Physicochemical characteristics of goat's milk in Austria—seasonal variations and differences between six breeds

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Abstract Despite the increasing economic importance of goat's milk in Europe, no current data on the chemical composition and physical properties of this milk species are available in Austria. Thus, milk samples of six dairy goat breeds in Austria (*Bunte Deutsche Edelziege*, *Pinzgauer Ziege*, *Saanenziege*, *Strahlenziege*, *Toggenburger Ziege*, *Weißer Deutsche Edelziege*) were analysed for physicochemical characteristics for 8 months from March to October. Considerable seasonal variations, but nearly no statistically significant differences between milk samples from these six goat breeds were observed regarding most parameters. The mean values obtained for all breeds during the whole season were as follows: pH 6.55, freezing point depression 0.549 °C, ash 0.828%, total solids 12.24% (w/w), crude protein 3.35% (w/w), casein 2.40% (w/w), whey protein 0.63% (w/w), urea 0.325 g·L⁻¹, fat 3.67%, lactose 4.23%, citric acid 0.913 g·L⁻¹, phosphorus 1.088 g·L⁻¹, chloride 1.708 g·L⁻¹, sodium 0.304 g·L⁻¹, potassium 1.759 g·L⁻¹, calcium 1.256 g·L⁻¹, magnesium 0.128 g·L⁻¹, orotic acid 13.59 mg·kg⁻¹, β-carotene 0.419 mg·L⁻¹, retinol 0.502 mg·L⁻¹, riboflavin 1.050 mg·L⁻¹, and cholesterol 12.4 mg·100 g⁻¹ milk, respectively. The studies on fatty acid profiles revealed the following mean values: C4:0 2.73%, C6:0 2.10%, C8:0 1.86%, C10:0 5.80%, C12:0 2.52%, C14:0 7.07%, C16:0 23.73%, C18:0 11.84%, and C18:1 28.14%. Unexpected high levels were obtained for C18:2 (5.06%) and C18:3 (0.59 %), respectively. This work provides an updated information on the current physicochemical characteristics of goat's milk in Austria, which can be of great importance in the fields of dairy and food technology, nutrition science, and food analysis, respectively.

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季节和品种对山羊奶物理化学特性的影响

摘要 尽管山羊奶对欧洲经济的作用越来越大,但是目前在奥地利还没有对不同品种和不同季节山羊奶化学组成和物理特性的相关报道。本文对来自于奥地利6个品种的山羊奶(Bunte Deutsche Edelziege, Pinzgauer Ziege, Saanenziege, Strahlenziege, Toggenburger Ziege, Weiße Deutsche Edelziege)进行了为期8个月(3月到9月)物理化学特性的跟踪分析。实验结果表明,季节变化对山羊奶物理化学特性的影响显著。但是6个品种山羊奶中多数物理化学性质指标没有显著性差异。6个品种山羊奶在整个泌乳期内物理化学性质指标的平均值如下: pH:6.55、冰点:0.549 °C、灰分:0.828%、总固形物:12.24% (w/w)、粗蛋白:3.35% (w/w)、酪蛋白:2.40% (w/w)、乳清蛋白:0.63% (w/w)、尿素:0.325 g·L⁻¹、脂肪:3.67%、乳糖:4.23%、柠檬酸:0.913 g·L⁻¹、磷:1.088 g·L⁻¹、氯化物:1.708 g·L⁻¹、钠:0.304 g·L⁻¹、钾:1.759 g·L⁻¹、钙:1.256 g·L⁻¹、镁:0.128 g·L⁻¹、乳清酸:13.59 mg·kg⁻¹、β-胡萝卜素:0.419 mg·L⁻¹、维生素A: 0.502 mg·L⁻¹、核黄素:1.050 mg·L⁻¹、胆固醇:12.4 mg·100 g⁻¹;乳脂肪酸的平均值如下: C4:0: 2.73%、C6:0:2.10%、C 8:0:1.86%、C10:0:5.80%、C12:0:2.52%、C14:0:7.07%、C16:0:23.73%、C 18:0:11.84%、C18:1 28.14%;高含量的脂肪酸是C18:2(5.06%)和C18:3 (0.59%)。本文提供了奥地利山羊奶物理化学特性的最新信息,这些信息对乳品和食品科技、营养科学和食品分析具有重要的意义。

