# Changes in the composition of goat colostrum and milk fatty acids during the first month of lactation

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**ABSTRACT**: Changes in the composition of colostrum and milk fatty acids during the first month of lactation of ten 3-years-old White Shorthaired goats fed a winter diet were investigated. Thirty-eight fatty acids (FAs) were identified in the milk fat. Saturated FAs accounted for 67.0% of the total determined FAs in colostrum and 62% at 30 days post partum. Monounsaturated FAs made up 28.2% of the total FAs in colostrum and increased with the progress of lactation at the expense of saturated FAs. The percentage of polyunsaturated FAs varied from 4.4 to 4.8%. The major FAs in colostrum and milk were palmitic and oleic acids, followed by stearic and myristic acids (30.1, 25.3, 11.8, 11.4% and 23.6, 30.3, 13.6, 8.6% in colostrum and milk 30 days post partum, respectively). The levels of palmitic and myristic acids in colostrum were higher than in mature milk, whereas the levels of capric, stearic and oleic acids were lower. The medium-chain FA (caprylic, capric, lauric) content increased from 8.7% of FAs in colostrum to 11.1% on the fourth day of lactation. These acids are efficient antimicrobials, thus may contribute to the protection of young goats from microbial pathogens.

**Keywords**: goat; colostrum; milk; composition; fatty acids; serum

The initial nutrient supply for newborn goats is provided by colostrum, which is the first secretion from the mammary gland after parturition. Colostrum changes with time to become mature milk. There exist numerous studies on the composition of goat colostrum (e.g. Attaie et al., 1993; Hadjipanayiotou, 1995; Kráčmar et al., 1999, 2002; Argüello et al., 2006; Yang et al., 2009) and goat milk (e.g. Chilliard, 1997; Czauderna et al., 2010; Tudisco et al., 2010). Less information, however, is available on changes in the composition of goat milk during the transition from colostrum to mature milk in the first weeks after delivery. Argüello et al. (2006) observed that the protein, immunoglobulin, and fat concentrations in colostrum were high on the first day after parturition and then gradually lowered, whereas the low lactose content in colostrum milk was increasing from the second day after parturition. To our knowledge, no detailed information on the fatty acid (FA) composition of goat colostrum, transition milk and mature milk is available. Gajdůšek et al. (1993) analysed only the most important FA from day 1 to day 255 of lactation. Yang et al. (2009) focused on a short period (3–168 h) after delivery. In contrast, Pavlíková et al. (2010) presented changes in the contents of 70 FAs from day 1 to day 60 of lactation in sheep. For this reason, the objective of the present experiment was to investigate changes in the composition of milk and in the fatty acid profile of milk fat during the

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transition from colostrum to mature milk in goats receiving a winter diet. The metabolic profiles of dams were also evaluated.

Goat milk is richer than cow milk in caproic, caprylic and capric acids (Chilliard, 1997), i.e. in FAs with 6, 8, and 10 carbon atoms, respectively. The names of the acids are derived from the Latin word "capric" which pertains to goats. Saturated fatty acids with 8 to 12 carbon atoms (medium-chain fatty acids, MCFAs) are efficient antimicrobials (Desbois and Smith, 2010). As young goats in the transitional period are vulnerable to infections, attention was paid to changes of MCFAs concentration in milk.

## MATERIAL AND METHODS

### Animals and diets

A total of 10 clinically healthy 3-years-old pregnant White Shorthaired goats (dairy goats widespread in the Czech Republic) were studied. The goats were housed at the Ruminant Clinic of the University of Veterinary and Pharmaceutical Science. All of the goats were fed meadow hay *ad libitum* and 350 g of granules per goat twice a day and had constant access to drinking water. After parturition, the kids stayed with their mothers for 69 days. The amount of feed was increased after parturition and it was divided into 3 portions per day. In addition to pelleted feed (600 g per goat), each animal received 450 g of barley groats daily.

### Sampling and analyses

Colostrum and milk samples from the 10 goats were collected at the beginning of lactation and 1, 2, 3, 4, 5, 6, 10, 20, and 30 days post partum. The content of dry matter was measured gravimetrically by oven drying at 102°C to constant weight, and milk fat was measured by the FT-NIR technique using a Nicolet Antaris Near-IR Analyser Spectrometer (Thermo Electron Scientific, Madison, USA). The titratable acidity was assayed using the Soxhlet-Henkel procedure (CTS 570530, 1972). The fat of milk samples taken 0, 1, 2, 5, 10, and 30 days post partum was extracted with diethyl ether:petrol ether (1:1) according to standard ISO 1211 (2001). Alkaline trans-methylation of extracted fatty acids was carried out according to standard ISO 5509 (1994). For gas chromatography analysis of methyl esters a HP 6890 gas chromatograph (Agilent Technologies, Inc., Santa Clara, USA) with a programmed 60 m DB-23 capillary column (J&W Scientific, Folsom, USA) was applied. Fatty acids were identified on the basis of retention times by comparison to the retention times of standards. The standards PUFA 1, PUFA 2, PUFA 3 and

