

PAPER

Macro and micro elements profile of yak (*Bos grunniens*) milk from Qilian of Qinghai plateau

Wancheng Sun,¹ Sergio Ghidini,²Yihao Luo,¹ Emanuela Zanardi,²Haiqing Ma,³ Adriana Ianieri²¹Animal Science Department, Qinghai University, China²Dipartimento di Produzioni Animali, Biotecnologie Veterinarie, Qualità e Sicurezza degli Alimenti, Università di Parma, Italy³Service of Animal Husbandry and Veterinary Medicine in Qilian, Qinghai, China

Abstract

Twelve elements were analyzed by the ICP-AES method for macro (calcium, phosphorus, sulphur, magnesium, potassium, sodium) and micro (cobalt, chromium, copper, iron, zinc, manganese) elements. The macro and micro elements of yak (Qilian) milk were analyzed among different farms and a significant difference was found in phosphorus and sulphur concentrations ($P < 0.05$). Potassium and sulphur concentrations in yak milk were higher while calcium concentrations were similar to cow milk but lower than milk of other species. Sodium, magnesium and phosphorus concentrations found in this study were in the mid-range of those in milk of different animal species. The higher concentrations of potassium and lower concentrations of sodium found in yak milk should be of benefit to patients with hyperpiesia. The composition of yak milk was particularly rich in cobalt, manganese and chromium, while it was deficient in zinc.

Introduction

Yaks graze on pasture and the herdsmen almost never provide additional feedstuff. Yaks in Qinghai are currently facing increasingly difficult conditions due to grassland degeneration and malnutrition in winter and early spring. The yak (*Bos grunniens*) is a unique farm animal native to central Asia and well adapted to the high altitude, cold and dry

plateau climate (Zhang *et al.*, 2008). The total yak population is estimated to be around 14.2 million; 13.3 million in Chinese territories, approximately 0.6 million in Mongolia, and the rest in other countries (Gerald *et al.*, 2003). On the Qinghai Plateau, the yak population of approximately 5.0 million is the largest in the world (Zhu, 2005).

The yak of the Qinghai-Tibetan Plateau (often called Plateau or Grassland yak) and those found in the Hengduan mountain region (often called Alpine or Valley yak) have long been considered to be *types*. This classification was initially based on the geographical and topographical parameters of their habitats and on the body size of different yak populations in the different environments. There are many different yak breeds, including those used in our milk sampling in Qilian county in Qinghai and the Maiwa yak in Sichuan, known as the Plateau type. Yak products are almost completely organic and offer many elements that can be of benefit to the health of the inhabitants of Qinghai, China. Yak herding is primarily a family business, and increased demand for yak will contribute to the economic wellbeing of the semi-nomadic herders in China, India, Nepal, and other countries. Although yaks are multipurpose animals, they are mainly raised for milk production. Yak milk and milk products are widely consumed by local herders and provide the main ingredients of their daily diet (Zhang *et al.*, 2008). Furthermore, the population in Qinghai province regards these products as an economic resource.

Compositional characteristics including proximate composition and amino acid profile of yak milk from India (Jain and Yadava, 1985) and Nepal (Neupaney *et al.*, 2003) have been described (Jain and Yadava, 1985). Recently, Sheng *et al.* (2008) have reported fatty acid, amino acid and mineral composition, as well as protein profile of Chinese yak milk from 7 mid-lactating yaks (Maiwa breed) in Hongyuan County of the Sichuan Province of China. Furthermore, the composition of yak milk is higher than that of Jersey and Holstein dairy cows. The total dry matter is around 17-18% during the main lactating period, fat content is around 6.5%, protein and lactose are each around 5.5%, and ash 0.8% (Or-Rashid *et al.*, 2008). Concentrations of unsaturated fatty acid, such as conjugated linoleic acid (CLA), were greater than those of cow milk (Or-Rashid *et al.*, 2008). The aim of this study was to set up a detailed database of macro and micro elements from yak milk samples collected in Qilian on the Qinghai Plateau which could possibly reveal yak physiology and the impact on herdsmans' health.

