Donkey milk concentration of calcium, phosphorus, potassium, sodium and magnesium

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1. Introduction

Donkey milk, traditionally used in Europe as a human milk substitute (Salimei, 2011), is considered a valid alternative to the available hypoallergenic formulae for infants suffering from cows’ milk protein allergy (Carroccio et al., 2000; Iacono et al., 1992; Tesse, Pagliuona, Braccio, & Armenio, 2009). The use of donkey milk is also reported to be useful, from an immunological point of view, in the treatment of human immune-related diseases and in the prevention of atherosclerosis (Tafaro et al., 2007). Donkey milk has been already characterized for its composition (Salimei & Chiofalo, 2006) but only limited data are available on mineral fraction despite the importance of mineral nutrition for newborn health and growth.

Aiming to increase the knowledge about the mineral composition of donkey milk the concentrations of Ca, P, K, Na and Mg were studied, also taking into account the effects of stage of lactation and dietary treatment and the interrelationships between elements.

2. Material and methods

2.1. Animals, diet and sampling

During a 3 month period 16 clinically healthy lactating Martina Franca breed derived donkeys were used to provide milk samples. Jennies (6–12 years old; 3–7 parities; average live weight 205.4 kg; 32–58 days from foaling at the beginning of the trial) were fed 8 kg of meadow hay and 2.5 kg of mixed feed, daily. Eight of the jennies received a mixed feed supplemented with (kg−1) 185 mg Fe, 36 mg Cu, 163 mg Zn, 216 mg Mn, 3.2 mg I, 2.78 mg Co, 0.70 mg Se. The mixed feed was gradually administered starting at the 1st sampling time, immediately following milking. Jennies were housed with the foals that were separated from the dam 3 h before milking. Individual milk samples were collected every 2 weeks (7 sampling times) at 11:00 am by mechanical milking as described by Salimei et al. (2004). All glasses and polyethylene tubes used for collection, storage and analysis of samples were previously washed with 3% nitric acid (suprapur quality, Merck, Darmstadt, Germany) solution.

2.2. Calcium, phosphorus, potassium, sodium and magnesium analyses

Optimized digestion of thawed milk samples (n = 112) was carried out by placing 0.25 mL of sample in a Teflon® digestion vessel, followed by 3 mL of HNO3 (65%; suprapur quality, Merck) and 0.5 mL of H2O2 (30%; suprapur quality, Merck). A microwave sample preparation system (Milestone, MLS 1200 Mega, Sorisole, Italy) was used for digestion as described by Rivero Martino, Fernandez Sanchez, and Sanz-Medel (2001). The concentrations of Ca, P, K, Na and Mg in the acid digested solution were measured by inductively coupled plasma-mass spectrometry (ICP-MS) (Agilent Technologies, 2011).
7500 cx series, Santa Clara, CA, USA). The accuracy of the analytical procedure was assessed by quadruplicate analysis of non-fat milk powder reference material (NIST SRM 1549). The analytical results were in good agreement with the certified values (observed Ca 1.26%, P 1.07%, K 1.72%, Na 0.513%, Mg 0.124%; certified Ca 1.30%, P 1.06%, K 1.69%, Na 0.497%, Mg 0.120%).

2.3. Statistical analysis

To evaluate the effects of stage of lactation (within subject factor) and dietary treatment (between subject factor) data were processed by analysis of variance for repeated measures (SPSS Inc., Chicago, IL, USA). Data from the 1st sampling were used as covariate when significant. In the case of significant effects (P < 0.05) differences between means were analyzed by least significant difference. The effect of dietary treatment on the investigated variables was not significant and not further considered in this paper. Association between variables was examined by calculating simple linear correlations. Significant correlations were declared strong (r > 0.7), moderate (r from 0.3 to 0.7) or weak (r < 0.3).

