

# Evaluation of 20 Macro and Trace Mineral Concentrations in Commercial Goat Milk Yogurt and Its Cow Milk Counterpart

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## Abstract

Concentrations of 20 different minerals in commercial goat milk yogurt (CGY) and its cow milk yogurt (CCY) counterpart were evaluated in reference to goat milk yogurt manufactured from Fort Valley State University (FVGY), Fort Valley, GA, USA. Three different lots of CGY and CCY each were purchased from local retail stores at Warner Robins, GA, and 3 batches of FVGY were made using goat milk from the University milking herd. All 3 types of experimental yogurts were stored at 4°C refrigerator for 4 weeks. Twenty major and trace minerals were analyzed by an Inductively Coupled Plasma Optical Emissions Spectrometer (Thermo Jarrel Ash Enviro 36, Worcester, MA), using argon as the carrier gas and the EPA method 6010. Total solids (TS) content (%) of FVGY, CGY and CCY products were 11.03, 13.1 and 11.3, respectively, indicating CGY had higher TS than the CCY and FVGY yogurt. Respective mean mineral concentrations (ppm, wet basis) of FVGY, CGY and CCY were: Ca 1057, 1162, 1160; P 838, 974, 929; K 1327, 1717, 1208; Mg 102, 133, 113; Na 545, 449, 475; Fe 4.28, 3.33, 2.11; Mn 0.24, 0.19, 0.13; Cu 10.5, 9.85, 7.22; Zn 17.5, 11.7, 11.8. Levels of all macro minerals except potassium were higher in commercial goat and cow yogurts than FVGY, which may be due to the higher TS contents. FVGY had higher Fe, Mn, Cu and Zn than both commercial products. The heavy metal (Pb, Cd and Ni) contents (ppm) appeared to be normal range, while Al contents of FVGY, CGY and CCY were 11.9, 8.66 and 7.65, respectively, which were higher than those of Pb, Cd and Ni. Both commercial products contained higher major mineral contents than the university yogurt, which might be attributable to the differences in diet, breed, and stage of lactation of milking animals, as well as the tapioca additive used in the commercial products.

## Keywords

Macro, Trace, Minerals, Yogurt, Goat Milk

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## 1. Introduction

Yoghurt has been popular fermented dairy foods in many parts of the world, especially in Europe, the Middle East and North America. Because of its nutritional, therapeutic and health benefits, there has been increased consumption and popularity of yoghurt especially among women, children and diet conscious consumers [1]-[3]. Some of beneficial effects of yoghurt in human health includes: cholesterol metabolism, immunomodulation, diarrhea, *Helicobacter pylori* eradication, antimutagenic, antimicrobial, anti-cancer, and antioxidant activity [4].

Due to the lack of availability of cow milk products, goat milk and its products are important daily food sources of protein, phosphate and calcium in under-developed and developing countries [5] [6]. While yogurt has a variety of health benefits to humans, its texture, firmness and sensory characteristics are important properties affecting the food quality and consumer acceptability of yogurt products [7] [8]. Adequate firmness without syneresis is essential for the superior quality of yogurt, while goat milk tends to have less of firmness [7] [9].

Mineral composition of yogurt is directly related to the original milk used for the manufacture of the products, which are also important for nutritional and health benefits of the fermented product. Mineral contents of goat milk from French-Alpine and Anglo-Nubian breeds showed higher Ca, P, K, Mg and Cl, and lower Na and S levels than bovine milk [10]. Mineral contents of commercial US goat milk yogurt have been shown to have significant differences in the levels of Ca, Mg, P, Fe, Zn and Al between different yogurt varieties [1]. Concentrations of 12 major and trace minerals and cholesterol in commercial goat fluid milk, evaporated, powdered, yogurt, and cheese products manufactured in the US were studied [11], where it was found that that K contents of cheeses were lowest among all the goat products due to its loss during cheese manufacturing processes, and the levels of all trace minerals were higher in yogurt and cheeses than in fluid milk. Güler *et al.* [3] reported that among all non-essential elements, boron (B) was the most abundant and berillyum (Be) was the lowest in Turkish goat milk and yogurt products. There were no significant differences among the levels of non-essential element contents in ewe and goat Torba yoghurts.

