

Differences in the composition of total and whey proteins in goat and ewe milk and their changes throughout the lactation period

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ABSTRACT: This study was conducted to evaluate changes in composition of whey proteins of Czech White Short-haired goat and East Friesian ewe milk and their comparison throughout lactation. Some differences in composition between ewe and goat milk were found. The results showed that the mean total protein (%), whey protein (g/100 g), and β -lactoglobulin (β -Lg, g/100 g) contents of goat milk were 2.75, 0.433, and 0.119 respectively and of ewe milk 6.36, 1.11, and 0.732 respectively. The contents of total protein as well as acid whey proteins in goat milk were nearly constant throughout the lactation period and fluctuated around the mean value while the contents of total protein as well as acid whey proteins in ovine milk were dependent on the period of lactation. The total protein content in ovine milk continuously increased during the lactation period. A higher content of ovine acid whey proteins was noticed at the beginning and in the final period of lactation. The average ratio of whey to total protein was $15.8 \pm 2.61\%$ in goat milk and $17.4 \pm 2.68\%$ in ewe milk and ranged from 13.0 to 20.4% in goat and from 14.0 to 20.8% in ewe milk. The total contents of two major whey proteins, α -lactalbumin and β -lactoglobulin (α -La + β -Lg = AG), averaged 87% of total whey protein, 92% in ovine milk. The main component of acid whey proteins in goat milk was α -La while in ovine milk the main component of acid whey proteins was β -Lg, however, at the end of the lactation period the content of β -Lg for both kinds of milk increased steeply, and the β -Lg/ α -La ratio reached a maximum value of 1.94 in goat milk and of 9.74 in ewe milk. In addition, goat milk contains a similar amino acid profile to ewe milk but the amino acid pattern in whey proteins differs from that in milk. Total essential amino acids were approximately 40% of the total amino acids in goat and ewe milk as well as in goat and ewe whey.

Keywords: total proteins; whey proteins; β -lactoglobulin; α -lactalbumin; amino acids; goat; ewe

Sheep and goat breeding has recently expanded in the Czech Republic, primarily on private farms with direct cheese production. Goat and ewe cheeses are a non-traditional commodity and an increasing interest in these foodstuffs is evident. The consumers consider goats and ewes ecologically bred animals and the products from them are increasingly adapted to maintain human health. The White Short-haired (WSH) goat and East Friesian ewe (EF)

are the most significant Czech breeds used for production of milk processed into goat and ewe cheeses.

The cheese quality depends closely on the composition and quality of milk. Protein contents vary widely within species, and are influenced by breed, stage of lactation, feeding, climate, parity, season, and udder health status (Park et al., 2007).

A large amount of whey is produced by the cheese-making process. Whey proteins keep even higher

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nutritive value than casein. Due to suitable composition of their amino acids, whey proteins represent one of the best-quality sources of readily available proteins. Whey is also a high-quality source of vitamins and mineral substances (Sinkiewicz and Riedel, 1990). Although whey proteins keep a high nutritive value, only a small part of them is used as human nourishment in Central Europe. One of the possibilities is žinčica, a drink made from sheep milk whey similar to kefir or sydora from goat milk whey and urda sheep whey cheese.

According to most studies, milk whey proteins account for approximately 20% of total proteins. β -lactoglobulin (β -Lg) and α -lactalbumin (α -La) are the most important whey proteins due to their high content in total whey proteins and significance for the food industry (Janovič et al., 2005). α -La and β -Lg are strongly correlated with the nutritional value and the functional properties (i.e. gelling, film-forming, foaming, and emulsifying) of whey and whey products (De Wit, 1989; Kinsella and Whitehead, 1989; Casper et al., 1999).

Goat as well as ewe wheys have a unique whey protein composition compared to bovine whey (Moatsou et al., 2005), in which β -Lg represents approximately 50% and α -La 25% (Walzem, 1999). Ewe whey is especially rich in proteins (Alichanidis and Polychroniadou, 1996; Pintado et al., 1999). The main characteristics of ewe acid whey are a high level of β -Lg and a low α -La percentage. In general, the β -Lg percentage of goat acid whey is lower compared to ewe acid whey. The β -Lg/ α -La ratio depends on the type of breed, and differences in the β -Lg/ α -La ratios could be related to different functional properties of the individual wheys (Moatsou et al., 2005). However, limited studies on the distribution of individual proteins in ewe and goat whey and the lactational variance have been published (Pintado and Malcata, 1996; Fellippe and Law, 1997; Casper et al., 1998).

