Chemical composition and fatty acid profile of Carpathian goat milk as related to the stage of lactation

Andreea Anghel[1,2], Dorina Nadolu[1], Angela Sava[3], Ana Cismileanu[3], Mariana Ropota[3] I. Voicu[3]

1 ANCC Caprirom; 2 Ovidius University Constanta; 3 INCDBNA Balotesti

SUMMARY

The aim of this study was to evaluate the variation of milk production, biochemical composition and milk fatty acid profile according to the lactation stage, on 60 multiparous goats of the Carpathian breed, grown in an extensive system (Dobrogea, southern Romania). The goats were milked twice a day for 8 months, (February to September). Milk yield was recorded monthly and milk samples representative of the two daily milking were analysed for: protein, fat and lactose contents. In addition, fatty acid methyl esters were quantified using a gas chromatograph. The maximum amount of milking milk was recorded at the end of April (1635.23 ± 0.048 g milk/ animal / day) and the smallest milk production was recorded in September (823.14 ± 0.191 g milk / goat / day). The biochemical composition of milk has varied considerably during lactation: in the first and last part of the lactation there was an insignificant increased concentration of its components (fat, protein, lactose, minerals). Monounsaturated and polyunsaturated acids levels increased during the summer months compared to spring months and the saturated fatty acid level decreased during the summer months. The percentage of polyunsaturated fatty acids recorded the highest value in August (6.16 mean gFAME / 100g Total FAME), and the lowest value was at the beginning of lactation (4.51 mean gFAME / 100g Total FAME). The data recorded in our study show an increase in CLA (conjugated linolenic acid) concentration by April (0.85 mean gFAME / 100g Total FAME), when it reaches a maximum, it remains at an increased value until July, followed by an insignificant decrease (0.54 mean gFAME / 100g Total FAME) towards the end of the lactation. A ratio of ω6 / ω3 fatty acids decreased in April under 4, the decrease of this ratio being significant compared to the first 2 months of lactation ($p < 0,05$).

Keywords: goat milk, chemical composition, fatty acids, lactation stage

INTRODUCTION

Goat rearing in Romania intensified lately, first of all due to the favourable conditions from our country and, second, due to the increased acknowledgement by the consumers of the quality of goat milk and meat. The advantage of goat rearing also comes from the large areas cultivated with crops whose residues are important feed sources for goats (crop residues, chaff, baking residues, etc.) and large areas covered with vegetation specific to an efficient feeding of goats (over 400,000 hectares with shrub vegetation). The specificity and feeding behaviour of the goats induce a different chemical composition of the goat milk than of sheep and cow milk. The chemical composition of the milk is also conditioned by the breed, individual animal, area, age, level and nature of feeding, stage of lactation, season, duration of milking and health state (Morand-Fehr et al, 2004, 2007).

The large amount of medium chain fatty acids, characteristic to goat milk, has many benefits to human health. The evidences show that specific types of feeds, particularly the leguminous plants, can influence significantly the fatty acids composition and bioactive lipids of ruminant milk (Shingfield at al., 2008). The additional advantages to consumer health of the goat milk lipids, can be assigned to the selective feeding behaviour of the goats and to the interaction between the dietary components and the digestive system (Chilliard and Ferlay, 2004; Shinfield et al., 2008).

In Romania, over 90% of the stock of goats is reared in the extensive and semi-intensive systems. The trees, shrubs and some species of herbs are very important sources of feeds for these ruminant animals. Most wild plants are dicotyledonous, with small amounts (up to 50% DM) of polyphenols, many of them being tannins. Unlike the cattle and sheep, which select predominantly plant leaves in spring, the goats feed all year long on the spontaneous pasture flora, which accounts for 50-80% of their feed. This behaviour is a specific adaptive mechanism of the goats, which maintain an increased intake of pasture plants by their higher capacity to use and convert tannins-high feeds.

The aim of this study was to evaluate the variation of milk production, biochemical composition and milk fatty acid profile according to the lactation stage, on 60 multiparous goats of the Carpathian breed, grown in an extensive system (Dobrogea, southern Romania).