Corresponding author: Prof. Adriana Ianieri, Dipartimento di Produzioni Animali, Biotecnologie Veterinarie, Qualità e Sicurezza degli Alimenti, Sezione di Sicurezza degli Alimenti, Facoltà di Medicina Veterinaria, Università di Parma, via del Taglio 10, 43126 Parma, Italy.
Tel. +39.0521.032754 – Fax: +39.0521.032752.
E-mail: adriana.ianieri@unipr.it

Key words: Yak milk, Macro elements, Micro elements, Qinghai Plateau.

Acknowledgments: the authors would like to thank Paolo Formaggioni, Piero Franceschi and Andrea Summer for their suggestions. The authors are grateful to the Department of Qinghai Science and Technology in Qinghai for funding.

Received for publication: 1 May 2011.

Last revision received: 25 January 2012.

Accepted for publication: 26 January 2012.

This work is licensed under a Creative Commons Attribution NonCommercial 3.0 License (CC BY-NC 3.0).

©Copyright W. Sun *et al.*, 2012

Licensee PAGEPress, Italy

Italian Journal of Animal Science 2012; 11:e33

doi:10.4081/ijas.2012.e33

Materials and methods

Collection of yak milk samples

From August to September, 63 raw milk samples were collected from 63 mid-lactating yaks from 10 different farms (identified by letters A, B, C, D, E, F, G, H, N and X) spread over 200 km from north to south in an area in Qilian County of Qinghai Province in China. The samples were milked directly from each yak by hand, stored in phials, and transported in an ice bag to the laboratory. The samples were kept at -20°C until analysis.

Analysis of trace elements

The yak milk samples (1.5 g) were stirred and digested in a microwave system (Milestone 1200 Mega) using 2 mL of ultra purity nitric acid 65% (Romil Ltd., Cambridge, UK). After mineralization, the samples were diluted to 50 mL by addition of ultra-pure water.

Analytical measurements were taken using an Ultima 2 Inductively Coupled Plasma Atomic Emission Spectrometer (HORIBA Jobin Yvon Srl, Opera, MI, Italy). The sample was introduced into the instrument via a Mainhard

nebulizer coupled to a cyclonic chamber at a flow rate of 1 mL per min. The gas (argon) flow was set at 12 L per min, while the radio frequency generator power was 1000 W. The instrument was constantly flushed at a 2 L per min nitrogen flow in order to be able to use wavelengths below 190 nm. The wavelengths adopted were 228.616 nm for cobalt (Co), 283.563 nm for chromium (Cr), 257.610 nm for manganese (Mn), 324.754 nm for copper (Cu), 213.856 nm for zinc (Zn), 259.940 nm for iron (Fe), 213.618 nm for phosphorus (P), 180.676 nm for sulphur (S), 317.93 nm for calcium (Ca), 766.490 nm for potassium (K), 588.990 nm for sodium (Na), and 279.550 for magnesium (Mg). Multi-element calibration standards were prepared by appropriate dilution of 1000 mg/L single-element standard solutions.

Data analysis

Data were analyzed using the SPSS statistical package for Windows version 16.0 (SPSS Chicago, IL, USA) using ANOVA one-way analysis of variance to find the statistical difference between mean values for the different yak farms. Statistical analysis was made according to the model:

$$Y_{ij} = \mu + \alpha_i + \epsilon_j$$

where

Y_{ij} is dependent variable; μ is general mean; α_i is fixed effect of the farm ($i=1-10$); ϵ_j is residual error.

The LSD (least significant difference) was applied to check significant difference ($P<0.05$).

