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Variations of vitamin and mineral contents in raw goat milk of the indigenous Greek breed during lactation

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Abstract

Raw goat milk samples from the indigenous Greek breed in the area of Ioannina, northwestern Greece, were collected during one lactation and analyzed for vitamins A, E, B_1, B_2, and C and for minerals Ca, Mg, P, Na, K, Cu, Fe and Zn. Also, the major constituents of goat milk, namely fat, protein, lactose and solids-non-fat, were determined. The average composition (%) of milk was: fat 4.10, protein 3.36, lactose 4.48 and solids-non-fat 8.54. The mean concentration of the fat-soluble vitamins retinol (A) and α-tocopherol (E) were 0.013 and 0.121 mg/100 ml, respectively. The mean concentration of the water-soluble vitamins, thiamin (B_1), riboflavin (B_2) and ascorbic acid (C) were 0.260, 0.112 and 5.48 mg/100 ml, respectively. Seasonal variations were observed for all vitamins studied. Thiamin had significantly ($P < 0.05$) higher concentrations during summer than in winter and early spring. The observed variations of the studied vitamins might be attributed to the differences in the feeding of goats during lactation. The mean mineral contents (mg/100 g) of goat milk were Ca 132, P 97.7, Na 59.4, K 152, Mg 15.87, Cu 0.08, Fe 0.06, Zn 0.37 and Mn 6.53 μg/100 g. Seasonal variations were observed for the major minerals Ca, P, K, and the trace elements Cu and Zn.

Keywords: Vitamins; Minerals; Goat milk

1. Introduction

In recent decades an increasingly important role in the human diet has been attached to goat milk, since it possesses unique properties which distinguish it from cow milk and make it a valuable alternative, not just for infants but also for adults and especially nursing mothers (Baldo, 1984). The fat globules of goat milk are smaller than those of cow milk and probably this is one of the reasons for the easy digestion of goat milk (Fevrier, Mourot, Jaquelin, Mounier, & Lebreton, 1993; Haenlein, 1996). There are also differences in the fatty acid profile between the two kinds of milk. Goat milk has higher percentage of short- and medium-chain (C_6–C_{14}) fatty acids than has cow milk. These fatty acids are of considerable interest in medicine because they are used for the treatment of various ailments (e.g., malabsorption syndromes, intestinal disorders, coronary diseases, premature infant nutrition, and cystic fibrosis) and because of their unique metabolic abilities in providing energy and at the same time lowering, inhibiting and dissolving cholesterol deposits (Babayan, 1981; Haenlein, 1993). Barrionuevo, Alferez, Lopez Aliaga, Sanz Sampelayo, and Campos (2002) reported, also, the beneficial effect of goat milk, compared to cow milk, on the metabolism of iron and copper in control rats and rats with resection of the distal small intestine and they suggested that goat milk should be studied for use in human malabsorption syndrome.

There are also qualitative and quantitative differences in milk proteins between cow and goat milk, especially the α_{s1}-casein in goat milk contributes to a softer curd than does that in cow milk. This is probably another reason for the better digestion of goat milk compared to cow milk (Ambrosoli, Stasio, & Mazzocco, 1988). Also,

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the better tolerance of goat milk by infants and children suffering from hypersensitivity to cow milk (direct or indirect milk allergy) could be attributed to the differences in proteins between the two kinds of milk (Baldo, 1984).

Greece is the first among European countries in goat population (6,000,000 animals) and produces about 450,000 tonnes of goat milk per year (Anifantakis, 2001). Most of the animals (85%) belong to the Greek native breed and they are frugal in feeding, durable and well adapted to the mountainous environmental conditions of Greece (Simos, Voutsinas, & Pappas, 1991). Goat milk in Greece is mainly used for cheesemaking and recently there is increasing consumption of fluid milk on a commercial basis.

