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FATTY ACID PROFILE AND QUALITATIVE EVALUATION OF THE FAT FRACTION IN GOAT WHITE BRINED CHEESE ON THE 45TH DAY OF THE RIPENING PROCESS

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Abstract

It has been investigated the fatty acid composition of white brine cheese on the 45th day of the ripening process, produced from goat's milk from three groups of animals: Bulgarian White Dairy (BWD) breed and its crosses with Anglo-Nubian (BWD x AN) and Togenburg (BWD x TG) breeds during the lactation. An assessment has been made of the fatty acid composition in milk fat on the product as a healthy source for human nutrition. MUFAs predominate in the cheese from the crosses of BWD x AN breed- 25.87 g/100 g fat and PUFAs in the cheese from purebred goats- 3.39 g/100 g fat. The biologically important ratio of omega-6/omega-3 in the analyzed batches (2.91-3.09) is kept within the limits of optimal values (up to 5) according to modern notions of rational nutrition. The lipid preventive score is highest in BWD cheese- 61.47 g/100 g cheese, and the AI and TI in BWD x TG cheese - 2.62, 2.75. The analyzed cheeses from three goat groups are defined as products with low content of trans fatty acids and high content of SFA.

Key words: *fatty acids, goat white brined cheese, lipid indices*

INTRODUCTION

Cheese has a long history in the human diet as a source of essential nutrients - proteins, bioactive peptides, amino acids, fatty acids, vitamins and minerals. Goat milk cheese was an important nutritional product and an integral part of a healthy diet, and low levels of lactose make it suitable for use by people with digestive disorders. This demonstrates the importance of cheese as a functional food that, in addition to the presence of physiologically active components, provides nutritional and health benefits (Hasler, 2000).

One of the biggest differences between goat and cow's milk was in terms of the physicochemical structure and composition of milk fat (Park, 2005). Depending on the breed, the milk fat in goat's milk can range from 2.45 to 7.76% (Park, 2005). The fatty acid composition of milk fat in goat's milk is characterized by a significantly higher content of short and medium chain fatty acids (C4:0-C14:0) than cow's milk (Tziboula-Clarke, 2003; Amigo and Fontecha, 2011; Barłowska et al., 2011; Park, 2017).

Short-chain fatty acids in goat's milk account for 15-18% of total fatty acids, compared to 5 - 9% for cows. Goat's milk contains almost twice as much caproic (C6:0), caprylic (C8:0) and capric (C10:0) fatty acids than cows, which has been attributed to differences in the polymerization of acetate from abdominal microflora in goats (Amigo and Fontecha, 2011). The fatty acid profile, especially the content of fatty acids with less than 11 carbon atoms, also plays an important role in the formation and development of the organoleptic characteristics of dairy products, determining their specific taste. The total fatty acid content was high during the summer months (July, August and September). During the early phases of lactation (May and June) and the last phase of lactation (October), the total concentration of fatty acids in cheese is about half that of August. This may be explained by the heat during the summer months, which shows an increase in fat consumption with ration and high levels of lipolysis (Palmquist et al., 1993), leading to an increase in the proportion of long chain fatty acids in milk.

Cheeses obtained from the milk of pasture rearing animals are distinguished by a higher content of unsaturated fatty acids, antioxidants and aromatic constituents and lower cholesterol than those obtained from milk from indoor rearing animals (Rubino and Chilliard, 2003; Chilliard et al., 2005; Luna et al., 2005; Nudda et al., 2005; Cabiddu et al., 2006).

The content of long chain and polyunsaturated fatty acids, as well as that of conjugated linoleic acid and omega-3 fatty acids, was significantly higher and the ratio of omega-6: omega-3 fatty acids was lower in the cheese obtained from goat's milk, received less concentrated feed (Volkmann et al., 2014).

According to EU regulatory measure No 1924/2006, the content of saturated fatty acids and trans fatty acids in solid products should not exceed 1.5 g/100 g fat, where these foods are referred to as foods with low content of saturated fatty acids.

It has been investigated the fatty acid composition of white brine cheese on the 45th day of the ripening process, produced from goat's milk from three groups of animals – Bulgarian White Dairy (BWD) breed and its crosses with Anglo-Nubian (BWD x AN) and Togenburg (BWD x TG) breeds during the lactation. An assessment has been made of the fatty acid composition in milk fat on the product as a healthy source for human nutrition.