Although a few studies may have been reported, very limited research data have been available on mineral profiles of goat milk yogurts, especially mineral levels of commercial caprine milk yogurts compared with those of bovine products. Therefore, the aims of this study were to: 1) quantify the levels of 20 different mineral elements in commercially marketed goat milk and cow milk yogurts with reference to goat milk yogurt manufactured from Fort Valley State University, Fort Valley, Georgia, USA; and 2) ascertain any differences in those minerals among three different types of the yogurt products.

## 2. Materials and Methods

### 2.1. Experimental Design

The experiment was conducted in a  $3 \times 3 \times 3$  factorial arrangement (3 batches, 3 yogurt types, and 3 storage time periods). Three lots of commercial cow milk yogurt (CCY) and 3 lots of goat milk yogurt (CGY) were purchased from a retail store located at Warner Robins, GA, USA, and 3 batches of plain goat milk yogurt of Fort Valley (FVG) were manufactured at the Georgia Small Ruminant Research & Extension Center, Fort Valley State University, Fort Valley, GA, USA. All experimental yogurt samples were subjected to refrigeration storage in a 4°C refrigerator for 0, 2 and 4 weeks.

### 2.2. Preparation of Goat Milk for Manufacture of Experimental Goat Yogurt at Fort Valley

Goat milk used was taken from the bulk tank milk collected from the University milking heard consisted of Alpine and Saanen breeds at the Georgia Small Ruminant Research & Extension Center, Fort Valley State University, Fort Valley, Georgia, USA. The milking goats were fed Bermuda grass hay *ad libitum*, and 0.454 kg of concentrate daily.

### 2.3. Manufacture of Fort Valley State University Goat Milk Yogurt (FVG)

The raw goat milk produced from Fort Valley State University was pasteurized at 85°C (180°F) for 30 minutes, and the pasteurized milk was cooled to 45°C (113°F). Upon cooling, ayogurt culture (Direct Vat Set type freeze dried YC-180; Chr. Hansen, Hoersholm, Denmark) was added to the pasteurized milk at the rate of 25 g/100kg milk. The inoculated milk was filled in individual 16 oz containers, and incubated at 45°C in an incubator (Fisher Scientific, Isotemp Incubator Model No. 5370) for 4 hours. When the pH of yogurt was attained to 4.5 - 4.8, and

the titratable acidity was 0.9%, the incubated yogurt was cooled to 7.2°C (45°F) for 1 hour. The finished yogurt product containers were stored in a walk-in-cooler at 4°C for 0, 2, and 4 weeks of experimental periods.

## 2.4. Chemical Analysis of Nutrients

### 2.4.1. Total Solids

Total solids content of the yogurt samples were determined by the oven drying in a laboratory oven at 105°C for 24 hr [12]. All samples were analyzed in triplicate.

### 2.4.2. Protein

Total nitrogen content was assayed using the vario MAX CN (Model Elementar, Analysensysteme GmbH, Americas, Inc., Mt. Laurel, NJ, USA) according to the manufacturer's procedure. In this instrument, nitrogen is separated from combustion gas (oxygen) with the help of specific adsorption columns and determined in succession with a thermal conductivity detector (TCD). Helium serves as flushing and carrier gas. Total protein was calculated by % total N x factor of 6.38.

### 2.4.3. Fat

Percent fat in fluid and condensed milk samples were determined by Babcock method as described by Richardson [13] and AOAC [12].

### 2.4.4. Ash

Ash content was quantitated by dry ashing yogurt samples in a muffle furnace at 550°C for 8 hours (overnight) as described in AOAC [12].