There are many studies concerning the main constituents and some physicochemical properties of goat milk (Anifantakis & Kandarakis, 1980; Jenness, 1980; Juarez & Ramos, 1986; Merin, Rosenthal, & Maltz, 1988; Simos et al., 1991; Veinoglou, Baltadjeva, Anifantakis, & Edearyan, 1982; Voutsinas, Pappas, & Katsiari, 1990). However, there is little information on the vitamins content of goat milk (Lavigne, Zee, Simard, & Beliveau, 1989; Haenlein, 1996; D'Urso, 2000) and no information at all on the vitamin content of goat milk of the native Greek breed. Goat milk has not been studied extensively for its nutritive value in contrast to cow milk, for which much information about vitamins content can be found in the literature (Bendicho, Espachs, Arandegui, & Martin, 2002; Cremin & Power, 1985; Haddad & Loewenstein, 1983; Sieber, Eberhard, Fuchs, Gallman, & Strahm, 1996; Vassila, Badeka, Kondyli, Savvaidis, & Kontominas, 2002; Vidal-Valverde & Diaz-Pollan, 2000).

Thus, the objective of this work was to obtain data on the vitamin and mineral contents of raw goat milk of the native Greek breed in the region of Ioannina, throughout one lactation period.

2. Materials and methods

2.1. Milk samples

Milk samples were obtained from a herd, which consisted of 145 native Greek goats in the region of Ioannina, northwestern Greece. The animals were fed from April to November exclusively by pasturing on highlands, while the rest of the year they were fed pasture, alfalfa hay and a mixture of 60% maize and 40% cottonseed cake. During the days of bad weather the animals remained indoors and received only alfalfa hay and the feed mixture. Four milk samples were taken every month during the period from December to July and analysed for fat, protein, lactose and milk solids-not-fat (MSNF), vitamins A, E, B_1, B_2 and C and minerals Ca, P, Na, K, Mg, Cu, Fe, Zn and Mn. The fat, protein, lactose and MSNF were determined by using the Milkoscan, model FT 6000 (Foss Electric, Denmark).

2.2. Determination of vitamins

The method of Zahar and Smith (1990), with slight modifications, was used for the determination of fat-soluble vitamins retinol (vitamin A, the all-*trans*-retinol isomer) and α-tocopherol (vitamin E). Two ml of goat milk were added in a glass centrifuge tube, followed by the addition of 5 ml absolute ethanol containing 0.1% (w/v) ascorbic acid and 2 ml of 50% (w/v) KOH. The tubes were stoppered, agitated carefully and placed in a waterbath at 80 °C for 20 min. During this period the tubes were agitated periodically. After saponification, the tubes were cooled in an iced waterbath and 20 ml of petroleum ether:diethylether mixture (1:1), containing 0.01% butylated hydroxy toluene (BHT), were added. The content of tubes was mixed in a vortex for 1 min and allowed to stand for 2 min and then vortexed again for 1 min. Fifteen ml of cold water (1–2 °C) were added to each tube and the tubes inverted at least 10 times. Centrifugation was performed at 2000*g* for 15 min. The upper organic layer was accurately removed by a pipette into a tube and the solvent was evaporated to dryness under vacuum at 40 °C using a rotary evaporator. The residue was immediately redissolved in 2 ml of methanol (HPLC grade). Peak areas of vitamins A and E in the sample extracts were measured and compared with those of the standards.

The HPLC equipment consisted of a Waters 600 Controller pump, a Waters μ-Bondapack stainless steel column (3.9 mm i.d. × 30 cm length, operated at room temperature) and a Waters 486 UV detector (Waters, Milford, USA). The mobile phase used for the separation of vitamins was methanol:water (95:5) at a flow rate 0.8 ml/min. The UV detection was performed at 323 nm for retinol and 292 nm for α-tocopherol. The peak areas were integrated and quantified by using the Millenium 32 software (Waters, Milford, USA).

The water-soluble vitamins thiamin and riboflavin were determined according to Albala-Hurtado, Veciana-Nogues, Izquierdo-Pulido, and Marine-Font (1997). The same equipment and column were used for the separation of these vitamins, as for A and E. The mobile phase contained 5 mM octanesulfonic acid, 0.5% triethylamine, 2.4% glacial acetic acid and 15% methanol and its flow rate was 1 ml/min. The UV detection was performed at 246 nm for thiamin and 268 nm for riboflavin. Ascorbic acid was determined according to Barrefors, Granelli, Appelqvist, and Bjoerck (1995) with slight modifications. One ml of 1.12% metaphosphoric acid was added to 1 ml of goat milk. The samples were centrifuged at 12,000*g* for 30 min, the supernatant was filtered and analyzed immediately for ascorbic acid by using the same HPLC system and the same column as for fat-soluble vitamins. The mobile phase, which consisted of 80 mM sodium acetate buffer, pH 4.8, containing 0.015% metaphosphoric acid, was used at a flow rate of 1 ml/min for the separation. The UV detection was done at 254 nm.