MATERIAL AND METHODS

A group of 60, Carpathian goats, at their second lambing, was formed after the finish of the lambing period, in early February 2016. During the first 45 days after lambing (in February and March) the goats were not milked, all their milk going to the kids. The milk yield during the suckling

period was estimated by the bodyweight gain of the kids. After their kids were weaned, the goats were milked twice daily, for 6 months, period when milk samples were collected twice monthly for analysis. A Funke Gerber Lactostar analyser standardised for goat milk was used to determine the following biochemical parameters: fat, proteins, lactose, non-fat dry matter and minerals. We also determined the milk fatty acids profile, as fatty acids methyl esters (FAME) by gas chromatography (Ropota, 2014).

The goats were taken out to pasture as of April 2016, where they had free access (09:00-17:00 hrs) to a permanent pasture with 30% leguminous and 70% gramineous. Samples of alfalfa hay, corn silage, corn and barley grains and of pasture plants were collected. The chemical composition of these feeds was evaluated by the commonly accepted methods [EC 152/2009 Regulation]: dry matter (DM), crude protein (CP), crude fibre (CF), ether extractives (EE), ash. On the basis of the analytical chemical results we calculated the feeding potential of the feeds (milk feed unit, FUmilk), the intestinally digestible protein allowed by the nitrogen content (IDPN) and intestinally digestible protein allowed by the energy content (IDPE), the calcium and phosphorus contents.

Based on the feeding values of the dietary components, we formulated the diets for the Carpathian female goats according to their weight and milk yield. During the nursing period, the diets consisted of 1.2 kg alfalfa hay, 1.6 kg corn silage and 0.65 kg concentrate mixture (corn and barley grains). After the kids were weaned, throughout the lactation period, the goats received the same supply of 8 kg pasture/goat/day, 0.2 kg alfalfa hay and 0.315 kg corn and barley grains. At the beginning of the feeding trial, the goats had an average body weight of 44.75 kg. Both during the nursing period, and during the milking period, the dietary forages provided goats requirement of dry matter, feed units, intestinally digestible protein, minerals and trace elements, according to the physiological norms for their particular body weight (Burlacu, 2002).

RESULTS AND DISCUSSION

In goats, reproduction is seasonal. Therefore, the stage of lactation is closely related to the reproduction season. Generally, lactation starts in the early months of the year, when the animals are kept indoors, fed on stored feeds. After they are taken out to graze, the milk yield increases, only to decrease towards the end of lactation (autumn) (Taftă, 2002). Table 3 shows data on the milk yield of Carpathian female goats. The average milk yield varied between 800 and 1600 g/goat/day. During the first month of lactation the average milk yield, calculated from the daily weight gain of the kids, was 1260 g milk/goat/day. The experimental data show that the highest milk yield was recorded in end April (1635 g milk/goat/day), while

the lowest milk yield was in September (823 g milk/goat/day). Similar results for the lactation curve of the Carpathian goats were reported by Pascal (2015).

Table 3. Variation of the milk yield (g) and milk composition (%) throughout lactation in Carpathian female goats (mean± standard deviation)

Stage of lactation	Amount (g)	Fat (g%)	Protein, (g%)	Lactose, (g%)	Non-fat dry matter (g%)	Minerals, (g%)
February	1260.00±0.066	4.89±0.2138	3.96±0.1969	5.71±0.2885	11.02±0.527	0.89±0.0376
March	1500.65±0.025	4.35±0.361	3.49±0.5327	5.63±0.7678	10.78±1.4125	0.88±0.0573
April	1635.23±0.048	3.21±0.133	2.59±0.1593	5.21±0.2289	9.23±0.4223	0.53±0.0186
May	1560.36±0.069	3.36±0.9621	2.62±0.2034	4.58±0.2838	8.37±0.5295	0.66±0.1005
June	1420.84±0.120	3.47±0.3984	3.28±0.2173	4.41±0.3027	8.71±0.5639	0.74±0.0368
July	1250.32±0.096	3.75±0.1166	3.32±0.0885	4.62±0.1273	9.01±0.2366	0.81±0.0123
August	1100.22±0.067	4.88±0.4911	3.88±0.6136	4.68±0.8767	9.22±0.6195	0.65±0.1103
September	823.14±0.191	4.97±0.0572	3.92±0.0302	4.71±0.0423	9.87±0.0835	0.49±0.0121

In terms of the chemical composition of the milk, the concentration of the different constituents is conditioned, mainly, by the individual animal and by the month of lactation, but also by the breed and age, frequency and length of milking (Pascal, 2015). Goat milk fat is one of the most important technological, nutritional and dietetic parameters. In our experiment, the concentration of lipids was higher immediately after lambing (4.89% in February), it decreased in April-June (a low of 3.21% in April), increasing again towards the end of lactation, with a peak of 4.97% in September. This is due to two phenomena: an effect of dilution, because of the higher volume of milk up to the peak of lactation, and an effect if lower mobilisation of the lipids, which decreases the plasma level of non-esterified fatty acids, particularly C18:0 and C18:1, necessary for lipid synthesis in the mammary gland (Chilliard, 2003).