Keywords Goat's milk · Physicochemical characteristics · Goat breeds · Austria

关键词 山羊奶 · 物理化学特性 · 山羊品种 · 奥地利

1 Introduction

Although goat's milk does not have this economic importance and long tradition as in other European countries (e.g. in particular in the Mediterranean area), it became more and more important also in Austria in recent years. This is probably due to the fact that goat's milk products (yoghurt and in particular different cheese varieties) can provide a profitable alternative to cow's milk products because of their specific taste and the natural and healthy image for consumers (Mayer 2005).

Data on the chemical composition and physical properties (Allgöwer and Bachmann 1990; Anifantakis 1986; Brendehaug and Abrahamsen 1986; Jandal 1996; Jenness 1980; Juárez and Ramos 1986; Ramos and Juárez 1981; Trancoso et al. 2010) and nutritive value (Haenlein 2004) of caprine milk are available from many countries all over the world and have been recently reviewed (Morgan et al. 2003; Park et al. 2007; Raynal-Ljutovac et al. 2008) and also compiled in books (Park 2006).

However, almost no information is available on the chemical composition and physical properties of goat's milk in Austria. As goat's milk specialities do not any longer represent just a niche product in human nutrition in Austria, additional information is therefore requested regarding the nutritional composition of these alternative products.

The aim of this work was to investigate the physicochemical characteristics of goat's milk in Austria with particular focus on seasonal variations and differences between goat breeds that are common in Austria.

2 Materials and methods

2.1 Milk samples

Pooled milks of 15 individual goats from each of the six most common breeds in Austria (Coloured = *Bunte Deutsche Edelziege*, Pinzgau = *Pinzgauer Ziege*, Saanen = *Saanenziege*, Strahlen = *Strahlenziege*, Toggenburg = *Toggenburger Ziege*, White = *Weiß Deutsche Edelziege*) (Sambras 2001) were collected at fortnightly intervals over a period of 8 months from March to October ($n=17$ for each breed). All goats were kept and fed under identical conditions (e.g. seasonal breeding, climate, grazing, feeding stuff) on the same goat farm in Lower Austria. Milking was switched to once per day in the end of September, due to low milk yield at the end of lactation. In addition, individual milk samples of all 90 goats included were taken four times during the season (May, June, July, September). Milk samples were kept frozen (-27°C) until they were analysed.

2.2 Physicochemical analyses

Milk samples were analysed for chemical composition and physicochemical parameters according to standard procedures. All measurements were performed in triplicate. Total solids were determined by the oven method in accordance with ISO 6731 (ISO-IDF 2010a). Total nitrogen (TN) was determined by the Kjeldahl method according to ISO 8968-1 (ISO-IDF 2001a), non-casein N (NCN) according to ISO 17997-1 (ISO-IDF 2004) and non-protein N (NPN) according to ISO 8968-4 (ISO-IDF 2001b). Whey protein N was calculated from the difference between NCN and NPN, and casein N from TN and NCN, respectively. Protein equivalents were calculated from nitrogen data using the factor 6.38. Fat content was determined gravimetrically according to ISO 1211 (ISO-IDF 2010b). Fatty acid profiles were analysed on a MEGA 5160 HR chromatograph (Carlo Erba, Milan, Italy) in accordance with Ulberth and Schrammel (1995), and cholesterol was also analysed by GC (MEGA 5300, Carlo Erba) (Ulberth and Reich 1992). Lactose, citric acid and urea were determined using the lactose/D-galactose (Catalogue number 10176303035), the citric acid (cat. no. 10139076035) and the urea (cat. no. 10542946035) UV test combinations (Boehringer Mannheim/R-Biopharm AG, Darmstadt, Germany), respectively. Orotic acid content was analysed by high-performance liquid chromatography according to Kneifel and Mayer (1991) using a Waters model 600 E multisolvent delivery system (Waters, Milford, MA, USA). Retinol, β -carotene and riboflavin contents of milk samples were analysed according to Schwarz (1997). Chloride was determined using the potentiometric titration method in line with ISO 5943 (ISO-IDF 2006a), and phosphorus content was analysed by molecular absorption spectrometry according to ISO 9874 (ISO-IDF 2006b). The analysis of sodium, potassium, calcium and magnesium using atom absorption spectrometry was performed in accordance with Kahlhofer (1971). Freezing point depression was analysed by the thermistor cryoscope method according to ISO 5764 (ISO-IDF 2009).