Results and discussion

Method of validation

The analytical method was validated using BCR[®] 063R (skim milk powder) reference material. Six aliquots of the sample were prepared using the same method adopted for the samples. The samples were then analyzed by ICP-AES (inductively coupled plasma-atomic emission spectrometry) on three different days in order to evaluate accuracy and intra- and inter-day precision. The results of the validation process are reported in Table 1.

Six aliquots of the sample were mineralized and analyzed on three successive days. The intra- and inter-day percent coefficient of variation is reported together with the detection limit and the recovery calculated on the reference material.

Macro elements

The macro element composition of yak milk from Qinghai Plateau were compared to macro element composition of yak milk from the Chinese Maiwa region and with milk of other species reported in literature (Table 2).

In general, Ca values were lower than those found for the other species except for mare (Martuzzi *et al.*, 1998), but is higher than Ca values from Maiwa yak milk. Potassium values were higher than all species considered, except for values for cows reported by Do

Table 1. Validation results. BCR[®] 063R (skim milk powder) was used as reference material.

Element	Certified, $\mu\text{g/g}$	Mean, $\mu\text{g/g}$	Recovery, %	Intra-day precision	Inter-day precision	Detection limit, $\mu\text{g/g}$
Calcium	13490	13900	103	2.2	3.6	0.87
Potassium	17680	17100	97	2.8	3.5	1.11
Magnesium	1263	1210	96	3.1	4.2	0.48
Sodium	4370	4280	98	2.1	4.1	0.58
Phosphorus	1110	1160	104	1.8	3.2	1.08
Sulphur	-	360	-	2.0	4.0	0.98
Copper	0.60	0.58	96	2.0	2.9	0.01
Iron	2.32	2.44	108	1.7	2.7	0.01
Zinc	49.0	51.0	104	2.8	3.6	0.01
Cobalt	-	0.28	-	2.6	3.4	0.01
Chromium	-	0.31	-	2.2	2.8	0.01
Manganese	-	0.55	-	0.9	3.0	0.01

Table 2. Macro element content of milk from different animal species.

	Macro elements					
	Calcium, $\mu\text{g/g}$	Potassium, $\mu\text{g/g}$	Magnesium, $\mu\text{g/g}$	Sodium, $\mu\text{g/g}$	Phosphorus, $\mu\text{g/g}$	Sulphur, $\mu\text{g/g}$
Yak (Qilian) ^o	1243±253	1372±201	144±29	341±92	1173±202	399±74
Yak (Maiwa) [†]	1149±40	1066±33	105±4	-	-	-
Cow [§]	1300	1690	120	497	1060	-
Cow [^]	1220	1190	-	-	-	266
Sheep [§]	3953	1199	195	743	1387	-
Buffalod	1740	641	-	-	1190	357
Buffalo ^{oo}	1470	-	230	-	1260	-
Goat ^{††}	1340	1240	120	510	-	-
Goat ^{§§}	1342	409	510	433	823	296
Horse (mare) ^{§§}	1155	573	-	167	678	-

^oPresent research; [†]Li *et al.*, 2009; [§]Do Nascimento *et al.*, 2010; [^]Benincasa *et al.*, 2008; [§]Sahan, 2005; ^{oo}Anilkumar, 2003; ^{††}Garcia *et al.*, 2007; ^{§§}Guler, 2007.

Table 3. Micro element content of milk from different animal species.

	Micro elements					
	Cobalt, $\mu\text{g/g}$	Chromium, $\mu\text{g/g}$	Copper, $\mu\text{g/g}$	Iron, $\mu\text{g/g}$	Manganese, $\mu\text{g/g}$	Zinc, $\mu\text{g/g}$
Yak (Qilian) ^o	0.53±0.03	0.43±0.03	0.16±0.06	0.56±0.16	0.65±0.03	1.12±1.21
Cow [†]	0.002	0.006	0.058	0.273	0.017	4.74
Sheep [§]	0.090	0.450	0.900	3.330	0.310	21.6
Buffalo	0.002 [^]	0.00034 [^]	0.200 [§]	1.70 [§]	0.00247 [^]	5.00 [§]
Goat ^{oo}	0.89	0.77	0.48	3.88	0.70	4.68

^oPresent research; [†]Hermansen *et al.*, 2005; [§]Coni *et al.*, 1999; [^]Benincasa *et al.*, 2008; [§]Anilkumar, 2003; ^{oo}Guler, 2007.