The HPLC determination of whey proteins can also be used for detection of adulteration of one type of milk by another (Frutos et al., 1991; Romero et al., 1996; Ferreira and Cacote, 2003; Borková and Snášelová, 2005).

The objective of this study was to determine the changes in the amount of total protein and amount and composition of major acid whey proteins in Czech White Short-haired breed goat and East Friesian breed ewe milk throughout the lactation period. The differences in protein composition between goat and ewe milk were also observed.

MATERIAL AND METHODS

Collection of milk samples

Bulk goat's milk samples from one flock of goats of the Czech White Short-haired breed (about 400 heads) from southern Moravia were collected monthly throughout the whole lactation period (March to October). Kidding was in the course of March and April and lactation lasted for 8 months. The daily feeding ration consisted of oats haylage with the addition of pea plant (*Pisum sativum* subsp. *arvense*), grass hay, fodder barley, crushed wheat, and forage straw. The goats were watered with whey from treated milk.

Bulk sheep milk samples from one flock of ewes of East Friesian breed (about 50 heads) in their second lactation period from eastern Bohemia were collected monthly throughout the whole lactation from June to October. Kidding was in April–May and lactation lasted for 7 months. The feeding ration consisted of pasture with the addition of hay and fodder barley.

No mineral supplements containing additives, which could intentionally change the composition of milk, were fed. The samples were taken after the colostrum period.

The samples were cooled to 4°C. Concentrations of total protein were determined immediately after sample transportation to the laboratory. The portions of each sample were stored at –20°C until the whey proteins and amino acids analyses.

Compositional analysis

Concentrations of total protein (TP) were determined by near infrared absorption spectroscopy (Milco Scan 133B FOSS Electrics, FOSS, Hillerød, Denmark) calibrated monthly.

The total undenaturated acid whey proteins, α -La and β -Lg, were determined by size-exclusion chromatography (SEC) using photo diode array detector (PDA) according to IDF-Standard 162-2002. The substances eluting in retention time 8.5–12 min are considered as whey proteins. The total amount of whey proteins is expressed in concentration of β -Lg (t_r = ca. 10.8 min).

The individual amino acids in hydrolyzed samples were determined by reversed-phase high performance liquid chromatography (RP-HPLC) after precolumn derivatization using fluorescence

detection (FD) according to Waters AccQ Tag™ Method. The Method is based on a derivatizing reagent Waters AccQ Fluor™ developed specifically for amino acids analysis. Milk samples were placed in an autoclave and hydrolyzed using 6M hydrochloric acid in a laboratory dryer at 145°C for 4 h.

Tryptophan is destroyed by acid hydrolysis (McKenzie, 1970), therefore its values are not reported. Because glutamine is converted to glutamate and asparagine to aspartate during the hydrolysis, the values reported as glutamate include both glutamate and glutamine and those for aspartate include both aspartate and asparagine. Total amino acid concentration is the sum of all particular amino acids analysed. Tryptophan was not included in the amino acid concentration. The amino acid pattern of milk is defined as the amount of each particular amino acid divided by the total amount of amino acids.

All of the used chemical substances including water were either of HPLC or p.a. quality. Samples were analysed in triplicate (milk samples were taken on 3 consecutive days).

Statistical analysis

Data were statistically analysed using ANOVA (method of one-way analysis of variance by the multiple mean comparison method and probability level either 95 or 99% implemented into software program STATISTICA CZ 9 version) procedure of SAS (SAS, 2001). The studied factors were breed, month of sample collection, and type of proteins. Milk samples in triplicate were analyzed monthly and the average of each variable was used for mean comparison between the months of lactation.

Statistical evaluation of the differences between goat and ewe milk quality. The following parameters were evaluated: total protein content, total undenaturated acid whey protein content (TWP), content of β -lactoglobulin (β -Lg), sum of β -lactoglobulin and α -lactalbumin (AG), β -Lg/AG, β -Lg/TWP, and AG/TWP.

The breed was the factor, individual monthly samplings were considered as individual occurrences.

Evaluated parameters – amino acids. For the purpose of statistical evaluation (representation of amino acids in (1) total protein of goat and ewe milk, (2) total undenaturated acid whey protein of

goat and ewe milk, (3) total and whey goat protein, (4) total and whey ewe protein), four experimental data sets were created and evaluated for each amino acid separately.