Table 1 Chemical composition and some physical characteristics of goat's milk in Austria—mean values obtained during the whole season ($n=17$ for each breed)

Milk composition	Goat's milk (from six different breeds)						Goat's milk (overall means)	
	Coloured	Pinzgau	Saanen	Strahlen	Toggenburg	White		
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Average mean±SD	Min–max
Total solids (g·100 g ⁻¹)	12.25±1.14	12.40±1.39	12.37±1.10	12.04±0.94	12.47±1.19	11.93±1.25	12.24±1.16	10.52–15.36
Lactose (g·100 g ⁻¹)	4.04±0.45	4.09±0.63	4.31±0.56	4.16±0.32	4.46±0.40	4.33±0.40	4.23±0.48	3.07–5.21
Fat (g·100 g ⁻¹)	3.51±0.51	3.79±0.56	3.73±0.46	3.56±0.59	3.86±0.74	3.58±0.71	3.67±0.60	2.81–5.54
Crude protein (g·100 g ⁻¹)	3.34±0.54	3.44±0.67	3.34±0.58	3.29±0.44	3.40±0.57	3.29±0.53	3.35±0.55	2.71–4.90
True protein (g·100 g ⁻¹)	3.03±0.51	3.12±0.67	2.99±0.57	2.98±0.41	3.10±0.55	2.98±0.52	3.03±0.59	2.27–4.62
Casein (g·100 g ⁻¹)	2.38±0.37	2.49±0.43	2.40±0.44	2.38±0.36	2.46±0.38	2.31±0.41	2.40±0.40	1.56–3.56
Whey protein (g·100 g ⁻¹)	0.64±0.17	0.62±0.22	0.59±0.16	0.60±0.11	0.64±0.20	0.67±0.22	0.63±0.17	0.34–1.22
Urea (g·L ⁻¹)	0.346 ^{ab} ±0.127	0.304 ^{ab} ±0.097	0.341 ^{ab} ±0.059	0.347 ^{ab} ±0.113	0.249 ^a ±0.114	0.361 ^b ±0.118	0.325±0.112	0.040–0.542
Cholesterol (mg·100 g ⁻¹ milk) ^a	–	–	–	–	–	–	12.4±3.9	8.0–21.9
Freezing point (°C)	0.550 ^{ab} ±0.007	0.550 ^{ab} ±0.005	0.551 ^a ±0.005	0.544 ^b ±0.006	0.549 ^{ab} ±0.007	0.550 ^{ab} ±0.005	0.549±0.006	0.534–0.559
pH	6.55 ^{ab} ±0.06	6.55 ^{ab} ±0.08	6.53 ^a ±0.08	6.54 ^{ab} ±0.08	6.59 ^b ±0.07	6.55 ^{ab} ±0.09	6.55±0.08	6.39–6.82
Retinol (mg·L ⁻¹) ^a	–	–	–	–	–	–	0.502±0.189	0.252–0.840
β-Carotene (mg·L ⁻¹) ^a	–	–	–	–	–	–	0.419±0.155	0.136–0.706
Riboflavin (mg·L ⁻¹) ^a	–	–	–	–	–	–	1.050±0.861	0.472–3.102
Orotic acid (mg·kg ⁻¹)	16.04±4.15	13.42±4.94	13.02±3.60	13.67±2.92	12.39±4.04	12.95±4.04	13.59±4.07	8.54–24.51
Ash (g·100 g ⁻¹)	0.820±0.082	0.843±0.090	0.819±0.073	0.830±0.041	0.829±0.081	0.827±0.072	0.828±0.073	0.734–1.050
Phosphorus (g·L ⁻¹)	1.088±0.213	1.122±0.218	1.072±0.144	1.068±0.102	1.096±0.153	1.082±0.135	1.088±0.163	0.862–1.627
Chloride (g·L ⁻¹)	1.691±0.152	1.731±0.193	1.739±0.255	1.701±0.197	1.655±0.209	1.733±0.212	1.708±0.202	1.297–2.234
Citric acid (g·L ⁻¹)	0.853±0.275	0.898±0.323	0.865±0.272	0.918±0.165	1.059±0.151	0.882±0.265	0.913±0.253	0.367–1.351
Calcium (g·L ⁻¹)	1.232±0.200	1.303±0.212	1.249±0.188	1.243±0.184	1.283±0.192	1.227±0.201	1.256±0.194	0.898–1.645