2.3. Determination of minerals

The milk samples for mineral analysis were dried overnight at 102 °C and ashed at 550 °C for 6 h; the ash was analyzed as described by Egan, Kirk, and Sawyer (1981). The calcium (Ca), magnesium (Mg), copper (Cu), iron (Fe), zinc (Zn) and manganese (Mn) concentrations were determined by atomic absorption spectrometry (Varian AA-10, Vic., Australia). The sodium (Na) and potassium (K) concentrations were determined by flame photometry, using a Corning 410 Flame Photometer (Ciba Corning Diagnostics Scientific Instruments, Essex, England). The phosphorus (P) content was determined according to the method described by the International Dairy Federation (IDF, 1990).

2.4. Statistical analysis

The data were subjected to one way analysis of variance by using the Statgraphics (Statistical graphics corp., Rockville, MD, USA) statistical programme. Means with significant differences were compared by Duncan's multiple range test.

3. Results and discussion

3.1. Main constituents of goat milk

The concentrations of the main constituents of goat milk of the indigenous Greek breed during lactation are given in Table 1. The stage of lactation had significant ($P < 0.05$) effects on the contents of fat, protein, lactose and MSNF (Table 1). Generally, the composition of goat milk was found to be similar to that reported by Simos et al. (1991) for goat milk of the same breed. The only difference observed was in the fat content of milk, whose value was found, in the present study, to be lower than the value reported by the above authors.

3.2. Vitamin content

The concentrations of the fat-soluble vitamins retinol (A) and α-tocopherol (E) in the goat milk during lactation are shown in Table 2. Vitamin A is an alcohol and exists in several *cis*/*trans* isomeric forms, however, only two isomers are of real importance. The all-*trans*-retinol, which is the major naturally occurring form of vitamin A and the form with the highest biological activity, and the 13-*cis*-isomer, which has less biological activity, ~75% of the all-*trans*-retinol. Vitamin E, also exists in many forms, such as α-, β-, γ-, δ- tocopherols and tocotrienols but usually α-tocopherol is considered when the vitamin E content of foods is calculated since it has higher biological activity than the other forms of vitamin E (Cremin & Power, 1985). The mean contents of vitamins A and E were 0.013 and 0.121 mg/100 ml of goat milk, respectively. The mean value of vitamin A found in this study was lower than those reported by D'Urso (2000) and Haenlein (1996) for goat milk and by Vassila et al. (2002) and Zygoura et al. (2004) for cow milk. On the other hand, the average content of vitamin E was higher than that reported by D'Urso (2000) and Haenlein (1996) for goat milk but similar to the content reported by D'Urso (2000) for cow milk. Seasonal variations were found for the concentration of vitamin A in goat milk. Higher concentrations of vitamin A were observed in summer than in winter. The same trend was reported by Cremin and Power (1985) for cow milk.

The concentrations of water-soluble vitamins B_1 (thiamin), B_2 (riboflavin) and C (ascorbic acid) are shown in Table 2. Significant ($P < 0.05$) seasonal variations were observed for thiamin concentration, i.e., low thiamin content in winter and high content in late spring and summer. The concentration of thiamin during winter was almost the same as that reported by Lavigne et al. (1989), Haenlein (1996) and D'Urso (2000) for other goat milks. However, the mean thiamin content (Table 2) was higher than the values reported for goat milk (D'Urso, 2000; Haenlein,

Table 1
Composition (%) of goat milk of the indigenous Greek breed during lactation

Month	Fat	Protein	Lactose	MSNF
December	4.46^{b}	3.70^{b}	4.53^{b}	8.93^{b}
January	4.17^{b}	3.37^{b}	4.62^{b}	8.69^{b}
February	4.35^{b}	3.40^{b}	4.70^{b}	8.80^{b}
March	4.02^{ab}	3.33^{ab}	4.60^{b}	8.63^{b}
April	3.98^{a}	3.23^{a}	4.51^{b}	8.44^{ab}
May	3.93^{a}	3.18^{a}	4.31^{a}	8.19^{a}
June	3.94^{a}	3.24^{a}	4.38^{a}	8.32^{a}
July	3.96^{a}	3.41^{b}	4.21^{a}	8.32^{a}
Mean	4.10	3.36	4.48	8.54
Se	0.34	0.24	0.15	0.19

MSNF, milk solids-not-fat.
Mean, average of 32 samples.
Se, standard error.
[a,b] Means within a column without a common superscript differ significantly ($P < 0.05$).