Our studies revealed an average milk protein concentration of 3.4%, with a range of 2.59 to 3.96%. The highest milk protein concentration was noticed in the beginning of lactation (3.96%). In April-May it hits a low of 2.59% (April), increasing towards the end of lactation, with a high of 3.93% in September. These results are in agreement with the average values reported for milk protein concentration in Carpathian goats, of 3.2% (Pascal, 2015).

Lactose is the main carbohydrate from milk, being synthesised in the mammary gland from glucose and galactose. It is an important nutrient because it favours the intestinal absorption of calcium, magnesium, phosphorus and the use of vitamin D. it is also particularly important for the maintenance of the osmotic balance between the blood flow and the alveolar cells from the mammary gland. The average concentration of milk carbohydrates in our study (4.94%) is higher than other reports on the Carpathian goats, such as 4.18% for goats reared in the semi-intensive

system and 4.23% goats reared in the intensive system, or 4.4% (Pascal, 2015). The highest concentration of carbohydrates (5.71%) was recorded in the beginning of lactation. It decreases thereafter towards mid lactation and remains rather constant towards the end of lactation. The same curve of milk carbohydrates concentration was noticed in other goat breeds (Noutfia et al., 2014), although other studies reported lower concentrations of carbohydrates in early lactation (in colostrum) and in late lactation (Park et al., 2007).

The content of non-fat dry matter reached a high in the first month of lactation (11.02%), followed by a nonsignificant decrease to a low of 8.37% in May. Thereafter, the average content of non-fat dry matter increases towards the end of lactation. Similar results have been reported by studies conducted on Baldi goats (Mestawet, 2012), although different variations have been reported for other breeds, such as in Alpine goats, where the maximum of non-fat dry matter concentration was noticed in the last months of lactation (Soryal et al., 2004).

The concentration of milk minerals varied in our study between 0.89 g% in early lactation and 0.49 g% in late lactation, with an average of 0.7 g%.

Fatty acids profile

The fatty acids profile varied function of the month of the year, similar results being reported by studies on goats kept mainly on pastures (Tudisco et al, 2014). According to Park et al. (2007), five fatty acids, C10:0 (capric acid), C14:0 (myristic acid), C16:0 (palmitic acid), C18:0 (stearic acid), C:18-1n9cis (oleic acid) account for 75% of the total milk fatty acids. In our study, the percentage of these five fatty acids varied between 77.09 and 79.42% (Table 4).

A characteristic feature which can distinguish the goat milk from cow milk, is the ratio of the Lauric acid (C12:0) and the capric acid (C10:0): (0.46 in goat milk vs. 1.16 in cow milk) (Strzałkowska et al. 2009). In the samples of goat milk that we examined, the value of this indicator throughout lactation was 0.40, 0.45, 0.38, 0.37, 0.37, 0.37, 0.36, and 0.35, which shows that the concentration of capric acid remained rather constant.

The milk levels of monounsaturated, polyunsaturated fatty acids and conjugated linoleic acid increased during the summer months compared to the spring months, while the level of the saturated fatty acids decreased during the summer months (Table 5). Similar results have been reported by other feeding trials conducted on grazing animals (Eknes si col, 2009, Nudda şi col., 2006).