Table 1 (continued)

Milk composition	Goat's milk (from six different breeds)						Goat's milk (overall means)	
	Coloured	Pinzgau	Saanen	Strahlen	Toggenburg	White		
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Average mean±SD	Min–max
Magnesium (g·L ⁻¹)	0.127±0.019	0.129±0.028	0.125±0.019	0.129±0.016	0.130±0.020	0.129±0.021	0.128±0.020	0.093–0.183
Sodium (g·L ⁻¹)	0.299±0.046	0.308±0.059	0.304±0.056	0.299±0.032	0.304±0.069	0.312±0.050	0.304±0.052	0.234–0.476
Potassium (g·L ⁻¹)	1.741±0.137	1.732±0.096	1.741±0.099	1.755±0.109	1.780±0.166	1.804±0.121	1.759±0.124	1.443–2.092
Main fatty acids (g·100 g ⁻¹ total fatty acids)								
C4:0	2.74±0.42	2.82±0.48	2.72±0.49	2.74±0.45	2.69±0.49	2.69±0.38	2.73±0.46	1.85–3.36
C6:0	2.06±0.21	2.13±0.24	2.09±0.27	2.09±0.22	2.13±0.25	2.08±0.22	2.10±0.24	1.64–2.49
C8:0	1.78 ^a ±0.16	1.82 ^{ab} ±0.16	1.84 ^{ab} ±0.17	1.91 ^{ab} ±0.21	1.89 ^{ab} ±0.20	1.92 ^b ±0.22	1.86±0.19	1.42–2.18
C10:0	5.71±1.01	5.80±0.97	5.79±0.94	6.01±0.97	5.71±0.98	5.75±0.87	5.80±0.96	3.94–8.13
C12:0	2.58±0.90	2.46±0.94	2.52±0.71	2.63±0.63	2.42±0.64	2.52±0.55	2.52±0.83	1.71–4.79
C14:0	7.42±2.31	6.89±2.19	7.05±1.95	7.28±1.58	6.65±1.80	7.14±1.58	7.07±1.92	4.72–12.15
C16:0	24.17±2.85	23.59±2.74	23.76±2.87	23.91±2.90	23.20±2.54	23.77±3.01	23.73±2.82	19.62–29.81
C18:0	11.57±3.17	11.75±3.09	11.99±3.05	12.12±2.64	12.04±2.83	11.60±2.95	11.84±3.14	6.08–16.52
C18:1	28.20±3.71	28.09±4.15	28.14±3.31	27.77±3.09	28.72±3.89	27.71±4.10	28.14±3.73	20.73–37.34
C18:2	5.19±1.32	5.07±1.24	5.18±1.06	4.88±0.97	5.21±1.28	4.88±1.08	5.06±1.27	3.01–7.69
C18:3	0.58±0.15	0.58±0.14	0.60±0.18	0.59±0.13	0.61±0.15	0.56±0.11	0.59±0.15	0.38–0.98