Table 2
Contents (mg/100 ml) of fat-soluble (A and E) and water-soluble (B_1, B_2 and C) vitamins of goat milk of the indigenous Greek breed during lactation

Month	A	E	B_1	B_2	C
December	0.013^{a}	0.090^{a}	0.069^{a}	0.138^{bc}	6.07^{bc}
January	0.012^{a}	0.183^{b}	0.069^{a}	0.101^{a}	5.36^{ab}
February	0.011^{a}	0.123^{a}	0.067^{a}	0.109^{a}	5.52^{b}
March	0.013^{a}	0.096^{a}	0.169^{ab}	0.098^{a}	5.29^{ab}
April	0.013^{a}	0.101^{a}	0.169^{ab}	0.096^{a}	5.70^{b}
May	0.013^{a}	0.089^{a}	1.041^{c}	0.099^{a}	6.41^{c}
June	0.016^{b}	0.127^{a}	0.385^{b}	0.118^{b}	4.97^{a}
July	0.015^{b}	0.140^{ab}	0.350^{b}	0.146^{c}	4.64^{a}
Mean	0.013	0.121	0.260	0.112	5.48
Se	0.000	0.009	0.016	0.003	0.09

Mean, average of 32 samples.
Se, standard error.
[a–c] Means within a column without a common superscript differ significantly ($P < 0.05$).

1996; Lavigne et al., 1989) and cow milk (Haddad & Loewenstein, 1983; Vidal-Valverde & Diaz-Pollan, 2000).

The average riboflavin (B_2) content of goat milk was 0.112 mg/100 ml, slightly lower than the values reported by Haenlein (1996) and D'Urso (2000) for goat milk and by Haddad and Loewenstein (1983) for cow milk. Significant ($P < 0.05$) seasonal variations were observed for riboflavin, the highest concentrations were found in December and July and the lowest in March, April and May.

Ascorbic acid is the most important of the various compounds that possess vitamin C activity (Cremin & Power, 1985). The mean content of vitamin C was 5.48 mg/100 ml, a value higher than those reported by D'Urso (2000) and Haenlein (1996) for other goat and cow milks, and similar to that found by Lavigne et al. (1989) for goat milk. Significant ($P < 0.05$) seasonal variations were also found for vitamin C content of goat milk. Generally, goat milk is not considered a source of vitamin C but this study showed that goat milk contains enough, such that one portion (250 ml) of goat milk (with this content of vitamin C) could supply up to 40% of the daily requirements of an adult (Lavigne et al., 1989). The seasonal variations observed for all the determined vitamins are probably due to differences in the feeding of the animals.

3.3. Mineral contents

The results of the mineral analysis of milk samples are given in Table 3. Ca, P, K, Cu, Zn and Mn showed significant ($P < 0.05$) variations during lactation, while Na, Mg and Fe did not. These variations were probably due to the differences in the feeding of the animals during lactation (Cashman, 2003).

The mean Ca concentration was 132 mg/100 g, a little lower than that reported by Voutsinas et al. (1990) for Alpine goat milk and by Simos et al. (1991) for goat milk of the indigenous Greek breed. The Ca content found in this study was similar to that reported by Haenlein (1996) for goat milk and higher than the value reported by Cashman (2003) for cow milk. The Ca concentration was higher at the beginning of the lactation period than at the end, a trend which is in contrast to the results reported by Voutsinas et al. (1990) and Brendehaug and Abrahamsen (1986). This difference could be attributed to the differences in the nutritional status of the animals as well as to environmental and genetic factors (Cashman, 2003).

The P content of goat milk found (Table 3) was lower than the value reported by Voutsinas et al. (1990) for goat milk and higher than the value reported by Haenlein (1996) for cow milk. The P content of goat milk was higher in the winter than in the summer, a trend which is opposite to that reported by Voutsinas et al. (1990) and Brendehaug and Abrahamsen (1986).