MATERIALS AND METHODS

Samples of white brine cheese (3 x 3 pieces) during the lactation period from milk of Bulgarian White Dairy (BWD) breed and its crosses with Anglo-Nubian (BWD x AN) and Togenburg (BWD x TG) for fatty acid composition and evaluation of fatty acid composition and evaluation source have been established. The milk was taken in April, June and September and subjected to technological processing for cheese production. The white brine goat's milk cheeses were examined at day 45 of the ripening process, and the results are presented arithmetically.

Milks from experimental animals reared in one flock were used under the same production conditions at the RIMSA-Troyan base, aged 3 to 5 years (second-fourth lactation), with the indications being in February and the rearing system was pasture-grazing.

Extraction of total lipids was carried out by Roese-Gottlieb method, using diethyl and petroleum ether and subsequent methylation with sodium methylate (CH_3ONa, Merck, Darmstadt) and drying with $NaHSO_4.H_2O$. The fatty acid methyl esters/FAME/ were analyzed using a Shimadzu-2010 gas chromatograph (Kioto, Japan) equipped with a flame ionization detector and an automatic injection system (AOC-2010i). The assay was performed on a capillary column CP 7420 (100 m x 0.25 mm i.d., 0.2 μm film, Varian Inc., Palo Alto, CA). Hydrogen was used as the carrier gas and nitrogen was used as the make-up gas. The four-step furnace mode was programmed – the initial column temperature is 80ºC/min, which was maintained for 15 minutes, then increases by 12ºC/min. to 170ºC and maintained for 20 minutes, followed by a new increase of 4ºC/min. to 186ºC for 19 min. and up to 220ºC with 4ºC/min. until the process is complete.

The qualitative assessment of the fat fraction includes the following indicators: lipid preventive score (LPS), atherogenic (AI) and thrombogenic index (TI) (Ulbricht and Southgate, 1991), the ratio of hyper- and hypocholesterolemic (h/H) fatty acids, trans fatty acids (TFA) and the amount of saturated fatty acids (Regulation (EC) No1924/2006).

LPS=FAT+2xSFA-MUFA-0.5PUFA

AI=12:0+4×14:0+16:0/[ΣMUFAs+PUFAn6+ PUFAn3]

TI=(14:0+16:0+18:0)/[0.5×ΣMUFAs+0.5× PUFAn6+3×PUFAn−3+PUFAn3/PUFAn6]

h/H=(C18:1n-9+C18:1n-7+C18:2n6+C18:3n-3+C18:3n-6+C20:3n-6+C20:4n-6+C20:5n-3+C22:4n-6+C22:5n-3+C22:6n3)/(C14:0+C16:0)

The data were processed using the variation statistics methods using the statistical package of the EXCEL 2013 computer program.

RESULTS AND DISCUSSIONS

The investigated white brined cheeses on the 45th day of the ripening process were characterized by a fat content in BWD from 22.61% to 27.71% during the lactation period, from 23.15% to 29.65% for BWD x TG and from 23.44% to 27.38% for BWD x AN.

It was established that of the saturated fatty acids (Table 1), in all three batches of cheese, palmitic (C-16:0) followed by stearic (C-18:0), capric (C-10:0) and myristic (C-14:0). High results for the butyric acid (C-4:0) were observed with BWD x TG - 3.95 g/100 g fat, and the values for capron (C-6:0), caprylic (C-8:0) and capric acid (C-10:0) predominate in BWD x AN cheese - 3.39; 3.29; 11.03 g/100 g fat.

Table 1. Saturated fatty acids, g/100 g fat (n=3)