Table 4. Macro elements concentration (mean) of yak milk from different yak farms.

	Different yak farms									
	Farm A (N=9)	Farm B (N=6)	Farm C (N=7)	Farm D (N=4)	Farm E (N=6)	Farm F (N=6)	Farm G (N=5)	Farm H (N=9)	Farm N (N=5)	Farm X (N=6)
Phosphorus ^o , µg/g	1051.980± 24.390 ^{ab}	1112.187± 31.001 ^{ab}	1165.866± 19.495 ^{abc}	1252.906± 24.612 ^{bc}	980.536± 28.839 ^a	1289.760± 34.751 ^{bc}	1255.824± 36.358 ^{bc}	1196.660 ± 16.432 ^{abc}	1146.638± 15.291 ^{abc}	1361.012± 27.969 ^c
Sulphur ^o , µg/g	352.655± 6.529 ^a	391.721 ± 8.143 ^{ab}	386.709± 7.820 ^{ab}	456.738± 9.234 ^b	343.412± 5.739 ^a	464.794± 10.95 ^b	416.279± 7.626 ^{ab}	389.040± 6.109 ^{ab}	382.162± 7.059 ^{ab}	459.737± 7.354 ^b
Calcium, µg/g	1117.884± 55.038	1339.664± 29.822	235.480± 171.163	1332.336± 62.417	988.349± 38.749	1324.083± 62.595	1184.105± 33.576	1261.655± 48.898	1360.472± 66.642	1378.472 ±67.433
Potassium, µg/g	1175.043± 21.686	1362.903± 16.215	1435.242± 10.391	1440.774± 14.414	1303.043± 19.987	1512.701± 26.887	1372.896± 15.385	1391.646± 21.194	1386.774± 25.587	1463.450± 20.636
Sodium, µg/g	296.096± 5.875	332.801± 7.581	329.292± 4.675	470.505± 8.331	323.748± 5.019	343.241± 5.195	325.911± 7.719	328.112 ± 5.736	391.917± 5.376	346.453 ±5.853
Magnesium, µg/g	137.47± 5.53	148.27± 9.31	138.81± 5.04	150.26± 3.59	114.47± 3.87	155.69± 5.56	141.39± 5.42	142.98± 8.99	150.42± 6.57	167.52± 6.12

^oThe mean difference is significant at P<0.05; ^{ab,c}different letters in the same row were significantly different from each other.

Nascimento *et al.* (2010). Compared to other studies, K values from buffalo milk (Benincasa *et al.*, 2008), goat milk (Guler, 2007) and mare milk (Martuzzi *et al.*, 1998) were much lower (Benincasa *et al.*, 2008a; Guler, 2007; Martuzzi *et al.*, 1998). Magnesium concentrations were higher than those reported for Maiwa yak milk by Sheng *et al.* (2008), cow milk by Do Nascimento *et al.* (2010) and goat milk by Garcia *et al.* (2006); they were lower than values reported for sheep by Sahan (2005) and much higher than Mg concentrations reported by Anilkumar (2003) for buffalo milk and Guler (2007) for goat milk. Sodium values were the lowest of all considered species except for mare (Martuzzi *et al.*, 1998); very high concentrations were reported by Sahan (2005) for sheep milk. Phosphorus values were lower than those reported by Sahan (2005) for sheep milk and by Anilkumar (2003) for buffalo milk; they were higher than values reported by Do Nascimento (2010) for cow milk, while the values reported by Guler (2007) for goat milk and by Martuzzi *et al.* (1998) for mare milk were very low compared to the other species considered. It was difficult to evaluate S values from the reference samples by macromineral analyses. However, S levels in this study were higher than those of other considered species in which the highest concentrations were in the sulphur containing amino acids of yak milk, such as cystine, cysteine, methionine.