Individual occurrences correspond to the representation of the amino acids in the sample in a monthly sampling (8 samples of goat milk and 5 samples of ewe milk).

Statistical evaluation of the differences in goat and ewe milk quality between the months of lactation. All the monitored parameters of goat and ewe milk were evaluated separately. The month of the sample collection was the factor. If there were significant effects of the period of lactation (month), Tukey's HSD test was used to locate significant differences between the means.

RESULTS AND DISCUSSION

Concentrations of total and acid whey proteins

The differences in contents of total protein and total acid whey protein in goat and sheep milk ($P < 0.01$) were determined.

The average total protein content in EF sheep milk ($6.36 \pm 1.81\%$) was higher than in WSH goat milk ($2.75 \pm 0.20\%$). Goat milk protein content ($2.57 \pm 0.02\%$ to $3.15 \pm 0.02\%$) was within the normal range for goat milk (Chornobai et al., 1999; Guo et al., 2001; Vilanova et al., 2008) and similar to values reported in WSH goat breed (Kuchník and Sedláčková, 2003; Ciappesconi et al., 2004). Sheep milk protein content ($4.78 \pm 0.29\%$ to $8.61 \pm 0.73\%$) was higher in comparison with milk of the other sheep breed (Bencini and Purvis, 1990; Ochoa-Cordero et al., 2007; Oravcová et al., 2007) and slightly higher than values reported in EF sheep milk (Kuchník et al., 2008). According to the literature (Aganga et al., 2002; Othmane et al., 2002; Guo et al., 2004; Soryal et al., 2005), the content of total protein in goat and sheep milk highly depended on the stage of lactation and, in addition, different types of lactation curves were observed. In the present study the total protein content in goat milk showed fluctuations around the mean value of 2.75% and total protein content in sheep milk continuously increased during the lactation period (Figure 1). The highest content ($P < 0.05$) of the total protein in goat and sheep milk was consistently observed in the final stage of lactation in

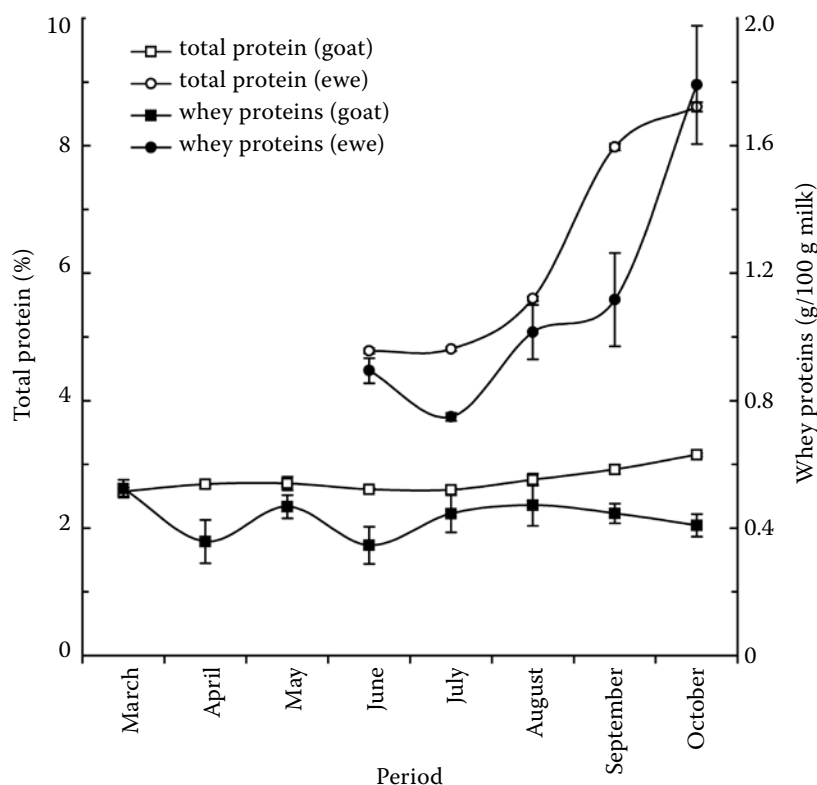


Figure 1. Changes of the total and whey proteins in the goat and ewe milk throughout the lactation period

accordance with Chornobai et al. (1999), Aganga et al. (2002), Soryal et al. (2005), and Kuchtik et al. (2008). The initial higher protein content reported by Zeng and Escobar (1996) was not recorded as the samples were taken after the colostrum period.