3. Results and discussion

3.1. Calcium, phosphorus, potassium, sodium, magnesium, Ca/P ratio and Na/K ratio in donkey milk

Descriptive statistics of overall concentrations of Ca, P, K, Na and Mg in donkey milk are summarized in Table 1. Results from the current studies were slightly different than those reported in previous studies on donkey milk (Li, Peng, Zhu, Zhao, & Li, 2010; Ofstedal & Jenness, 1988; Salimei et al., 2004). Only a previous study on donkey milk samples distributed over 8 months of lactation reported much lower values of Ca and Mg concentrations (Fantuz, Maglieri, Leboroni, & Salimei, 2009a). Differences between current results and those reported in literature for donkey milk may be due to differences in breed, stage of lactation, milk protein content, sample size and accuracy of analytical methods. Except for K, donkey milk macro minerals concentration fell in the range reported for mare milk (Doreau & Martin-Rosset, 2011). The concentration of macro minerals is reported to be lower in human milk, except Na which is similar (Darragh & Lonnerdal, 2011), but higher in ruminant milk commonly used for human consumption such as cow (Gaucheron, 2005) and goat (Park, Juarez, Ramos, & Haenlein, 2007). The Ca/P ratio in donkey milk (Table 1) was consistent with data from Salimei et al. (2004), lower than that in human and mare milks, and similar to that in cow and goat milks (Darragh & Lonnerdal, 2011; Doreau & Martin-Rosset, 2011; Gaucheron, 2005; Park et al., 2007). Similar to the case in mare milk, the highest average concentration was observed for Ca, followed by K, P, Na and Mg (Table 1), whereas K is the most represented in human, cow and goat milk (Darragh & Lonnerdal, 2011; Doreau & Martin-Rosset, 2011; Gaucheron, 2005; Park et al., 2007). The lower concentration of macro minerals in donkey milk compared to milk from cow and goat is consistent with the lower ash content (Guo et al., 2007; Salimei et al., 2004).

3.2. Effect of stage of lactation

The effect of stage of lactation was significant (P < 0.01) for all the investigated variables. The Ca concentration of milk decreased by approximately 30% throughout the trial (Fig. 1). Phosphorus and Mg concentrations showed a significant decrease by the 3rd sampling period (70–86 days of lactation) of approximately 20% and 35% (Fig. 1), respectively. The decreasing trends observed during lactation for Ca, P and Mg are consistent with the decline of ash content reported for donkey milk during lactation (Guo et al., 2007; Salimei, Maglieri, Varisco, La Manna, & Fantuz, 2009) and they can partially explain the variability reported in literature for macro mineral in donkey milk. Potassium and Na concentrations (Fig. 1) were also affected by the stage of lactation but did not follow a consistent trend. The Ca/P ratio declined (P < 0.01) continuously from 1.41 to 1.18 with the advancing of lactation. The Na/K ratio was relatively constant throughout the trial with only one significant but limited increase at the 5th sampling period (data not shown).

There are no published data on the effect of stage of lactation on macro mineral composition of donkey milk but decreasing Ca, P and Mg concentrations with the advancing of lactation were also observed in mare milk (Summer, Sabbioni, Formaggioni, & Mariani, 2004).

3.3. Correlation coefficients

The correlations between the investigated macro minerals in milk were positive and significant except between Ca and Na (Table 2). Phosphorus was strongly correlated with Ca, Mg and K.

![Fig. 1. Effect of stage of lactation on donkey milk concentration of Ca (■), P (●), K (○), Na (▲) and Mg (▼). Means within the same line with different superscripts differ at P < 0.05. Error bars represent standard error.](image)

### Table 1

Descriptive statistics for essential macro minerals (mg L⁻¹), Ca/P ratio and Na/K ratio in donkey milk.