Pooled milk samples of 15 individual goats (from each of the six breeds included in this study) were collected from one farm in Austria at fortnightly intervals over a period of 8 months from March to October. Means within a line followed by different superscript letters are significantly ($P<0.05$) different

Coloured: Bunte Deutsche Edelziege; Pinzgau: Pinzgauer Ziege; Saanen: Saanenziege; Strahlen, Strahlenziege; Toggenburg: Toggenburger Ziege; White: Weiße Deutsche Edelziege

^a Milk samples of all six goat breeds were collected and pooled at fortnightly intervals and analysed as mixed samples each ($n=17$)

2.3 Statistical analyses

Chemical composition of milk samples was evaluated by means of one-way analysis of variance using statistical package SPSS 15.0. Differences between milk samples from the six dairy goat breeds included in this study were tested according to Tukey test and considered to be significant when $P < 0.05$.

3 Results and discussion

3.1 Physicochemical characteristics of goat's milk from six dairy breeds

As the suitability of goat's milk for the manufacture of dairy products depends on its chemical composition and physical properties, attention was paid to the physicochemical characteristics of goat's milk in Austria as influenced by seasonal effects and differences between breeds. Table 1 shows the mean values of the chemical composition and some physical parameters of goat's milk in Austria obtained during the whole season.

It is well established and had been shown by different authors that there might be considerable differences in chemical composition and physical properties of milk from different goat breeds (Alichanidis and Polychroniadou 1996; Morgan et al. 2003; Raynal-Ljutovac et al. 2008; Trancoso et al. 2010). However, the six dairy breeds included in this study showed very similar chemical composition and physical properties as shown in Table 1 and in Figs. 1, 2 and 3. This was probably due to the fact that goats were kept and fed under identical conditions at the same farm. Thus, no statistically significant differences between physicochemical characteristics of milk samples from these goat breeds were found except for the parameters urea, freezing point, pH and caprylic acid, respectively (see Table 1).

Results obtained in the present study are within the broad range that has been reviewed recently, although quite significantly differing levels concerning gross composition of goat's milk have also been reported by some authors (Jandal 1996; Morgan et al. 2003; Park et al. 2007; Raynal-Ljutovac et al. 2008; Souci et al. 2000).

For example, total solids up to 14.8% (w/w), fat up to 5.63% (w/w) and crude protein contents up to 4.09% (w/w) as reported in literature (Raynal-Ljutovac et al. 2008) are far beyond the levels that were found in this study, as the average means were calculated with 12.24% (total solids), 3.67% (fat) and 3.35% (crude protein) only (Table 1). In addition, average concentrations given in a reference book (Souci et al. 2000), which is very often used by food chemists as a source of reference values concerning the composition of foods, are also significantly higher (13.4% total solids, 3.92% fat and 3.69% crude protein) than results obtained in the present study. In contrast, unexpected high levels were found for C18:2 (5.06%) and C18:3 (0.59%) in comparison with other data (Alonso et al. 1999), which was probably due to feeding with commercial concentrate mixtures (rich in oilseeds and grains).

3.2 Seasonal variations

All milk constituents analysed were more or less influenced by seasonal effects (caused by changes in physiological status of goats during lactation), which is

Fig. 1 Seasonal variations of physicochemical characteristics of goat's milk in Austria. Pooled milk samples of 15 individual goats (from each of the six breeds included in this study) were collected from one farm in Austria at fortnightly intervals over a period of 8 months from March to October

in good accordance with results obtained in other studies (Allgöwer and Bachmann 1990; Brendehaug and Abrahamsen 1986; Park 2006; Souci et al. 2000).

