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

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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 Mawai 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 herdsmen 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 herdsmen 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 herdsmen’s health.

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:

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

where $Y_{ij}$ is dependent variable; $\mu$ is general mean; $\alpha_i$ is fixed effect of the farm $(i=1-10)$; $\varepsilon_{ij}$ 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, $\mu g$ | Mean, $\mu g$ | Recovery, % | Intra-day precision | Inter-day precision | Detection limit, $\mu g$ |
| 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           | 96          | 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, $\mu g$ | Potassium, $\mu g$ | Magnesium, $\mu g$ | Sodium, $\mu g$ | Phosphorus, $\mu g$ | Sulphur, $\mu g$ |
| Yak (Qilian)°   | 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              | -                         |
| Buffalo°°       | 1740             | 641            | -              | -                   | 1190              | 357                       |
| Buffalo°°°      | 1470             | -              | 230            | -                   | 1260              | -                         |
| Goat°°          | 1340             | 1240           | 120            | 510                 | -                 | 823                       |
| Goat°°°         | 1342             | 409            | 510            | 433                 | 823               | 296                       |
| Horse (mare)°°° | 1155             | 573            | -              | 167                 | 678               | -                         |

| Table 3. Micro element content of milk from different animal species. |
|-----------------------------------------------|
| Micro elements                                                                                   |
| Cobalt, $\mu g$ | Chromium, $\mu g$ | Copper, $\mu g$ | Iron, $\mu g$ | Manganese, $\mu g$ | Zinc, $\mu g$ |
| Yak (Qilian)°   | 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          | 0.065          | 0.273              | 0.017            | 4.74                     |
| Sheep§          | 0.080            | 0.450          | 0.900          | 3.300              | 0.310            | 21.6                     |
| Buffalo°°       | 0.002            | 0.00034        | 0.200$^*$      | 1.70$^*$           | 0.00247$^*$      | 5.00$^*$                 |
| Goat°°°         | 0.89             | 0.77           | 0.48           | 3.88               | 0.70             | 4.68                     |

*Present research; ‡Li et al., 2005; ‡Do Nascimento et al., 2010; ‡Benincasa et al., 2008; ‡Sahan, 2005; ‡Anilkumar, 2003; ‡Garcia et al., 2007; ‡Guler, 2007.
Table 4. Macro elements concentration (mean) of yak milk from 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=9) | Farm H (N=5) | Farm N (N=6) | Farm X (N=6) |
|---------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Phosphorus, µg/g | 1051.98± 24.39 | 1112.187± 31.001 | 1165.866± 19.495 | 1252.906± 24.612 | 980.538± 28.833 | 1288.760± 34.751 | 1255.824± 36.358 | 1196.660± 16.432 | 1146.638± 15.291 | 1361.012± 27.969 |
| Sulphur, µg/g | 352.655± 6.529 | 391.721± 8.143 | 386.709± 7.820 | 456.738± 9.234 | 343.412± 5.739 | 464.794± 10.952 | 416.279± 7.626 | 389.040± 6.109 | 382.162± 7.059 | 459.737± 7.354 |
| Calcium, µg/g | 1117.88± 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± 48.888 | 1369.472± 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± 26.036 |
| Sodium, µg/g | 296.096± 5.675 | 322.801± 7.581 | 329.292± 6.475 | 470.505± 8.331 | 323.748± 5.019 | 343.241± 5.195 | 325.911± 7.719 | 328.112± 5.736 | 391.917± 5.576 | 346.453± 5.853 |
| Magnesium, µg/g | 137.47± 5.53 | 148.27± 9.31 | 138.81± 5.04 | 150.24± 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 |

*The 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 (Martuzzi et al., 2008), goat milk (Guler, 2007) and mare 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 herdsmen could possibly risk Zn deficieny; 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 higher 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.

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