Progression of the total acid whey protein lactation curve is similar to that of the protein lactation curve (Figure 1). Whey proteins content in goat milk showed fluctuations around the mean value 0.433 g/100 g in the concentration range from 0.346 to 0.524 g/100 g. Total ewe acid whey protein content exhibited a descending phase in early lactation after reaching the trough (the second month of lactation) followed by an ascending phase in the concentration range from 0.749 to 1.791 g/100 g. The highest contents of whey proteins were noticed in the beginning and at the final stage of lactation. It has recently been shown that the concentration of whey component related to support of the immune system increased toward the end of lactation (Leitner et al., 2011).

The mean value of whey protein contents in total protein was $15.8 \pm 2.61\%$ in goat milk and $17.4 \pm 2.68\%$ in ewe milk, respectively. In both cases it is less than the commonly given value of 20%. The range of the determined value in WSH goat milk (13.0–20.4%) is, however, similar to the findings of Albenzio et al. (2006) in Garganica goat milk (10.3–16.7%) and the

range of the determined value (14.0–20.8%) in EF ewe milk is similar to the values (17–22%) given by Park et al. (2007) in ewe milk generally. The coefficient of variation is very similar – 15.4% in ewe milk and 16.6% in goat milk, respectively.

Concentrations of β -lactoglobulin and α -lactalbumin

Attention was paid particularly to the determination of β -Lg and α -La in ewe and goat milk (Table 1). The total content of these two major whey proteins (AG) represented on average in ewe milk $92.4 \pm 7.22\%$ and in goat milk $86.7 \pm 2.23\%$ of the total whey protein. Differences ($P < 0.05$) in the content of all monitored parameters (Table 1) with the exception of the representation of the AG/TWP between goat and ewe milk were found. It is also known that goat's whey contains minor components which, although present at low concentrations, can influence profound metabolic, immunological and physiological processes and thus contribute to some of the key advantages of goat milk in developing nutritional products (Silanikove et al., 2010). Thus, in future studies it would be interesting to follow the changes of other components of the whey fraction in different stages of lactation.

Table 1. Changes in the content of goat and ewe whey proteins throughout the lactation period

	AG (g/100 g)	β -Lg (g/100 g)	β -Lg/AG (%)	β -Lg/TWP (%)	AG/TWP (%)
Goat whey proteins					
March	0.462 \pm 0.036 ^b	0.091 \pm 0.009 ^{ab}	19.70 \pm 0.44 ^c	17.37 \pm 1.72 ^d	88.17 \pm 1.82 ^a
April	0.322 \pm 0.029 ^a	0.109 \pm 0.011 ^{ab}	33.85 \pm 0.43 ^b	30.45 \pm 3.07 ^c	89.94 \pm 1.97 ^a
May	0.404 \pm 0.036 ^{ab}	0.090 \pm 0.008 ^{ab}	22.28 \pm 0.28 ^d	19.27 \pm 1.62 ^{abd}	86.51 \pm 3.65 ^a
June	0.289 \pm 0.026 ^a	0.095 \pm 0.008 ^{ab}	32.87 \pm 0.19 ^{ab}	27.46 \pm 2.31 ^{bc}	83.53 \pm 4.94 ^a
July	0.396 \pm 0.034 ^{ab}	0.082 \pm 0.009 ^b	20.71 \pm 0.50 ^{cd}	18.43 \pm 1.50 ^{ad}	88.99 \pm 1.88 ^a
August	0.400 \pm 0.039 ^{ab}	0.127 \pm 0.011 ^a	31.75 \pm 0.30 ^a	26.91 \pm 2.33 ^{abc}	84.75 \pm 3.56 ^a
September	0.379 \pm 0.028 ^b	0.126 \pm 0.010 ^a	33.25 \pm 0.71 ^{ab}	28.25 \pm 2.25 ^{bc}	84.98 \pm 3.22 ^a
October	0.356 \pm 0.033 ^a	0.235 \pm 0.020 ^c	66.01 \pm 0.74 ^e	57.46 \pm 1.35 ^e	87.04 \pm 1.84 ^a
Mean	0.376	0.119	32.55	28.20	86.74
Median	0.387	0.102	32.31	27.18	86.78
SD	0.054	0.050	14.80	12.85	2.23
CV (%)	14.23	41.57	45.46	45.56	2.57
Ewe whey proteins					
June	0.817 \pm 0.009 ^a	0.508 \pm 0.006 ^a	62.18 \pm 0.09 ^a	56.82 \pm 0.67 ^a	91.39 \pm 0.95 ^a
July	0.715 \pm 0.008 ^b	0.489 \pm 0.004 ^a	68.39 \pm 0.29 ^b	65.29 \pm 0.56 ^b	95.46 \pm 1.01 ^b
August	0.980 \pm 0.010 ^c	0.637 \pm 0.008 ^b	65.00 \pm 0.23 ^c	62.76 \pm 0.79 ^c	96.55 \pm 0.96 ^b
September	1.10 \pm 0.015 ^d	0.721 \pm 0.005 ^c	64.55 \pm 0.66 ^c	64.54 \pm 0.40 ^{bc}	98.48 \pm 1.35 ^b
October	1.44 \pm 0.015 ^e	1.306 \pm 0.014 ^d	90.69 \pm 0.05 ^d	72.92 \pm 0.76 ^d	80.40 \pm 0.81 ^c
Mean	1.01	0.732	70.16	64.46	92.45
Median	0.98	0.637	65.00	64.54	95.46
SD	0.282	0.334	11.69	5.78	7.22
CV (%)	27.91	45.69	16.66	8.96	7.81