The above minerals play an essential role in the human organism and it is well known that milk and dairy products are good dietary sources of Ca and P and their contributions to the total Ca and P daily intake have been reported to be 52–75% and 30–45%, respectively (Cashman, 2003).

The mean Na and K contents (Table 3) were similar to those reported by Voutsinas et al. (1990) for goat milk, but Simos et al. (1991) and Haenlein (1996) reported higher values for K and lower for Na for goat milk. The mean Mg content was 15.9 mg/100 g, close to that reported for goat milk by several authors (Haenlein, 1996; Simos et al., 1991; Voutsinas et al., 1990). Table 3 shows also the profile of Na/K and Ca/P ratios obtained at different stages of lactation. There were no significant ($P > 0.05$) differences in these ratios during lactation. The mean values of these ratios were very close to those found by Voutsinas et al. (1990) for Alpine goat milk.

The mean content of the trace elements Fe and Zn were similar to those reported by Brendehaug and Abrahamsen (1987) for goat milk and by Cashman (2003) for cow milk. The average Cu and Mn contents were 0.08 mg/100 g and 6.53 μg/100 g, respectively, and lower than the mean values reported by Brendehaug and Abrahamsen (1987) for goat milk. Higher contents of Cu and Mn were observed during winter and lower during summer. This trend is in accordance with the results of Coni et al. (1996).

Table 3
Mineral contents of raw goat milk of the indigenous Greek breed during lactation

Month	Ca (mg/100 g)	P (mg/100 g)	Ca/P (mg/100 g)	Na (mg/100 g)	K (mg/100 g)	Na/K (mg/100 g)	Mg (mg/100 g)	Cu (mg/100 g)	Fe (mg/100 g)	Zn (mg/100 g)	Mn (μg/100 g)
December	149^{c}	111^{b}	1.35^{a}	65.0^{a}	135^{a}	0.49^{b}	16.08^{a}	0.11^{b}	0.09^{a}	0.38^{ab}	6.70^{bc}
January	136^{b}	100^{ab}	1.36^{a}	60.0^{a}	143^{a}	0.42^{b}	15.11^{a}	0.10^{b}	0.06^{a}	0.38^{ab}	9.07^{c}
February	139^{b}	101^{ab}	1.38^{a}	60.0^{a}	140^{a}	0.43^{b}	15.69^{a}	0.11^{b}	0.06^{a}	0.39^{ab}	9.03^{c}
March	126^{a}	91.4^{a}	1.38^{a}	60.0^{a}	153^{a}	0.39^{b}	14.96^{a}	0.06^{a}	0.06^{a}	0.35^{ab}	6.93^{bc}
April	127^{a}	92.2^{a}	1.38^{a}	55.0^{a}	155^{a}	0.36^{a}	15.01^{a}	0.06^{a}	0.06^{a}	0.37^{ab}	5.45^{b}
May	128^{a}	106^{b}	1.21^{a}	60.0^{a}	180^{b}	0.33^{a}	17.85^{a}	0.05^{a}	0.08^{a}	0.46^{b}	5.25^{b}
June	123^{a}	89.6^{a}	1.37^{a}	55.0^{a}	155^{a}	0.36^{a}	15.57^{a}	0.04^{a}	0.06^{a}	0.31^{a}	5.95^{b}
July	128^{a}	91.5^{a}	1.40^{a}	60.0^{a}	155^{a}	0.39^{b}	16.70^{a}	0.07^{a}	0.07^{a}	0.31^{a}	3.85^{a}
Mean	132	97.7	1.36	59.4	152	0.40	15.87	0.08	0.06	0.37	6.53
Se	1.93	1.30	0.02	1.62	3.48	0.01	0.40	0.01	0.003	0.01	0.06

Mean, average of 32 samples.
Se, standard error.
$^{a–c}$ Means within a column without a common superscript differ significantly ($P < 0.05$).

4. Conclusions

The results of this study showed that the goat milk of the native Greek breed in the region of Ioannina, generally, contained sufficient quantity of vitamins, a fact which has a great impact on its nutritional quality. Seasonal variations were observed for all vitamins. The mean concentrations of the macroelements Ca, P and Mg were slightly below or similar to those reported in the literature for goat milk and higher than those for cow milk. The mean concentrations of the trace elements Fe and Zn were similar to those reported for goat milk, while the values for Cu and Mn were slightly lower.

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