Fig. 2 Seasonal variations of physicochemical characteristics of goat's milk from six different dairy breeds in Austria. For explanations, see Fig. 1

Total solids (Fig. 1a), crude protein (Fig. 1c) and fat (Fig. 1d) contents of goat's milks showed marked seasonal variations with decreasing concentrations from onset of lactation in March, lowest values during the period from June to August and

Fig. 3 Seasonal variations of the freezing point of goat's milk from six different dairy breeds in Austria. **a** For explanations, see Fig. 1; **b** individual milk samples of all 90 goats included were taken four times during the season (May, June, July, September)

highest levels at the end of the lactation period in October. A sudden increase in the contents of these milk constituents at the end of September was obviously caused both by the end of lactation and changing the frequency of milking to once per day, which is also indicated with black arrows in Figs. 1, 2 and 3. Considerable differences could be observed between the extreme values. The contents (w/w) ranged between 2.71% and 4.90% (crude protein), 2.81% and 5.54% (fat) and 10.52% and 15.36% (total solids), respectively. Lactose (Fig. 1b), citric acid (Fig. 2d) and urea (Fig. 1e) contents showed a steady decrease from March to October, whereas the chloride (Fig. 2c) content was increasing until October continuously. Sodium (Fig. 2g) and orotic acid (Fig. 1h) contents decreased slightly from the beginning of lactation until June and increased continuously to highest values at the end of October. In contrast, potassium (Fig. 2h) content showed an increase until July, followed by a steady decrease until the end of lactation period. Calcium (Fig. 2e), magnesium (Fig. 2f) and phosphorus (Fig. 2b) contents decreased from onset of lactation reaching minimum levels in August and increased to very high values at the end of October. Changes in cholesterol levels were very similar to those of the fat content in goat's milk showing a decrease from the beginning of lactation until June and a further increase to maximum levels in October. Retinol, riboflavin (Fig. 1g) and ash (Fig. 2a) concentrations were at low levels until August, followed by an increase to very high levels towards the end of lactation. No clear trends were observed for the freezing point (Fig. 3), neither for the pooled milk samples of 15 individual goats from each of the six breeds (Fig. 3a) nor for the individual milk samples of all 90 goats included (that were taken four times during the season in May, June, July and September, respectively) (Fig. 3b).

As evident from Fig. 1c, crude protein content of goat's milk showed marked seasonal variations with decreasing concentrations from March to August and surprisingly high levels at the end of the lactation period in October, whereby the sudden increase in the protein content at the end of September was obviously caused by the natural increase at the end of lactation and by switching to just one milking per day. Thus, the extreme values (w/w) for crude protein were in the range 2.71–4.90% (average mean 3.35%) and for casein 1.56–3.56% (average mean 2.40%), respectively. Hence, a significant effect of these varying protein contents can be expected on the estimated cow's milk percentage when applying protein-based analytical techniques in adulteration control of mixed cheeses (Commission

Regulation 2001; Mayer 2005; Mayer et al. 1997). However, our results are only partly in accordance with the reference values given in reference books (Souci et al. 2000) concerning the composition of foods. The reported ranges 2.90–4.70% (w/w) for crude protein (3.69% on average) and 2.85–3.00% (w/w) for casein (2.90% on average) have been probably compiled from many studies all over the world and are obviously differing to a certain extent from results obtained in the present study. Therefore, more specific information on the recent and relevant ranges of protein content in goat's milk is needed for the accurate authentication of mixed cheeses using protein-based analytical methods (Mayer 2005; Mayer et al. 1997), and food analysts have to be aware of the possible ranges of protein contents in sheep's, goat's and cow's milks that have been originally used in manufacturing of unknown cheese samples, where milk species analysis has to be performed several months later (and under- or overestimation of cow's milk percentage has to be avoided).

4 Conclusions

With respect to the rapidly growing market for goat's milk products also in Austria, improved knowledge on the composition and nutritive value as well as on the parameters that influence the technological properties of this milk species is of great importance for the manufacture of high-quality dairy products (in particular yoghurt and cheese specialities) within the goat dairy sector. Due to the lack of relevant data on the chemical composition and physical properties of non-cow milk species in Austria, physicochemical characteristics of goat's milk from six different breeds were analysed and updated. As protein-based electrophoretic and chromatographic techniques are considerably affected by the protein content of milk used for cheese making, these results may also be of importance in authentication of goat's cheeses that have to be checked for the absence of cow's milk, or the goat's milk percentage, respectively.

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