AG = total contents of α -La + β -Lg, α -La = α -lactalbumin, β -Lg = β -lactoglobulin, TWP = total acid whey proteins in 100 g milk, SD = standard deviation, CV = coefficient of variation

^{a–e}means within a column not followed by the same superscript differ ($P < 0.01$)

Although the content of acid whey proteins in ewe milk increased in the second half of the lactation period, the percentage of AG in ewe acid whey proteins significantly decreased ($P < 0.01$) at the end of the lactation period. The content of acid whey proteins in milk as well as the percentage of AG in acid whey proteins fluctuated around the mean value. Ewe whey contained significantly more β -Lg than did goat whey. These relationships were consistent with previous reports (Law, 1995; Pintado and Malcata, 1996; Casper et al., 1998; Pintado et al., 1999; Moatsou et al., 2005).

Concentration of β -Lg in ewe milk was always higher than that of α -La. Concentration of β -Lg in goat milk was, with the exception of the end of the lactation period, always lower than the concentra-

tion of α -La. The average β -Lg/ α -La ratio in EF ewe milk was 3.44 and ranged from 1.65 to 9.74 during the lactation period. The average β -Lg/ α -La ratio in WSH goat milk was 0.59 and ranged from 0.25 to 1.94 during the lactation period.

At the end of the lactation period the β -Lg/ α -La ratio was consistently the highest ($P < 0.01$). The average β -Lg/ α -La ratio given by Moatsou et al. (2005) for the other ewe breeds ranged from 3.91 to 6.65 and was always higher than that for the East Friesien breed. Accordingly, the β -Lg/ α -La ratio for the other goat breeds ranged from 2.02 to 3.04 and it was also always higher than that for the Czech White Short-haired breed.

The highest concentration of β -Lg in both ewe and goat milk was consistently found at the end

of the lactation period. The importance in the increased content of β -Lg relates to the fact that it is a major protein in the whey of ruminant milk and may play important roles in the binding and transport of hydrophobic ligands such as retinoids, alkenes, and fatty acids. Moreover it is an important source of amino acids for the offspring (Kontopidis et al., 2004). The changes in concentration of individual whey proteins as well as in total whey protein content during the lactation period have not been sufficiently described yet. Seasonal variations were observed by Law and Brown (1994) in goat milk and by Casper et al. (1998) in individual ewe whey protein from Manchego-type cheese and goat whey from

Cheddar-type cheese but there was no significant change in whey from Chevre cheese. According to Casper et al. (1998) relative amounts of α -La decreased only with a slight drift among the obtained values throughout the season, but β -Lg rose in the middle phase of lactation and then gradually decreased toward the end of lactation in ewe whey from Manchego-type cheese while relative amounts of α -La fluently decreased and those of β -Lg increased in acid whey goat protein from Cheddar-type cheese. Pintado and Malcata (1996) reported similar trends in goat whey proteins and identified a decrease in total whey protein as the animals changed the stored feed diet for pasture in the middle of lactation.