Table 4 Milk fatty acids profile depending on the stage of lactation (g FAME/100g total FAME)

		February		March		April		May		June		July		August		September	
		mean	SEM	mean	SEM	mean	SEM	mean	SEM	mean	SEM	mean	SEM	mean	SEM	mean	SEM
C 4:0	Butyric	0.04	0.02	0.04	0.01	0.06	0.00	0.08	0.01	0.09	0.03	0.19	0.02	0.18	0.04	0.16	0.07
C 6:0	Caproic	1.63	0.15	1.50	0.07	1.63	0.02	1.65	0.03	1.71	0.11	1.76	0.15	1.93	0.16	1.79	0.17
C 8:0	Caprylic	3.69	0.21	3.55	0.11	3.49	0.09	3.41	0.08	3.45	0.12	3.43	0.09	3.50	0.14	3.42	0.05
C 10:0	Capric	12.35	0.81	13.06	0.26	11.82	0.52	11.75	0,45	11.25	0,36	11.15	0.47	11.08	0.49	10.58	0.17
C 11:0	Undecanoic	0.22	0.02	0.27	0.01	0.20	0.01	0.25	0.02	0.24	0.01	0.23	0.01	0.23	0.01	0.27	0.01
C 12:0	Lauric	5.02	0.38	5.93	0.07	4.47	0.15	4.45	0.14	4.23	0.16	4.13	0.19	3.97	0.19	3.70	0.05
C 13:0	Tridecanoic	0.08	0.00	0.10	0.00	0.08	0.00	0.09	0.01	0.08	0.01	0.08	0.01	0.08	0.01	0.07	0.02
C 14:0	Myristic	9.93	0.21	10.78	0.05	9.87	0.15	9.82	0.15	9.75	0.17	9.45	0.22	9.31	0.23	8.82	0.11
C 14:1	Myristoleic	0.30	0.02	0.35	0.00	0.30	0.02	0.31	0.02	0.30	0.03	0.30	0.01	0.31	0.02	0.31	0.00
C 15:0	Pentadecanoic	0.37	0.02	0.46	0.00	0.40	0.02	0.41	0.01	0.43	0.01	0.45	0.01	0.46	0.01	0.40	0.01
C 15:1	Pentadecenoic	1.03	0.05	1.29	0.01	1.22	0.02	1.23	0.02	1.21	0.01	1.22	0.02	1.21	0.04	1.35	0.02
C 16:0	Palmitic	26.16	0.28	26.11	0.06	24.40	0.18	24.12	0.06	24.36	0.16	24.18	0.26	24.65	0.32	26.49	0.16
C 16:1	Palmitoleic	0.96	0.06	0.89	0.01	1.35	0.03	1.34	0.01	1.32	0.01	1.29	0.06	1.24	0.04	1.08	0.01
C 17:0	Heptadecanoic	0.41	0.02	0.54	0.01	0.52	0.01	0.53	0.01	0.53	0.01	0.54	0.01	0.53	0.01	0.54	0.01
C 17:1	Heptadecenoic	0.58	0.04	0.64	0.00	0.74	0.02	0.72	0.01	0.71	0.01	0.72	0.01	0.72	0.01	0.78	0.01
C 18:0	Stearic	10.48	0.43	8.83	0.11	11.35	0.20	11.34	0.19	11.33	0.15	11.34	0.14	11.33	0.29	11.12	0.07
C18:1n9c	Oleic cis	20.50	0.89	19.17	0.16	20.42	0.65	20.52	0.63	20.54	0.68	20.59	0.71	20.67	0.89	22.33	0.19
C18:2n6t	Linoleic trans	0.66	0.04	0.49	0.02	0.98	0.10	0.99	0.06	0.98	0.05	1.01	0.06	1.03	0.09	0.73	0.04
C18:2n6c	Linoleic cis	2.83	0.11	3.00	0.06	2.40	0.07	2.51	0.05	2.42	0.05	2.41	0.04	2.38	0.07	2.25	0.04
C20:0	Arachidic	0.06	0.02	0.07	0.01	0.15	0.02	0.15	0.01	0.14	0.02	0.12	0.01	0.11	0.02	0.12	0.01
C 18:3n6	Linolenic gamma	0.00	0.00	0.03	0.01	0.08	0.01	0.07	0.01	0.06	0.02	0.06	0.01	0.06	0.01	0.07	0.00
C 18:3n3	Linolenic alfa	0.44	0.03	0.69	0.00	1.47	0.02	1.45	0.02	1.41	0.03	1.39	0.02	1.39	0.03	0.94	0.01
CLA	Conjugated Linoleic	0.40	0.03	0.38	0.01	0.85	0.07	0.84		0.83	0.03	0.80	0.04	0.77	0.03	0.53	0.01
C 20:2n6	Eicosadienoic	0.18	0.01	0.02	0.02	0.06	0.03	0.08	0.03	0.12	0.03	0.15	0.03	0.21	0.03	0.23	0.00
C 20:3n6	Eicosatrienoic	0.00	0.00	0.17	0.04	0.07	0.01	0.06	0.01	0.07	0.01	0.08	0.01	0.09	0.03	0.05	0.03
C 20:3n3	Eicosatrienoic	0.00	0.00	0.00	0.00	0.10	0.01	0.01	0.01	0.10	0.01	0.11	0.01	0.12	0.05	0.10	0.03
Other fatty acids		1.71	0.44	1.68	0.02	1.54	0.11	1.82	0.10	2.34	0.11	2.82	0.09	2.31	0.47	0.47	0.02