In summary, K and S concentrations of yak milk from the Chinese Qinghai Plateau were higher while Ca levels were closer to cow milk but lower than milk of other species. Lower

concentrations of Na, Mg and P in this study were in the mid-range of levels among milk from different animal species. In addition, there were higher levels of K and lower concentrations of Na in yak milk, which would be of benefit in the diet of hyperpiesia patients as high levels of K in food can lower blood pressure (Dorrance *et al.*, 2007; Charlton *et al.*, 2005; Nowson *et al.*, 2003).

Micro elements

The composition of micro elements of yak milk and of milk of other animal species are reported in Table 3. Compared to cow, sheep and buffalo milk, concentrations of Co in yak milk were very high although lower than in goat milk. Chromium levels were higher with respect to cow and buffalo milk, but lower than in sheep and goat milk. Copper concentrations of yak milk were higher than cow milk, which were reported to be 0.058 µg/g (Hermansen *et al.*, 2005) and lower with respect to the other species. Iron levels were higher than those reported in cow milk at 0.2 µg/g (Anderson, 1992), which are close to those reported by Hermansen (Hermansen *et al.*, 2005) and lower with respect to the other species considered. Concentrations of Mn were very high with respect to cow, sheep and buffalo, and similar to those of goat milk. As for zinc, its levels in yak milk were the lowest among the species considered. Zinc is an essential element for human, animal and plant nutrition. According to our research, the lowest Zn level is to be found in yak milk. Given that this is the

main diet Zn source, from yak yoghurt and yak milk tea, for local people in the Qilian region, local herdsman could possibly risk Zn deficiency; this will be evaluated in future studies.

Differences among farms

The difference among farms for macro- and micro-mineral elements of yak (Qilian) milk was analyzed using SPSS software version 16.0 (Table 4). Using the LSD test, statistically significant differences were found between farms in two elements, P and S. In particular, there was a statistically significant difference in P content (P<0.05). The difference is probably due to the different composition of the pasture grass and the different soil.

Conclusions

According to the macro element of the composition of yak milk from the Chinese Qinghai Plateau, K and S concentrations of yak milk were higher and Ca levels were close to those of cow milk but lower than those of milk of other species. The lower concentrations of Na, Mg and P found in this study were in the mid-range of levels in milk from different animal species. As for the micro elements, all concentrations were highest for goat milk and lowest for cow milk, except for Zn. Comparing buffalo and sheep milk with yak milk, Co and Mn were the highest concentrations reported, and Cu, Fe and Zn were the lowest, while Cr levels

were in mid-range. In conclusion, yak milk from the Chinese Qinghai Plateau was particularly rich in Co, Mn and Cr, while it was deficient in zinc.