	Breed group		
	BWD	**BWD x TG**	**BWD x AN**
Fatty acid	x±Sx	x±Sx	x±Sx
C-4:0	3.88±0.577	3.95±0.719	3.88±0.541
C-6:0	3.29±0.305	3.29±0.395	3.39±0.272
C-7:0	0.01±0.006	0.01±0.006	0.01±0.006
C-8:0	3.10±0.165	3.09±0.261	3.29±0.147
C-9:0	0.03±0.017	0.03±0.015	0.02±0.017
C-10:0	10.30±0.771	10.59±1.018	11.03±0.796
C-11:0	0.04±0.020	0.04±0.021	0.03±0.015
C-12:0	3.41±0.663	3.59±0.947	3.74±0.671
C-13:0	0.05±0.021	0.05±0.023	0.04±0.015
C-14:0	9.85±1.185	9.62±0.983	9.69±1.357
C-15:0	0.57±0.151	0.63±0.181	0.57±0.167
C-16:0	28.16±3.781	28.78±3.641	27.74±3.764
C-17:0	0.54±0.078	0.56±0.081	0.56±0.126
C-18.0	11.35±3.203	11.82±3.357	12.72±4.387
C-20:0	0.24±0.026	0.25±0.040	0.25±0.036
C-21:0	0.06±0.012	0.05±0.015	0.06±0.023
C-22:0	0.06±0.015	0.06±0.015	0.07±0.023
C-23:0	0.02±0.010	0.02±0.015	0.02±0.010
C-24:0	0.02±0.006a*	0.01±0.006	0.03±0.026
C-25:0	0.02±0.012	0.01±0.006	0.01±0
C-26:0	0.02±0.015	0.04±0.025	0.02±0.012

Note: a- BWD/BWD x TG; *P≤0.05

Zucali et al. (2007) received lower results than ours for (C4:0), (C6:0) and (C8:0), respectively - 1.86%, 2.01%, 3.20% for goat cheese from Alpine goats.

The content of lauric (C12:0), myristic (C14:0) and palmitic (C16:0) acids, which are associated with an increase in cholesterol levels in the human body, respectively: for (C12:0) from 3.41 g/100 g fat at BWD cheese to 3.74 g/100 g fat at BWD x AN, for (C14:0) from 9.62 g/100 g fat at BWD x TG to 9.85 g/100 g fat at BWD and (C16:0) from 27.74 g/100 g fat at BWD x AN to 28.78 g/100 g fat at BWD x TG, which was close to the results obtained by Popović-Vranješ et al. (2016) in hard goat cheese in Serbia.

White brined cheeses were good source of monounsaturated and polyunsaturated fatty acids. It was found that of the monounsaturated fatty acids in the studied cheeses (Table 2), oleic prevailed (C181c9) in the amounts from 20.34 g/100 g fat at BWD x TG to 21.99 g/ 100 g fat at BWD x AN and vaccenic acid (C18:1t11) from 0.92 g/100 g fat at BWD x TG to 0.96 g/100 g fat at BWD x AN. The content of both acids was highest for BWD x AN (0.96, 21.99 g/100 g fat) and lowest for BWD x TG (0.92, 20.34 g/100 g fat).

Table 2. Monounsaturated fatty acids, g/100 g fat (n = 3)

	Breed group		
	BWD	BWD x TG	BWD x AN
Fatty acid	x±Sx	x±Sx	x±Sx
C-10:1	0.17±0.046	0.15±0.032	0.17±0.046
C-12:1n1	0.02±0.006	0.04±0.035	0.04±0.049
C-14:1n5	0.05±0.012	0.04±0.026	0.03±0.017
C-16:19tr	0.10±0.179	0	0
C-16:1n7	0.33±0.053	0.38±0.056	0.35±0.089
C-17:1n7	0.19±0.042	0.18±0.029	0.19±0.036
C-16:3n4	0.01±0.006	0.01±0.006	0.01±0.006
C-18:1t4	0.01±0	0.01±0	0.01±0
C-18:1t5/6/7	0.16±0.030	0.16±0.040	0.17±0.055
C-18:1t9	0.19±0.036	0.18±0.032	0.18±0.042
C-18:1t10	0.17±0.017	0.18±0.015	0.17±0.046
C-18:1t11	0.93±0.523	0.92±0.587	0.96±0.581
C-18:1c9/C-18:1t12/13/	21.47±2.850	20.34±2.128	21.99±3.139
C-18:1t15/ C-18:1c11	0.40±0.061	0.43±0.092	0.42±0.096
C-18:1c12	0.10±0.025	0.10±0.015	0.10±0.029
C-18:1c13	0.23±0.087	0.24±0.093	0.26±0.139
C-18:1t16	0.02±0.010	0.02±0.006	0.03±0.006
C-18:1c14	0.05±0.020	0.06±0.023	0.06±0.032
C-18:1c15	0.08±0.012	0.09±0.021	0.09±0.021
C-22:1n9	0.03±0.010	0.04±0.015	0.03±0.006

Depending on the type of cheese, polyunsaturated fatty acids ranged from 1.66 to 11.03% (Barac et al., 2016). In our batches of white brined cheese, they were relatively close and varied within a narrow range - from 3.22 (BWD x TG) to 3.39 g/100 g fat (BWD x AN) (Table 3).