Table 1. Contents of fat and fat-free solids and acidity of colostrum and milk of the 10 goats over a period of 30 days after parturition

| Days after parturition | Fat (%) | Fat-free solids (%) | Acidity (°SH) |
|---|---|---|---|
| 0 | 5.67* | 16.03* | 8.85* |
| 1 | 4.11 | 13.24 | 7.08 |
| 2 | 4.48 | 14.40 | 8.83 |
| 3 | 3.49 | 13.04 | 8.36 |
| 4 | 3.99 | 13.05 | 7.97 |
| 5 | 3.78 | 12.40 | 7.34 |
| 6 | 4.51 | 13.28 | 7.62 |
| 10 | 3.77 | 12.45 | 6.81 |
| 20 | 3.87 | 12.93 | 7.56 |
| 30 | 3.48 | 11.20 | 6.05 |
| RMSE | 0.17 | 2.58 | 2.02 |

RMSE = residual mean square error, *significantly different from mature milk sampled 30 days after parturition

Table 2. Fatty acid composition (g/100 g fatty acids) in colostrum fat and milk fat of the 10 goats over a period of 30 days after parturition

| | | Days after parturition | | | | | | RMSE |
|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 5 | 10 | 30 | |
| **Saturated fatty acids** (SFAs) | | | | | | | | |
| Butyric | C 4:0 | 1.24* | 1.49 | 1.54 | 1.71 | 1.67 | 1.78 | 0.25 |
| Caproic | C 6:0 | 1.12* | 1.53 | 1.58 | 1.70 | 1.57 | 1.73 | 0.19 |
| Caprylic | C 8:0 | 1.26* | 1.80 | 1.84 | 1.94 | 1.70 | 1.91 | 0.26 |
| Capric | C10:0 | 4.82* | 5.92 | 5.92 | 5.96 | 5.12 | 5.50 | 0.74 |
| Undecanoic | C11:0 | 0.05 | 0.07 | 0.07 | 0.07 | 0.06 | 0.04 | 0.01 |
| Lauric | C12:0 | 2.67 | 2.84 | 2.73 | 2.85 | 2.53 | 2.79 | 0.48 |
| Tridecanoic | C13:0 | 0.08 | 0.08 | 0.09 | 0.08 | 0.08 | 0.07 | 0.01 |
| Myristic | C14:0 | 11.39* | 10.72 | 9.82 | 8.64 | 8.33 | 8.64 | 1.03 |
| Pentadecanoic | C15:0 | 0.92* | 0.83 | 0.81 | 0.81 | 0.81 | 0.82 | 0.13 |
| Palmitic | C16:0 | 30.14* | 28.17 | 26.62 | 24.79 | 24.13 | 23.64 | 1.05 |
| Margaric | C17:0 | 1.02 | 1.07 | 1.15 | 1.28 | 1.28 | 1.20 | 0.18 |
| Stearic | C18:0 | 11.83* | 11.28 | 12.40 | 14.23 | 14.72 | 13.57 | 1.28 |
| Arachidic | C20:0 | 0.30* | 0.23 | 0.22 | 0.22 | 0.23 | 0.23 | 0.04 |
| Henecosanoic | C21:0 | 0.07 | 0.05 | 0.04 | 0.04 | 0.05 | 0.06 | 0.02 |
| Behenic | C22:0 | 0.13* | 0.14 | 0.12 | 0.11 | 0.10 | 0.08 | 0.03 |
| Tricosanoic | C23:0 | 0.06 | 0.05 | 0.03 | 0.04 | 0.06 | 0.04 | 0.02 |
| Lignoceric | C24:0 | 0.06 | 0.04 | 0.03 | 0.03 | 0.04 | 0.04 | 0.02 |
| **Monounsaturated fatty acids** (MUFAs) | | | | | | | | |
| Myristoleic | C14:1 | 0.17 | 0.15 | 0.14 | 0.10 | 0.09 | 0.12 | 0.04 |
| Palmitoleic | C16:1 | 0.86 | 0.87 | 0.88 | 0.83 | 0.77 | 0.72 | 0.12 |
| Oleic | C18:1 c9 | 25.33* | 26.63 | 27.66 | 28.34 | 30.37 | 30.27 | 1.46 |
| | C18:1 c7 | 0.53 | 0.51 | 0.56 | 0.57 | 0.60 | 0.55 | 0.07 |
| Elaidic | C18:1 t9 | 0.40 | 0.38 | 0.41 | 0.39 | 0.39 | 0.40 | 0.05 |
| Vaccenic | C18:1 t11 | 0.66* | 0.58 | 0.66 | 0.63 | 0.68 | 0.82 | 0.13 |
| Eicosenoic | C20:1 n9 | 0.15 | 0.13 | 0.12 | 0.16 | 0.14 | 0.12 | 0.04 |
| Nervonic | C24:1 n9 | 0.06 | 0.06 | 0.05 | 0.02 | 0.04 | 0.04 | 0.02 |
| **Polyunsaturated fatty acids** (PUFAs) | | | | | | | | |
| Linoleic | C18:2 n6 | 2.88 | 2.65 | 2.70 | 2.74 | 2.76 | 2.94 | 0.29 |
| Linolelaidic | C18:2 n6 | 0.17 | 0.15 | 0.17 | 0.17 | 0.17 | 0.18 | 0.03 |
| CLA | C18:2 c9 t11 | 0.28* | 0.29 | 0.35 | 0.28 | 0.28 | 0.45 | 0.09 |
| | C18:2 t10 c12 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.00 |
| α-Linolenic | C18:3 n3 | 0.71 | 0.70 | 0.74 | 0.77 | 0.75 | 0.80 | 0.18 |
| γ-Linolenic | C18:3 n6 | 0.05 | 0.07 | 0.07 | 0.09 | 0.08 | 0.07 | 0.02 |
| Eicosadienic | C20:2 n6 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 |
| Eicosatrienoic | C20:3 n3 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.00 |
| | C20:3 n6 | 0.05 | 0.03 | 0.03 | 0.03 | 0.02 | 0.03 | 0.02 |
| Arachidonic | C20:4 n3 | 0.09 | 0.08 | 0.06 | 0.05 | 0.06 | 0.07 | 0.03 |
| | C20:4 n6 | 0.32* | 0.31 | 0.30 | 0.25 | 0.22 | 0.19 | 0.05 |
| EPA | C20:5 n3 | 0.03 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.01 |
| Clupadonic | C22:5 n3 | 0.03 | 0.02 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 |