References

- Anderson, R.R., 1992 Comparison of trace elements in milk of four species. *J. Dairy Sci.* 75:3050-3055.
- Anilkumar, K., SyamMohan, K.M., Ally, K., Sathian, C.T., 2003. Composition and mineral levels of the milk of kuttanad dwarf buffaloes of kerala. *Buffalo Bull.* 22:67-70.
- Benincasa, C., Lewis, J., Sindona, G., Tagarelli, A., 2008. The use of multi element profiling to differentiate between cowand buffalo milk. *Food Chem.* 110:257-262.
- Charlton, K.E., Steyn, K., Levitt, N.S., Zulu, J.V., Jonathan, D., Veldman, F.J., Nel, J.H., 2005. Diet and blood pressure in South Africa: Intake of foods containing sodium, potassium, calcium, and magnesium in three ethnic groups. *Nutrition* 21:39-50.
- Coni, E., Bocca, B., Caroli, S., 1999. Minor and trace element content of two typical Italian sheep dairy products. *J. Dairy Res.* 66:589-598.
- Do Nascimento, I.R., De Jesus, R.M., Dos Santos, W.N.L., Souza, A.S., Fragoso, W.D., Dos Reis, P.S., 2010. Determination of the mineral composition of fresh bovine milk from the milk-producing areas located in the State of Sergipe in Brazil and evaluation employing exploratory analysis. *Microchem. J.* 96:37-41.
- Dorrance, A.M., Pollock, D.M., Romanko, O.P., Stepp, D.W., 2007. A high-potassium diet reduces infarct size and improves vascular structure in hypertensive rats. *Am. J. Physiol. Regul. Integr. Comp. Physiol.* 292: R415-R422.
- Garcia, M.I.H., Puerto, P.P., Baquero, M.F., Rodriguez, E.R., Martin, J.D., Romero, C.D., 2006. Mineral and trace element concentrations of dairy products from goats' milk produced in Tenerife (Canary Islands). *Int. Dairy J.* 16:182-185.
- Gerald, W., Han, J., Long, R., 2003. The yak. FAO Regional Office for Asia and the Pacific Publ., Bangkok, Thailand.
- Guler, Z.Z.G., 2007. Levels of 24 minerals in local goat milk, its strained yoghurt and salted yoghurt (tuzlu yogurt). *Small Ruminant Res.* 71:130-137.
- Hermansen, J.E., Badsberg, J.H., Kristensen, T., Gundersen, V., 2005. Major and trace elements in organically or conventionally produced milk. *J. Dairy Res.* 72:362:368.
- Jain, Y.C., Yadava, R.S., 1985. Yield and composition of milk of Himachali yak, yak hybrid and hill cow. *Indian J. Anim. Sci.* 55:223-224.
- Li, H.M., He, S.H., Liu, T.Y., Ma, Y., 2009. Research development in physical and chemical characters of yak milk. *China Dairy Industry* 8:35-36.
- Martuzzi, F., Summer, A., Catalano, A.L., Mariani, P., 1998. Macro- and micro-mineral elements of the milk and sialic acid bound to casein and to whey proteins in nursing mares of Bardigiano horse breed. *Ann. Facoltà di Medicina Veterinaria - Università di Parma* 18:67-74.
- Neupaney, D., Kim, J., Ishioroshi, M., Samejima, K., 2003. Study on some functional and compositional properties of yak butter lipid. *Anim. Sci. J.* 74:391-397.
- Nowson, C.A., Morgan, T.O., Gibbons, C., 2003. Decreasing dietary sodium while following a self-selected potassium-rich diet reduces blood pressure. *J. Nutr.* 133:4118-4123.
- Or-Rashid, M.M., Odongo, N.E., Subedi, B., Karki, P., McBride, B.W., 2008. Fatty acid composition of Yak (*Bos grunniens*) cheese including conjugated linoleic acid and trans-18:1 fatty acids. *J. Agric. Food Chem.* 56:1654-1660.
- Sahan, N., 2005. Changes in chemical and mineral contents of Awassi Ewes milk during lactation. *Turk. J. Vet. Anim. Sci.* 29: 589-593.
- Sheng, Q., Li, J., Alam, M.S., Fang, X., Guo, M., 2008. Gross composition and nutrient profiles of Chinese yak (Maiwa) milk. *Int. J. Food Sci. Tech.* 43:568-572.
- Zhang, H., Xu, J., Wang, J., Menghebilige, Sun, T., Li, H., Guo, M., 2008. A survey on chemical and microbiological composition of kurut, naturally fermented yak milk from Qinghai in China. *Food Cont.* 19:578-586.
- Zhu, G., Zhang, Y., 2005. Current conditions and developing approaches of yak production in china. *Chinese J. Anim. Sci.* 41:61-63.