Table 2. Amino acids composition of total and whey protein

Amino acid ¹	Total protein		Whey protein		Relation WP/TP	
	goat milk	ewe milk	goat milk	ewe milk	goat milk	ewe milk
Aspartate ²	7.70 \pm 0.33 ^{B,a}	7.01 \pm 0.23 ^{A,c}	10.77 \pm 1.03 ^{C,b}	9.96 \pm 0.83 ^{C,d}	1.40	1.42
Serine	3.12 \pm 0.06 ^{B,a}	2.68 \pm 0.06 ^{A,c}	4.47 \pm 0.80 ^{C,b}	4.88 \pm 0.35 ^{C,d}	1.43	1.82
Glutamate ³	20.75 \pm 0.36 ^{B,b}	17.5 \pm 0.41 ^{A,d}	15.06 \pm 1.25 ^{C,a}	13.28 \pm 1.17 ^{C,c}	0.73	0.76
Glycine	1.93 \pm 0.06 ^{A,a}	2.04 \pm 0.04 ^{B,c}	5.47 \pm 1.16 ^{C,b}	5.91 \pm 0.40 ^{C,d}	2.83	2.90
Histidine	2.79 \pm 0.05 ^{A,b}	2.84 \pm 0.03 ^{A,d}	1.94 \pm 0.23 ^{C,a}	1.69 \pm 0.09 ^{C,c}	0.70	0.60
Arginine	3.76 \pm 0.23 ^{A,a}	3.75 \pm 0.15 ^{A,d}	3.61 \pm 0.25 ^{D,a}	2.93 \pm 0.37 ^{C,c}	0.96	0.78
Threonine*	3.79 \pm 0.38 ^{A,a}	3.42 \pm 0.05 ^{A,c}	5.62 \pm 0.87 ^{C,b}	5.58 \pm 0.35 ^{C,d}	1.48	1.63
Alanine	3.31 \pm 0.20 ^{A,a}	3.62 \pm 0.04 ^{B,c}	9.11 \pm 1.51 ^{C,b}	9.45 \pm 0.74 ^{C,d}	2.75	2.61
Proline	10.18 \pm 0.73 ^{A,b}	10.2 \pm 0.11 ^{A,d}	7.56 \pm 0.98 ^{D,a}	6.11 \pm 0.61 ^{C,c}	0.74	0.60
Cysteine	2.47 \pm 0.61 ^{A,a}	4.23 \pm 0.20 ^{B,d}	3.43 \pm 0.82 ^{C,b}	2.70 \pm 0.34 ^{C,c}	1.39	0.64
Tyrosine	3.41 \pm 0.48 ^{A,a}	3.92 \pm 0.17 ^{A,d}	2.33 \pm 0.99 ^{C,b}	2.38 \pm 0.89 ^{C,c}	0.68	0.61
Valine*	7.19 \pm 0.57 ^{A,a}	7.07 \pm 0.05 ^{A,c}	6.93 \pm 0.73 ^{C,a}	6.70 \pm 0.48 ^{C,c}	0.96	0.95
Methionine*	2.14 \pm 0.28 ^{A,b}	3.30 \pm 0.45 ^{B,d}	0.22 \pm 0.11 ^{C,a}	0.21 \pm 0.03 ^{C,c}	0.10	0.06
Lysin*	7.44 \pm 0.28 ^{A,a}	8.09 \pm 0.09 ^{A,c}	8.73 \pm 0.75 ^{C,a}	7.89 \pm 0.50 ^{C,c}	1.17	0.98
Isoleucine*	5.52 \pm 0.32 ^{A,a}	5.53 \pm 0.07 ^{A,c}	6.26 \pm 0.48 ^{C,b}	5.75 \pm 0.43 ^{C,c}	1.13	1.04
Leucine*	9.79 \pm 0.07 ^{A,a}	9.94 \pm 0.24 ^{A,c}	9.60 \pm 1.17 ^{C,a}	9.28 \pm 0.71 ^{C,c}	0.98	0.93
Phenylalanine*	4.68 \pm 0.06 ^{A,a}	4.83 \pm 0.13 ^{A,d}	2.44 \pm 0.36 ^{C,a}	2.21 \pm 0.12 ^{C,c}	0.52	0.46
TEAA ⁴ (%)	40.55 \pm 0.72 ^{A,a}	42.18 \pm 0.72 ^{B,d}	39.80 \pm 4.34 ^{C,b}	37.61 \pm 3.07 ^{C,c}	0.98	0.89