RMSE = residual mean square error, *significantly different from mature milk sampled 30 days after parturition

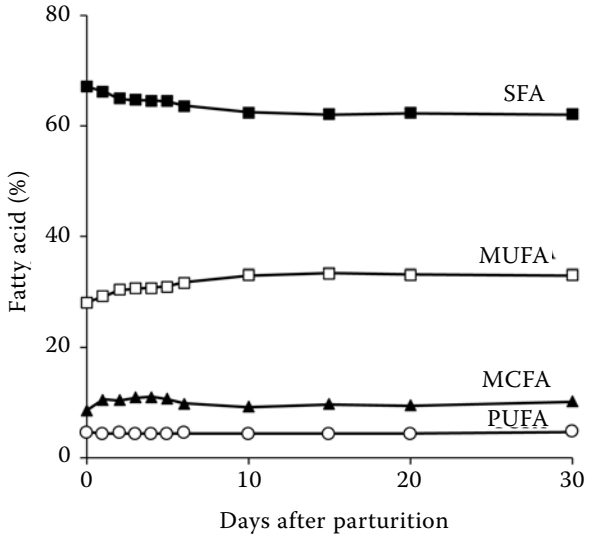


Figure 1. Content of saturated fatty acids (■ SFA), monounsaturated fatty acids (□ MUFA), medium-chain fatty acids (▲ MCFA), and polyunsaturated fatty acids (○ PUFA) in colostrum fat and milk fat of goats during 30 days following parturition (g/100 g fatty acids)

37 Component FAME Mix (Supelco, Bellefonte, USA) were used.

To obtain the serum, blood samples were taken from all the goats by jugular venipuncture on the days 0 (partum), 2, 7, 14, 21, and 28 after delivery. Total protein in the serum was determined using a Cobas Mira S access analyser (Roche Diagnostics, Rotkreuz, Switzerland), urea concentration was determined using a commercial kit Urea UV Kin (Erba Lachema Ltd., Brno, Czech Republic), and the level of β-hydroxybutyrate (BHB) was measured with Ranbut kit (Randox Laboratories, Crumlin, UK). Total immunoglobulins were assayed by the zinc sulphate method, and the results were expressed in units of zinc sulphate turbidity (McEwan et al., 1970).

The data were statistically analysed using the General Linear Models procedure of SAS (SAS Institute Inc, 2001).