Table 3. Polyunsaturated fatty acids, g/100 g fat (n=3)

	Breed group		
	BWD	BWD x TG	BWD x AN
Fatty acid	x±Sx	x±Sx	x±Sx
C-18:2t9,12	0.18±0.012	0.17±0.026	0.17±0.035
C-18:2c9,12/19:0	1.83±0.060	1.70±0.155	1.76±0.245
gC-18:3n6	0.06±0.015	0.06±0.015	0.06±0.006
aC-18:3n3	0.52±0.271	0.50±0.279	0.53±0.291
CLA9c,11t	0.43±0.093	0.39±0.112	0.42±0.110
CLA9c,11c	0.03±0.010	0.03±0.006	0.03±0
CLA9t,11t	0.01±0.006	0.01±0.015	0
C-20:2n6	0.03±0.017	0.04±0.023	0.04±0.021
C-20:4n6	0.03±0.006	0.03±0	0.03±0
C-20:3n3	0.14±0.040	0.17±0.029	0.15±0.044
C-22:2n6	0	0	0.09±0.020
C-22:5n3	0.10±0.026	0.10±0.040	0.10±0.032
C-22:6n3	0.02±0.006	0.02±0.006	0.01±0.006

It should be noted that the values of linoleic (C18:2) and linolenic (C18:3) acids in milk fat depend on animal nutrition, since they were not synthesized in the body and their lack causes a number of biological disorders (Gerchev et al., 2018). The content of g C-18:3n6 in the tested

cheeses was 0.06 g/100 g fat, and the g C-18:3n3 varied slightly - 0.50, 0.53 g/100 g fat.

CLA-containing products have been found to contribute to the reduction of body fat by inhibiting lipogenesis and stimulating lipolysis (Raff et al., 2009).

The established isomers of CLA were at very low concentrations, with higher levels distinguishing the biologically active (CLA9c,11t) - 0.43% for cheese from BWD, 0.39% for BWD x TG and 0.42% for BWD x AN, which coincides with that obtained by Mihailova (2007) - 0.49% CLA content in goat white brined cheese from the Central Balkan mountain.

Arachidonic acid (C20:4n6), which was the other representative besides the linoleic of the omega-6 group, had very low amounts both in the raw milk and in the white brine cheese produced (0.03 g/100 g fat).

Minimum amounts were established in the cheese at day 45 and eicosatrienoic (C20:3n3), eicosapentaenoic (C22:5n3) and docosahexaenoic (C22:6n3) acids.

Whatever of the low percentage of iso and anteiso fatty acids in milk fat, they were of great interest because of their potential role as non-invasive biomarkers of abdominal function, since their variations in milk may reflect changes in bacterial populations caused by nutritional composition rations (Fievez et al., 2012).

The main representative in the studied cheeses was C-17iso and C-17aiso followed by C-15aiso (Table 4).

Table 4. Branched fatty acids, g/100 g fat (n = 3)

	Breed group		
	BWD	**BWD x TG**	**BWD x AN**
Fatty acid	x±Sx	x±Sx	x±Sx
C-13iso	0.03±0.026	0.03±0.021	0.03±0.015
C-15iso	0.20±0.051	0.20±0.040	0.22±0.066
C-15aiso	0.23±0.058	0.28±0.089	0.25±0.060
C:16iso	0.19±0.049	0.21±0.067	0.20±0.050
C-17iso	0.29±0.025	0.29±0.032	0.31±0.032
C-17aiso	0.29±0.044	0.33±0.072	0.31±0.059
C-18iso	0.04±0.012	0.04±0.012	0.04±0.010

Table 5. Fatty acid groups, g/100 g fat (n = 3)

