						.321**	.914**	.977**	.304**	.207	.091	.230*	.202	-.063	.431**
K							.295*	.306**	.447**	.111	.371**	.320**	.021	-.046	.306**
Mg								.879**	.056	-.001	.202	.302**	.222**	-.051	.401**
Ca									.313**	.191	-.006	.097	.215	-.181	-.346**
Na										.551**	-.174	-.028	-.091	-.008	-.048
Cl											-.175	-.045	-.074	-.090	-.023
Fe												.810**	.038	.115	.297**
Al													.001	.277**	.394**
Mn														-.023	-.031
Cu															.239*

*P<.05.
**P<.01.

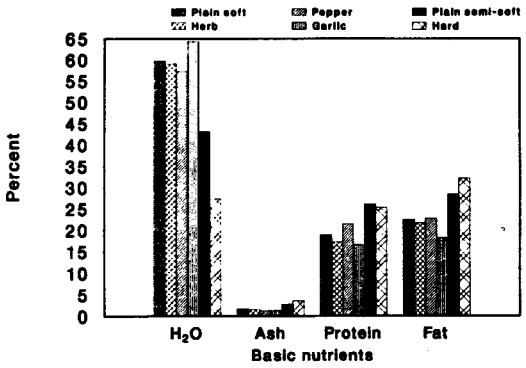

Figure 1. Comparison of percentage (wet basis) of basic nutrients among the six types of commercial goat cheeses. Each bar represents means of plain cheeses (soft, semi-soft, and hard) and spice cheeses (herb, pepper, and garlic). The number of observations for the corresponding types of cheeses were 32, 13, 14, 12, 9 and 6, respectively.

types of cheeses (Table 5). Garlic cheeses contained the highest and significantly ($P<.05$ or $P<.01$) greater amounts of moisture than the other groups of cheeses (Figure 1). Percentages of ash, protein, and fat were significantly ($P<.01$) higher in plain semi-soft and hard cheeses than in plain soft and spice-added cheeses (Figure 1, Table 5). The plain hard cheeses had the highest concentrations of P, K, Mg, Ca, and Na (Figure 2). The concentration of P and Ca in plain soft and hard cheeses and

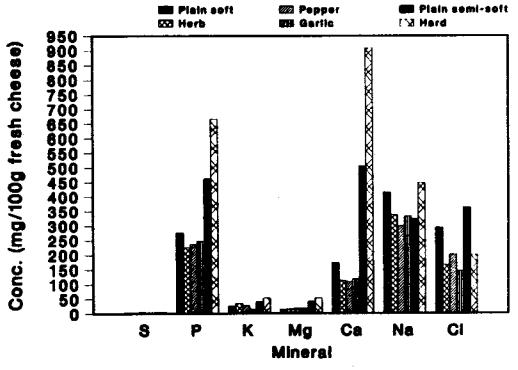

Figure 2. Concentrations of macrominerals (mg/100 g, wet basis) for the six types of commercial goat cheeses. Each bar represents means of plain cheeses (soft, semi-soft, and hard) and spice cheeses (herb, pepper, and garlic). The number of observations for the corresponding types of cheeses were 32, 13, 14, 12, 9, and 6, respectively.

TABLE 5. Comparison of significance of *F* values from analysis of variance of nutrient content and mineral ratios of six categories of goat cheeses.

Basic nutrient	*F* Value	Major mineral	*F* Value	Trace mineral	*F* Value	Mineral Ratio	*F* Value
Moisture	68.2**	S	1.37	Fe	.74	Ca:P	32.7**
Ash	16.7**	P	35.2**	Al	1.56	Ca:Mg	5.39**
Protein	4.11**	K	2.15	Mn	1.09	Fe:Zn	.82
Fat	11.4**	Mg	36.4**	Cu	1.45	Na:Cl	1.57
		Ca	44.3**	Zn	3.04*	Na:K	2.80
		Na	1.65				
		Cl	.94				

*$P<.05$.

**$P<.01$.

Mg in hard cheeses were significantly ($P<.01$) greater than the concentrations of these minerals in other cheeses (Figure 2, Table 5). The spice cheeses had significantly ($P<.05$ or $P<.01$) lower macrominerals than the plain cheeses (Figure 2). The differences in trace-mineral among the six types of cheeses were minimal, except for Zn, and were considerably lower than macromineral concentrations (Figure 3, Table 5). The high Fe and Al contents in semi-soft and hard cheeses (Figure 3) again suggest the possibility of contamination of those minerals during processing of the farmstead cheese.

Of the mineral ratios of Ca:P, Ca:Mg, Fe:Zn, Na:Cl, and Na:K for the six categories of cheeses, the Na:K ratio was highest value among all the mineral ratios (Figure 4). There were significant differences in Ca:P ($P<.01$), Ca:Mg ($P<.01$), and Na:K ($P<.05$) among the six types of cheeses. The hard cheeses had significantly ($P<.01$) higher Ca:P and Ca:Mg ratios than the other categories. The higher Ca:P ratios in the plain semi-soft and hard cheeses (Figure 4) are also supported by the high concentrations of Ca and P (Figure 2) and the high correlations between the two parameters (Table 4). There were no differences in Fe:Zn and Na:Cl ratios between the types of cheeses (Figure 4 and Table 5). The Ca:P and Ca:Mg ratios were lower in three types of spice cheeses than in the three plain types of goat cheeses.

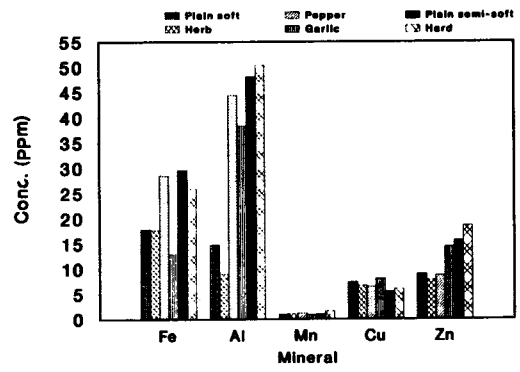

Figure 3. Concentrations of trace minerals (ppm; wet basis) for the six types of commercial goat cheeses. Each bar represents means of plain cheeses (soft, semi-soft, and hard) and spice cheeses (herb, pepper, and garlic). The number of observations for the corresponding types of cheeses were 32, 13, 14, 12, 9, and 6, respectively.

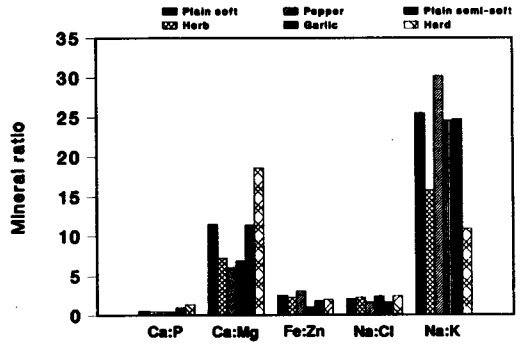

Figure 4. Comparison of mineral ratios for the six types of commercial goat cheeses. Each bar represents the mean ratios of Ca:P, Ca:Mg, Fe:Zn, Na:Cl and Na:K for plain cheeses (soft, semi-soft, and hard) and spice added cheeses (herb, pepper, and garlic). The number of observations for the corresponding types of cheeses were 32, 13, 14, 12, 9, and 6, respectively.

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