¹values (in %) are means calculated from the content of each particular amino acid (in g) divided by the total amino acid content (in g) excluding tryptophan

²aspartate includes both aspartate and asparagine

³glutamate includes both glutamate and glutamine

⁴TEAA = total essential amino acids

*essential amino acids

^{abcd}ABCD means within a line not followed by the same superscript differ ($P < 0.05$)

^{abcd}related to differences of particular amino acid in the same type of proteins in goat and ewe milk

^{ABCD}related to differences of particular amino acid in the same type of milk in total and whey proteins

Amino acid composition of total and whey proteins

Amino acids are vital nutrients for growth and maintenance of health in humans. Very few data are available on the amino acid composition of goat and sheep milk. Amino acids pattern in milk protein changes only within the frame of experimental error during the lactation period, therefore average amino acids pattern in goat (WSH breed) and sheep (EF breed) milk is given in Table 2. In accordance with findings of Davis et al. (1994) and Hejtmánková et al. (2004), goat milk amino acid profile is similar to that of ewe and also cow milk. Of the total amino acids present, the most abundant were glutamate (plus glutamine, ca. 20%), proline (ca. 10%), and leucine (ca. 10%). Total essential amino acids made approximately 40% of the total amino acids in goat and sheep milk.

The greatest difference in abundance of individual amino acids between goat and ewe milk was determined in the content of sulfur amino acids (cysteine and methionine) in accordance with Davis et al. (1994). The abundance of both these amino acids was accordingly higher in ewe milk. On the contrary, the smallest differences in abundance of individual amino acids in goat and ewe milk were in the content of arginine, proline, and isoleucine.

According to Velíšek and Hajšlová (2009), the abundance of cysteine in goat, ewe, and also human milk is very similar and always higher than in cow milk (in goat milk up to twice), however cow milk contains more methionine.

On the contrary, according to Rutherford et al. (2008) as well as Davis et al. (1994), the abundance of cysteine in goat and ewe milk is approximately half in comparison with human milk. According to the above-mentioned authors, total sulfur amino acids in milk do not differ between the species (except for rat and cat milk rich in total sulfur amino acids), but the given absolute values differ. In this study, for goat milk of WSH breed in comparison with data given by Davis et al. (1994), Rutherford et al. (2008), and Velíšek and Hajšlová (2009) for goat milk in general, higher contents of cysteine and equivalent contents of methionine and therefore total sulfur amino acids content in goat milk were clearly higher and got near the value for rat milk given by Davis et al. (1994). Total sulfur amino acids contents in sheep milk (EF breed) were still higher. Further research and more data are needed for determination and validation of the real pattern of sulfur amino acids in milk.

The amino acids pattern in whey proteins (Table 2) differs from that in milk, but total essential amino acids are approximately the same and their abundance is only slightly lower. No significant ($P < 0.05$) differences between amino acids composition of goat and sheep whey have been observed with the exception of arginine and proline. The most abundant amino acid continues to be glutamate (plus glutamine, ca. 14%), followed by alanine (ca. 9%), and leucine (ca. 9%). The greatest changes in the abundance of the individual amino acids were observed for methionine, glycine, and alanine. As the abundance of methionine decreased, the abundance of alanine and glycine increased. In comparison with milk, the abundance of lysine, isoleucine, leucine, valine, and arginine were practically invariable. Corresponding analyses are still not available in the scientific literature.

CONCLUSION

Some differences in composition between ewe and goat milk were found. The average total protein content as well as acid whey content in ewe milk is higher than in goat milk. Total protein content and acid whey content in sheep milk continuously increased during the lactation period, while goat milk protein and whey protein contents varied according to the period of lactation in goats. The amino acid profile of goat milk is similar to that of ewe milk but amino acids pattern in whey proteins differs from that in milk. Total essential amino acids were approximately 40% of the total amino acids in goat and ewe milk as well as in goat and ewe whey. The main component of ewe acid whey proteins was always β -lactoglobulin while the main component of goat acid whey proteins was α -lactalbumin, but at the end of the lactation period the content of β -lactoglobulin increased steeply and the β -Lg/ α -La ratio reached a maximum value of 1.94 in goat milk and 9.74 in ewe milk respectively. These variations in whey proteins throughout the lactation period could affect the products manufactured from goat and ewe milk whey. Further research and more data are still needed for determination and validation of the true relation.

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