The polyunsaturated fatty acids in general, due to their beneficial effect on consumer health, are the most valuable fatty acids in the milk (Soryal et al., 2005). In goats, the proportion of polyunsaturated fatty acids out of the total milk fatty acids varies between 3% and 5% (Strzałkowska et al. 2010). In our study, the proportion of polyunsaturated fatty acids in the milk from Carpathian goats ranged between 4.51 and 6.16%, with the highest value in August, and the lowest in early lactation (Table 5).

The most valuable polyunsaturated fatty acid is the conjugated linoleic acid (CLA). Milk lipids are the main source of CLA in human diets and the cover 75% of the daily requirement of the human organ ism for this component. CLA concentration in the milk is influenced particularly by the nutrition, but also by other factors such as stage of lactation, breed and age of the animal. If the animals are taken out on pastures, the synthesis of cis-9, trans-11-CLA isomer in the mammary gland of the goats can reach values of up to 91% of the total CLA from the milk lipids (Tudisco et al. 2014). The conjugated linoleic acids (CLA) are conjugated diene of the linoleic acid. There are 28 possible isomers, but the dominant isomer in the milk lipids is the rumenic acid (C18:2 cis-9, trans-11). The data recorded in our study show an increase of CLA concentration up to April, when it peaks,

remaining at high values until July, after which it decrease towards the end of lactation (table 5).

Table 5. Fatty acids profile and the content of conjugated linoleic acid (CLA) (average gFAME/100gTotal FAME) in Carpathian goats milk

	February	March	April	May	June	July	August	September
Saturated fatty acids	70.36	71.23	68.43	68.05	67.59	67.05	67.33	67.46
Monounsaturated fatty acids	23.36	22.32	24.16	24.12	24.08	24.12	25.00	25.88
Polyunsaturated fatty acids	4.51	4.77	6.03	6.01	5.99	6.01	6.16	5.06
ω6/ω3	9.51	5.91	2.84	3.12	2.97	3.00	3.09	3.91
CLA	0.40	0.38	0.85	0.84	0.83	0.80	0.77	0.54

The monounsaturated fatty acids don't undergo the process of becoming rancid as fast as the polyunsaturated fatty acids. Furthermore, in human diets they don't cause the build-up of cholesterol, as the polyunsaturated fatty acids do, but they increase the concentration of high density lipoproteins (HDL) and decrease the concentration of light density lipoproteins (LDL). The proportion of monounsaturated fatty acids in the goat milk varies between 20 and 35% (Markiewicz-Kęszycka et al. 2013). Of them, the oleic acid (C18:1) is in the highest proportion in the goat milk, between about 18% (Mayer and Fiechter, 2012) and 20% (Strzałkowska et al. 2009). In the samples analysed by us, the concentration of oleic acid ranged between 19.17% in the second month of lactation and 22.32 % in the last month of lactation. Other monounsaturated fatty acids that we determined in the milk samples were the myristoleic acid C14:1 (0.31% in average), the palmitoleic acid C16:1 (1.11% in average), and the heptadecenoic acid C17:1 (0.7% in average).