### 2.4.5. Mineral Analysis

The dry ashed samples in porcelain crucibles were solubilized with 10 ml of 6N HCl, quantitatively transferred into 25-ml volumetric flasks, and diluted to volume with double-deionized water [12]. Concentrations of the 20 major and trace minerals were analyzed by an Inductively Coupled Plasma Optical Emissions Spectrometer (Thermo Jarrel Ash Enviro 36, Worcester, MA), at different wavelengths for each different mineral using argon as carrier gas and the EPA method 6010. Wavelengths used for determination of the tested 20 minerals were: Al, 308.2; B, 249.6; Ba, 493.4; Ca, 315.8; Cd, 228.8; Co, 228.6; Cr, 267.7; Cu, 324.7; Fe, 259.9; K, 766.4; Mg, 279.0; Mn, 257.6; Mo, 202.0; Na, 588.9; Ni, 231.6; P, 214.9; Pb, 220.3; Si, 288.1; Sr, 421.5; Zn, 213.9 nm, respectively.

## 2.5. Statistical Analysis

All data were statistically analyzed using General Linear Model of SAS program [14]. Analysis of variance, Duncan's multiple mean comparison among different types of yogurt products were performed as described by Steel and Torrie [15].

## 3. Results and Discussion

The summary of basic nutrient compositions for the three types of experimental goat and cow milk yogurts are listed in **Table 1**. There were no statistical differences in basic compositions among the CCY, CGY and FVGY, while commercial goat milk yogurt (CGY) had higher total solids and fat contents than the other two (CCY and FVGY) yogurts. Unlike the CCY and FVGY, the CGY contained an additional ingredient, tapioca, which is a starch extracted from cassava root, that is added to the goat milk yogurt as a textural binder or stabilizer in goat milk products, since goat milk tends to make weaker or soft gell formation compared to cow milk counterpart. The CGY contained higher fat contents than the CCY and FVGY (**Table 1**), where the higher fat in CGY might be attributed to the differences in milk compositions of breeds, species of dairy animals and/or both. The previous report on plain goat milk yogurts [1] had higher protein and ash, but lower fat and carbohydrate contents than those in the present study. These results could be due to the differences in diet, species or breed within species, and stage of lactation, location and environmental or management conditions among the milking animals [1] [10] [16] [17].

**Table 1.** Basic chemical compositions (%) of experimental cow and goat milk yogurts.

Yogurt	Protein		Fat		Carbohydrate		Ash		Total Solids	
	X <sup>b</sup>	SD <sup>c</sup>	X	SD	X	SD	X	SD	X	SD
CCY	3.39	0.021	3.05	0.34	5.33	0.365	0.78	0.058	11.28	0.058
CGY	3.17	0.035	3.65	0.0	5.08	0.372	0.80	0.014	13.10	0.370
FVGY	3.20	0.028	2.55	0.66	3.35	0.488	0.74	0.035	11.03	0.436
PGY <sup>a</sup>	3.99	0.13	2.25	0.13	4.49	0.56	0.82	0.02	11.5	2.56

CCY: commercial cow milk yogurt; CGY: commercial goat milk yogurt; FVGY: Fort Valley State University goat milk yogurt. <sup>a</sup>PGY: plain goat yogurt (Park, 1994). <sup>b</sup>X: Mean. <sup>c</sup>SD: Standard deviation.

In light of mineral concentrations, all major minerals except potassium contents were higher in commercial products of both goat and cow milk yogurts than the FVGY (**Table 2**). Average mineral concentrations (ppm) of Ca, P, Mg, Na, K for CCY, CGY and FVGY were: 1160, 929, 113, 475, 1208; 1162, 974, 133, 449, 1717; 1057, 838, 102, 545, 1327, respectively. These data indicate that CGY contained higher values of all major minerals except Na among the three products (**Table 2**). When compared the Ca and P concentrations among the three yogurt groups, both macro-minerals were higher in commercial products than in FVGY (**Figure 1** and **Table 2**). Potassium content of CGY was especially higher ( $P < 0.01$ ) than the other two products, which may be related to the addition of the tapioca in the CGY product. However, Na content of CGY was lower than CCY and FVGY products. On the other hand, Park [1] reported that no differences were observed in K, Na and S concentrations between the pooled data of plain and fruit added types of goat yogurt produced in the US, whereas significant differences in the major minerals (Ca, Mg, P, K, Na, S) were found when the data were compared between the yogurt products from different manufacturers. The author indicated that these results may account for the variability in composition of original milk, fruit additives, as well as from the processing procedures of different manufacturers.