	Breed group		
	BWD	**BWD x TG**	**BWD x AN**
Fatty acid	x±Sx	x±Sx	x±Sx
ΣCLA	0.47±0.081	0.42±0.114	0.46±0.122
Σ C-18:1 trans	1.87±0.594	1.89±0.738	1.92±0.771
Σ C-18:1 cis	21.93±2.872	20.83±2.132	22.50±3.254
Σ SFA	75.02±2.587	76.35±1.883	74.18±4.886
Σ MUFA	25.21±3.034	24.14±2.330	25.87±3.851
Σ PUFA	3.39±0.360	3.23±0.530	3.31±0.592
Σ omega-3	0.79±0.261	0.79±0.283	0.79±0.290
Σ omega-6	2.23±0.036	2.10±0.157	2.17±0.314
Σ omega-6/Σ omega-3	3.09±1.188	2.91±1.102	3.02±1.270
Branched fatty acids	1.29±0.224	1.40±0.298	1.36±0.211
CLA	0.43±0.093	0.39±0.112	0.42±0.110

Total amount of CLA ranged from 0.42 to 0.47 g/100 g in cheese from the individual breed groups (Table 5).

Trans forms range from 1.87 g/100 g fat at BWD to 1.92 g/100 g fat at BWD x AN, and cis forms from 20.83 g/100 g fat at BWD x TG to 22.50 g/100 g fat at BWD x AN, which is lower than that obtained from Mihailova (2007) content of ΣC-18:1 trans forms - 2.59% and higher than that found by the same author content of ΣC - 18:1 cis forms - 17.92% in goat

white brined cheese from the Central Balkan mountain.
SFA is highest for BWD x TG - 76.35 g/100 g fat, MUFA predominates in BWD x AN cheese - 25.87 g/100 g fat, and PUFA in pure breed goat cheese - 3.39 g/100 g fat.
Popovic-Vranjes et al. (2016) found a lower content than what we found for SFA (42%), higher for MUFA (54.4%) and close to ours for PUFA (3.6%) in ripe cheese produced in Serbia.
The ratio of omega-6/omega-3 ranges from 2.91 to 3.09 in the batches of cheese tested and remains within the range recommended by nutritionists to 5.
Volkmann et al. (2014) found a ratio of omega-6/omega-3 lower than ours from 1.3 to 2.2% in cheese after 6 weeks of maturation from milk in two groups of German Alpine goats breed fed rations containing 10 and 40% (on dry matter base) concentrated feed.
The qualitative evaluation of milk fat was based on the following indices - LPS, AI, TI, h/H, TFA and SFA (Table 6).

Table 6. Goat cheese indices

Indices	BWD	BWD x TG	BWD x AN
LPS (g/100 g cheese)	61.47±4.309	56.91±5.929	55.38±5.273
AI	2.52±0.583	2.62±0.548	2.48±0.757
TI	2.60±0.406	2.75±0.352	2.63±0.537
h/H	0.64±0.137	0.60±0.109	0.67±0.166
TFA (g/100 g cheese)	0.51±0.131	0.47±0.146	0.48±0.169
SFA+TFA (g/100 g cheese)	21.18±1.336	19.61±1.857	19.08±1.713

The lipid preventive score is highest with the BWD cheese - 61.47 g/100 g cheese, and the atherogenic and thrombogenic index at the BWD x TG - 2.62, 2.75.
Trans fatty acids vary from 0.47 to 0.51 g/100 g cheese, that is why cheeses produced, can be categorized as low-TFA products under Regulation 1924/2006.

CONCLUSIONS

Based on the lipid indices obtained and the trans fatty acid content, it can be summarized that the white brined cheese on the 45th day of the ripening process was a product of low risk to human health.
The biologically important ratio of omega-6/omega-3 in the studied batches of cheese (2.91-3.09) was kept within the limits of optimal values (up to 5) according to modern notions of rational nutrition.
The studied cheeses are characterized by low cholesterolemic index - under 1.
The lipid preventive score is highest in Bulgarian white dairy breed cheese - 61.47 g/100 g cheese, and the atherogenic and thrombogenic index in Bulgarian white dairy crosses with Togenburg breed cheese - 2.62, 2.75.
The tested cheeses from the three goat groups were defined as a food product with a low content of trans fatty acids from 0.47 to 0.51 g/100 g cheese and a high content of saturated fatty acids - from 19.08 to 21.18 g/100 g cheese according to Regulation 1924/2006.

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