<table>
<thead>
<tr>
<th>Parameter*</th>
<th>Ca (mg L⁻¹)</th>
<th>P (mg L⁻¹)</th>
<th>K (mg L⁻¹)</th>
<th>Na (mg L⁻¹)</th>
<th>Mg (mg L⁻¹)</th>
<th>Ca/P</th>
<th>Na/K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>807.09</td>
<td>638.34</td>
<td>746.61</td>
<td>140.94</td>
<td>81.68</td>
<td>1.26</td>
<td>0.19</td>
</tr>
<tr>
<td>Median</td>
<td>803.42</td>
<td>628.14</td>
<td>731.94</td>
<td>139.99</td>
<td>81.30</td>
<td>1.25</td>
<td>0.19</td>
</tr>
<tr>
<td>SD</td>
<td>138.23</td>
<td>70.03</td>
<td>79.83</td>
<td>10.90</td>
<td>13.16</td>
<td>0.14</td>
<td>0.02</td>
</tr>
<tr>
<td>95% CI</td>
<td>779.09–835.10</td>
<td>624.07–652.61</td>
<td>730.17–763.05</td>
<td>138.89–142.98</td>
<td>79.02–84.35</td>
<td>1.23–1.29</td>
<td>0.18–0.19</td>
</tr>
<tr>
<td>CV</td>
<td>17.13</td>
<td>10.97</td>
<td>10.69</td>
<td>7.76</td>
<td>16.74</td>
<td>11.12</td>
<td>10.53</td>
</tr>
<tr>
<td>Min.</td>
<td>552.13</td>
<td>525.34</td>
<td>552.07</td>
<td>113.59</td>
<td>55.86</td>
<td>1.04</td>
<td>0.14</td>
</tr>
<tr>
<td>Max.</td>
<td>1176.73</td>
<td>845.74</td>
<td>962.34</td>
<td>172.31</td>
<td>112.94</td>
<td>1.64</td>
<td>0.26</td>
</tr>
<tr>
<td>1st quartile</td>
<td>715.13</td>
<td>580.74</td>
<td>693.64</td>
<td>135.72</td>
<td>71.38</td>
<td>1.14</td>
<td>0.375</td>
</tr>
<tr>
<td>3rd quartile</td>
<td>914.08</td>
<td>694.14</td>
<td>808.74</td>
<td>146.99</td>
<td>91.95</td>
<td>1.35</td>
<td>0.204</td>
</tr>
</tbody>
</table>

* SD, standard deviation; CI, confidence interval for the mean; CV, coefficient of variation.
Table 2
Correlation coefficients between macro minerals, Ca/P ratio and Na/K ratio in donkey milk.*

<table>
<thead>
<tr>
<th></th>
<th>P</th>
<th>K</th>
<th>Na</th>
<th>Mg</th>
<th>Ca/P</th>
<th>Na/K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca</td>
<td>0.81***</td>
<td>0.35***</td>
<td>NS</td>
<td>0.58**</td>
<td>0.77***</td>
<td>0.23*</td>
</tr>
<tr>
<td>P</td>
<td>0.73***</td>
<td>0.33***</td>
<td>0.80**</td>
<td>0.26**</td>
<td>0.44***</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>0.24*</td>
<td>0.65***</td>
<td>0.21*</td>
<td>0.74***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Na</td>
<td>0.29**</td>
<td>NS</td>
<td>0.46***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mg</td>
<td>NS</td>
<td>0.44***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ca/P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NS</td>
</tr>
</tbody>
</table>

* Significance is: *** P < 0.001; ** P < 0.01; * P < 0.05; NS, not significant.

Moderate correlations were observed between Mg and K, Mg and Ca, K and Ca, and between Na and P. Correlations were weak between Na and Mg and between Na and K. The milk Ca/P ratio was strongly correlated with Ca but weakly correlated with P (Table 2). A weak negative correlation was observed between Ca/P and K. The Na/K ratio was positively correlated with Ca (weak), P and Mg (moderate), and K (strong), but negatively correlated with Na (Table 2).

Moderate to strong positive correlations, also depending on stage of lactation, were previously observed among essential macro minerals, except between Na and Mg, in milk from nursing mares (Summer et al., 2004).

The correlation observed between Ca, P and Mg may be explained by the association of these minerals in the casein micelle and the observed decrease in Ca, P and Mg with the advance of lactation may be related to the decrease of total and casein nitrogen that occur during lactation in donkey milk (Fantuz, Maglieri, Varisco, La Manna, & Salimei, 2009b; Giosuè, Alabiso, Russo, Alicata, and Torrisi 2008).

4. Conclusions

The Ca, P, K, Na and Mg concentrations of donkey milk generally appear to be similar to those in mare milk and intermediate between the higher values of ruminant milk and the lower values of human milk, with Ca being the most commonly represented element followed by K, P, Na and Mg. However, the milk concentrations of macro minerals change with the advancing of lactation showing a decrease in Ca, P and Mg contents and Ca/P ratio. As a consequence, when describing donkey milk composition the stage of lactation should be specified. Data provided by the current study can be also used to support the assessment of macro mineral nutritional requirements of dam and newborn.

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References