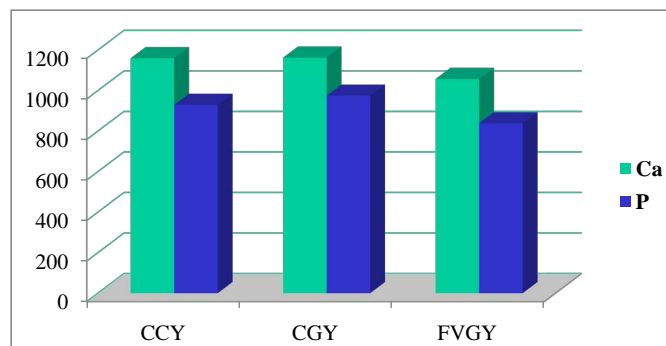
As far as the concentrations of trace mineral go, FVGY contained higher essential minerals such as Fe, Mn, Cu and Zn than those in both CGY and CCY products, which are the opposite trend of the major minerals shown above (**Figure 2** and **Table 2**). These results might have been resulted from the differences in the milk compositions of the milking goats, such factors may include diets and stages of lactation of the milking animals. Literature has shown that, although levels of major minerals in milk are usually not affected by main factors including diet, stage of lactation, location and environmental or management conditions between the milking animals, the concentrations of most trace minerals in the milk may be influenced by these main factors [10] [16]. The previous study by Park [1] showed that trace minerals Fe, Zn and Al levels were significantly ( $P < 0.05$ ) affected by the different varieties of yogurt, while other micro-minerals were not affected by the types of the goat milk yogurt products. **Figure 2** clearly displays that FVGY had higher levels of the levels of the four trace minerals than the commercial goat and cow yogurts. Among the four trace elements, Zn is the highest mineral among all for all products. These four minerals are essential and required for maintenance of body metabolism and health, where these minerals were higher in FVGY compared to the other two commercial products. These results might have been related to the difference in feeding regimen of the milking animals, where the university milking herd was pasture fed during day time in the university farm, while the two other commercial products might have been manufactured using milks of less pasture fed goats and cows, although the feeding records of the milking animals were not known for the commercial products.

Concerning the heavy or toxic metal concentrations of the three experimental yogurts, the levels of Pb, Cd and Ni appeared to be normal and not in the ranges of toxic level (**Figure 3** and **Table 2**). The differences in Al contents among the three products were greater than the other heavy metals, whereas the differences in Pb, Cd and Ni contents between the products were negligible (**Figure 3**). The respective Al contents of CGY, CCY and FVGY were 8.66, 7.65 and 11.9, suggesting that there was some differences in Al levels in all tested yogurt products, while those of the three heavy metals were consistently low. This outcome is in agreement with the observations on Al contents in the previous studies [1] [6], where a few goat milk yogurt samples had extremely high Fe and Al contents, which may have been due to the possible contamination from the processing utensils during manufacturing processes of the farmstead goat milk yogurts and cheeses.

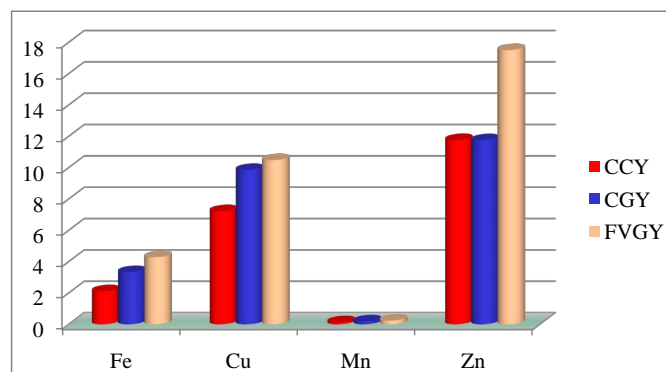
**Table 2.** Concentrations (ppm) of 20 different minerals in commercial cow and goat milk yogurts compared with goat milk yogurt made at Fort Valley State University, Fort Valley, GA<sup>1</sup>.