The saturated fatty acids are the main component of the lipids in human diets. The studies conducted as of 2000 contradicted the hypothesis that the consumption of milk and dairy products leads to a higher synthesis of LDL lipoproteins, which increase the risk of coronary diseases. Presently, it is considered that the higher blood LDL concentration can be assigned to the lauric C12:0, myristic C14:0 and palmitic C16:0 acids, while the rest of the saturated fatty acids from the milk neutralize their effect, because they cause a higher LDL level (Parodi, 2009). The saturated fatty acids are the dominating group in the milk of ruminants, with a proportion of 67-75% of the total fatty acids in the goats receiving fresh grass (Strzałkowska et al, 2009). Grazing has a major beneficial effect because it decreases the level of saturated fatty acids, compared to the winter diets, particularly with the diets based on concentrates and corn silage (Sanz Sampelayo, 2007; Chilliard, 2007). In our study we noticed rather similar values – 67.05% to

71.23% - with a lower level at the end of the lactation period, similar results being reported by Strzałkowska (2009).

The human diet rich in omega-6 (ω6) fatty acids leads to a high omega-6/omega-3 ratio. In the die of most of the population this ratio ranges between 15:1 and 16.7:1 (Simopoulos, 2008); however, the recommendation is to keep ω -6 fatty acids as low as possible in the diet. According to (Simopoulos, 2008), the optimal ω6/ ω3 ratio is specific to different diseases: 5:1 in the diet for asthma patients and 2.5: in the diet of people with rheumatoid arthritis and colon cancer. The clinical studies show that a higher proportion of ω3 fatty acids in the diet prevents and treats cancer, heart diseases, thrombosis, blood pressure, hyperlipidaemia, senile dementia, Alzheimer disease (Kouba and Mourot, 2011). The ω3 fatty acids are also used in the treatment of skin diseases such as psoriasis, acne and erythematous lupus (McManus et al., 2011). The World Health Organisation and FAO (Food and Agriculture Organisation) recommend ω6/ ω3 ratio below 4, value at which a significant reduction (70%) was noticed in the number of deaths caused by cardiovascular diseases. The data from our study shows that the Carpathian goats which get their feed mainly from grazing produce in summer, starting with April, milk with ω6/ ω3 ratio below 4, the decrease of this ratio being significant ($p<0.05$) compared to the first two months of lactation (Table 5).

Conclusions

The biochemical composition of the milk from Carpathian goats varies considerably along lactation: in the first and last part of the lactation it has a significantly higher concentration of constituents (fat, protein, lactose and minerals). The fatty acids composition of the goat milk from our study is in agreement with many other studies which have shown that the grazing goats produce milk richer in unsaturated fatty acids and conjugated linoleic acid, besides a high content of medium chain fatty acids. The ω6/ ω3 ratio decreased significantly ($p<0.05$), below 4, during the grazing period.

References

Burlacu Gh., Cavache A., Burlacu R., Potentialul productiv al furajelor si utilizarea lor, Ed. Ceres, Bucuresti, 2002, pp. 412-415

Chilliard Y, Ferlay A, Rouel J, Lamberet G, 2003, A review of nutritional and physiological factors affecting goat milk lipid synthesis and lipolysis, J. Dairy Sci., 86:1751-1770

Chilliard Y, Ferlay A, 2004, Dietary lipids and forage interaction on cow and goat milk fatty acid composition and sensory properties, Reprod.Nutr.Dev, 44:467-492

Chilliard, Y., Glasser, F., Ferlay, A., Bernard, L., Rouel, J., Doreau, M.,2007, Diet, rumen biohydrogenation, cow and goat milk fat nutritional quality: A review, Eur. J. Lipid Sci. Technol.;109:828–855

EC 152/2009 Commission Regulation laying down the methods of sampling and analysis for the official control of feed - 27 January 2009

Eknes M., Havrevoll O., Volden H., Hove K., 2009 – Fat content, fatty acid profile and off-flavours in goats milk – effects of feed concentrates with different fat sources during the grazing season. Animal Feed Science and Technology 152, 112-122.

Kouba M, Mourot J, 2011, A review of nutritional effects on fat composition of animal products with special emphasis on n-3 polyunsaturated fatty acids. Biochimie 93(1): 13-17

Markiewicz-Kęszycka M, Czyżak-Runowska G, Lipińska P, Wójtowski J, 2013, Fatty Acid Profile Of Milk - A Review, Bull Vet Inst Pulawy, 57, 135-139, Doi: 10.2478/Bvip-2013-0026

Mayer H.K., Fiechter G, 2012, Physical and chemical characteristics of sheep and goat milk in Austria, Int Dairy J, 24, 57-63.