## RESULTS AND DISCUSSION

The colostrum of goats contained a high content of total solids (217 g/l) and it was composed of 26.1% of fat and 73.9% of fat-free solids (Table 1). In the course of the 30-day experimental period, the contents of fat and fat-free solids decreased. The colostrum acidity (8.85°SH) decreased on the first day after parturition, then temporarily increased and finally decreased again to 6.05°SH at 30 days post partum. Thirty-eight FAs were identified in the milk fat. Saturated FAs made up 67.0% of the total determined FAs in colostrum and 62.1% at 30 days post partum (Figure 1). The percentage of monounsaturated FAs increased with the progress of lactation, at the expense of saturated Fas, from 28.2% in colostrum to 33.0% at 30 days post partum. The percentage of polyunsaturated FAs varied from 4.4 to 4.8%. Relatively low concentration of polyunsaturated FAs, which is typical of milk fat of ruminants, may be increased by supplements of plant oils or oilseeds as shown in lactating ewes fed diets supplemented with rapeseed or linseed oil (Cieslak et al., 2010). Medium-chain FAs (caprylic, capric and lauric) made up 8.7% of the FAs in the colostrum and increased to 11.1% on the fourth day of lactation. The detailed FA profiles of colostrum and milk are shown in Table 2. The major FAs in

Table 3. Development of protein, urea, immunoglobulins (IgG) and β-hydroxybutyrate (BHB) concentrations in the serum of the goats during the 4 weeks after parturition

| Days after parturition | Total protein (g/l) | Urea (mmol/l) | IgG (ZST units) | BHB (mmol/l) |
|---|---|---|---|---|
| 0 | 61.7* | 5.53 | 13.7* | 0.38* |
| 2 | 64.2 | 5.16 | 16.5 | 0.41 |
| 7 | 69.1 | 4.84 | 19.9 | 0.62 |
| 14 | 70.2 | 6.77 | 23.4 | 0.97 |
| 21 | 71.5 | 5.92 | 24.9 | 0.91 |
| 28 | 73.9 | 6.39 | 24.7 | 0.95 |
| RMSE | 4.3 | 1.58 | 4.5 | 0.41 |

RMSE = residual mean square error, *significantly different from serum sampled at 28 days after parturition ($P$ <0.05)

colostrum and milk were palmitic and oleic acids, followed by stearic and myristic acids. The contents of palmitic and myristic acids in colostrum were higher than in mature milk, whereas the contents of stearic and oleic acids were lower.

Table 3 presents the concentrations of protein, urea, BHB and immunoglobulins in the serum of goats during the four weeks after parturition. There was no effect of time on the urea concentration; however, the concentrations of serum protein, BHB and immunoglobulins progressively increased after parturition.

The decreases in the levels of colostrum fat and fat-free solids after parturition were similar to those observed in goats by Kráčmar et al. (2002). The postpartum decrease in colostrum and milk acidity is consistent with the increase in pH observed by Kráčmar et al. (2002) and Argüello et al. (2006), and with the decrease in the acidity of transition milk reported by Vilar et al. (2008).

Few authors have investigated the post-parturition changes in the FA composition of goat colostrum and milk. In the present study, 38 FAs were assayed in colostrum and milk fat during 30 days after parturition. Time-dependent changes in the myristic, palmitic and stearic acid contents in the colostrum and milk fat are consistent with those observed in sheep (Pavlíková et al., 2010). The oleic acid level, however, increased over time, whereas in the experiment carried out by Pavlíková et al. (2010), the oleic acid level decreased. It is worth noting that there was a high content of MCFAs (caprylic, capric and lauric acids) in the fat of colostrum and transition milk; the level of MCFAs increased from 8.7 g/100 g FA determined on the day 0 to 11.1 g/100 g FA four days after parturition. MCFAs dissipate the electrochemical proton gradient and deplete the energy reserves of bacterial cells (Hassinen et al., 1951; Nieman, 1954). In rabbits, MCFAs represent more than one-third of the FAs in milk and protect the offspring against infection (Skřivanová et al., 2009). The role of MCFAs in goats may be similar but less pronounced due to the lower concentration of MCFAs in the milk fat.

A significant effect of time on the serum concentrations of protein, immunoglobulins and BHB was noted. The concentrations of protein and urea were similar to those observed in the plasma of Red Syrian goats fed diets designed to cover 80% and 140% of the energy requirement (Celi et al., 2008). In goats fed the latter diet, plasma BHB concentrations were approx. 0.4 mmol/l, and in goats fed the former diet, they were approx. 0.8 mmol/l. In the present experiment, serum concentrations of BHB increased over time from 0.38 to 0.95 mmol/l, which indicates that the goats were mobilising their fat reserves.

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