Minerals	CCY		CGY		FVGY	
	X	SD	X	SD	X	SD
Al	7.653	2.122	8.664	2.773	11.89	3.864
B	1.342	0.080	1.394	0.372	1.730	0.409
Ba	0.441	0.096	0.795	0.070	0.830	0.499
Ca	1159.7	45.96	1162.1	18.30	1056.8	83.19
Cd	0.660	0.278	0.700	0.216	0.614	0.160
Co	0.442	0.051	0.513	0.063	0.672	0.034
Cr	0.946	0.008	1.158	0.181	1.213	0.564
Cu	7.222	0.370	9.854	1.433	10.48	1.039
Fe	2.108	0.355	3.333	1.148	4.277	1.451
K	1208.2	16.97	1717.0	126.6	1327.3	109.2
Mg	113.4	4.384	133.3	3.434	101.8	7.024
Mn	0.131	0.016	0.189	0.030	0.237	0.019
Mo	0.788	0.191	0.656	0.104	1.222	0.275
Na	474.8	55.57	449.4	40.81	545.2	90.42
Ni	0.917	0.091	1.110	0.132	0.898	0.181
P	929.1	40.49	973.7	26.02	838.1	90.64
Pb	4.200	0.600	4.003	0.687	4.280	0.589
Si	23.92	4.268	18.68	2.211	23.44	4.018
Sr	1.333	0.086	1.212	0.049	0.869	0.141
Zn	11.76	0.833	11.75	0.949	17.51	3.414

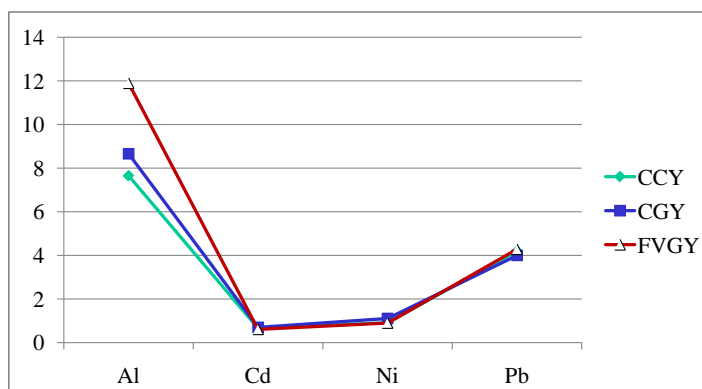
X: Mean; SD: Standard deviation. <sup>1</sup>Each mean value is the average of three lots or batches of different experimental yogurts.



**Figure 1.** Comparison of Calcium and Phosphorus contents (ppm) of yogurts among 3 different types of cow and goat products.



**Figure 2.** Profiles of Fe, Cu, Mn and Zn concentrations (ppm) in commercial cow and goat milk yogurts and Fort Valley goat yogurt.



**Figure 3.** Comparison of concentrations (ppm) of heavy metals among three types of cow and goat milk yogurts.

#### 4. Conclusions

Among all tested 20 minerals of the three types of experimental goat and cow yogurt samples, concentrations of all macro minerals except potassium were found to be higher in commercial products in both goat and cow yogurts than the Fort Valley State University goat yogurt. FVGY had higher Fe, Mn, Cu and Zn contents than both CGY and CCY products, while FVGY contained lower macro minerals than CGY, which may account for the differences in breed and diet fed, where certain breed such as Nubians contain higher total solids than other dairy goat breeds.

The heavy metal (Pb, Cd and Ni) concentrations (ppm) appeared to be normal and were not in exceeded ranges of toxic levels, while Al contents were higher than the levels of Pb, Cd and Ni in all three products. Both species commercial yogurt products contained higher levels of major minerals than the university made product except K, which may be attributable to the differences in diet, breed and lactation stage of milking animals, as well as certain additives such as tapioca used in the commercial goat yogurt products in this study.

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