McManus A., Merga M., Newton W., 2011, Omega-3 fatty acids. What consumers need to know?, Appetite, 57, 80–83

Mestawet T.A., Girma A., Ådnøy T., Devold T.G., Narvhus J.A. and Vegarud G.E., 2012. Milk production, composition and variation at different lactation stages of four goat breeds in Ethiopia, Small Ruminant Research, 105, 176–181

Morand-Fehr P, Boutonnet JP, Devendra C, Dubeuf JP, Haenlein GF, Holst P, Mowlem L, Capote J, 2004, Strategy for goat farming in the 21st century, Small Ruminant Research, 51:175-183.

Morand-Fehr, Fedele V., Decandia M, Frileux Y, 2007, Influence of farming and feeding system on composition and quality of goat and sheep milk, Small Ruminant Research, 68:20-34

Nudda A, Battacone G, Usai MG, Fancelli S, Pulina G, 2006, Supplementation with extruded linseed cake affects concentrations of conjugated linoleic acid and vaccenic acid in goat milk, J Dairy Sci, 89:277-282

Noutfia, Y., Zantar, S., Ibnelbachyr, M., Abdelouahab, S. and Ounas, I., 2014. Effect of stage of lactation on the physical and chemical composition of Drâa goat milk, African Journal of Food Agriculture Nutrition and Development, 14(4), 1981–1991

Park Y W, Juarez M, Ramos M, Haenlein G F, 2007, Physico-chemical characteristics of goat and sheep milk, Small Ruminant Research 68:88-213

Parodi P., 2009, Has the association between saturated fatty acids, serum cholesterol and coronary heart disease been over emphasized?, Int Dairy J 19, 345-361

Pascal C, 2015, Tratat de crestere a ovinelor si caprinelor, Ed Ion Ionescu de la Brad

Raducuta I, Calin I, Ion E, Nicolae CG, Marin MP, Priseceanu HI, 2015, Research on milk production at goats from Carpathian breed in relation with breeding system, AgroLife Scientific Journal - Volume 4(1) 137-140

Ropota M., Varzaru I., 2014, Gas chromatography utilization to evaluate the correlation between the fatty acid profile of the layer diets and the egg yolk, 30th International Symposium on Chromatography, At Salzburg AUSTRIA, September 4th 2014.

Sanz Sampelayo MR, Chilliard Y, Schmidely Ph, Boza J, 2007, Influence of type of diet on the fat constituents of goat and sheep milk, Small Ruminant Research, 68:42-63

Shingfield, K.J., Ahvenjärvi, S., Toivonen, V., Vanhatalo, A., Huhtanen, P. and Griinari, J.M., 2008, Effect of incremental levels of sunflower-seed oil in the diet on ruminal lipid metabolism in lactating cows, British Journal of Nutrition, 99(5), pp. 971–983

Simopoulos A., 2008, The importance of the omega-6/omega-3 fatty acid ratio in cardiovascular disease and other chronic diseases. Exp Biol M 233, 674-688.

Soryal K., Beyene F.A., Zeng S., Bah B., Tesfai K., 2005, Effect of goat breed and milk composition on yield, sensory quality, fatty acid concentration of soft cheese during lactation. Small Ruminant Research 58, 275-281

Soryal Ka, Zeng SS, Min BR, Hart SP, 2004, Effect of feeding treatments and lactation stages on composition and organoleptic quality of goat milk domiati chese, Small Ruminant Research, 52:109-116

Strzałkowska N., Jóźwik A., Bagnicka E., Krzyżewski J., Horbańczuk K., Pyzel B., Słoniewska D., Horbańczuk J.O., 2010, The concentration of free fatty acids in goat milk as related to the stage of lactation, age and somatic cell count. Anim Sci Pap Rep, 28, 389-395.

Strzałkowska N., Jóźwik A., Bagnicka E., Krzyżewski J., Horbańczuk K., Pyzel B., Horbańczuk J.O., 2009, Chemical composition, physical traits and fatty acid profile of goat milk as related to the stage of lactation. Anim Sci Pap Rep, 27, 311-320.

Tafta V, 2002, Productia si reproductia caprinelor, Ed Ceres Bucuresti

Tudisco R, Grossi M, Addi L, Musco N., 2014, Fatty acid profile and CLA content of goat milk: influence of feeding system, Journal of Food Research, 3(4):93-100