The Fatty Acids Composition and Health Lipid Indices in the Sheep Raw Milk Under a Pasture-Based Dairy System

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This research was conducted to study fatty acids composition, especially content of n-3 FA; c9,t11-CLA (rumenic acid) and t11-C18:1 (vaccenic acid) and health lipid indices of milk according to the feeding practices in sheep. The exeperimental diets consisted of: P - pasture without any diet supplementation, PC - pasture + standard concentrate (500 g/d), PCs - pasture + fat-enriched concentrate (camelina seed-based concentrate: 500 g/d). Camelina seeds (Cs - Camelina sativa L) were used to increase the beneficial FA concentration in milk fat. PC diet as compared to P diet increases daily milk yield and the content of milk fat, but it adversely affects the quality of milk fats. Fat in the milk of PC ewes had a higher content of hypercholesterolemic FA, while the polyunsaturated FA (PUFA) concentration decreased ($p < 0.001$). The use Cs in the concentrate mixture (PCs diet) increased by more than double the c9,t11-CLA, C20:5n-3 (EPA), C22:6n-3 (DHA), C18:3n-3 (ALA) and t11-C18:1 (VA) ($p < 0.001$) in milk fat, without any negative effects on milk yield and composition. Beneficial changes of health lipid indices milk fat (atherogenic index, thrombogenic index, n-6/n-3 FA) were detected when the diet of ewes was supplemented with fat-enriched concentrate (PCs group) because of high concentration of c9,t11-CLA, n-3 FA which has sanogenic properties. It is concluded that, when pasture quality and availability do not limit dairy production, supplementation of grazing ewes with concentrate mixture is not recommended, because compromised the milk FA profile. The using camelina seeds in strategies for supplementing the diet of ewes on pastures is a good choice both for the daily milk yield and even more so for the sanogenetic quality of milk fats.

Keywords: n-3 FA, conjugated linoleic acid (CLA), atherogenic index (AI), thrombogenic index (TI)

To improve the nutritional characteristics and impact of milk fat on human health, fatty acids (FA) profile must be modified for increasing the proportion of polyunsaturated fatty acids (PUFA), especially conjugated linoleic acid (CLA) and á-linolenic acid (ALA, C18:3n-3), at the expense of saturated fatty acids (SFA).

Grass represents an efficient way to modify milk FA composition, though a diet based only on grazing might jeopardize milk yield the when the quality and availability of pasture is limited (the drought summer season) [1, 2]. The use of feeding systems combining pasture with feed supplements is a common practice in many dairy sheep farming systems where the diet is based on pasture [3]. So the diet of ewes on farms is often supplemented with concentrates in order to sustain milk production [4]. Taking previous studies into account, this strategy for supplementing the diet of pasture-fed ewes could have a negative impact on sanogenetic quality of milk fat by decreasing the content in C18:3n-3, c9,t11-CLA and t11-C18:1 (VA, vaccenic acid) [5, 6]. In the last years, there is a growing interest for new sources of vegetable oils with high content of unsaturated fatty acids [7-12]. Thus, it has been suggested that camelina seeds (Camelina sativa L) should be used as strategy in order to avoid the negative impact on milk FA profile. The camelina seeds were chosen for this study because of their high content of linoleic and linolenic acids [13, 14], and because they proved efficient in increasing the contents of c9,t11-CLA, VA and n-3 FA in cow milk fat [15] and another reason was the limited data available on the effect of camelina seeds on the milk fat FA profile of dairy ewes [16].

This research was conducted to study the effects of supplementing the diet of pasture-fed dairy ewes (P) with standard concentrate (PC) or fat - enriched concentrate (PCs) on milk production, FA profiles, especially content of n-3 FA; c9,t11-CLA and t11-C18:1 and health lipid indices of ewes' milk.

Experimental part

Materials and metods

The experiment was conducted at the University of Oradea (Romania) during a period of 10 weeks, from mid - June to August (2016). The first 3 weeks were used for covariate period (week 1) and adaptation to dietary treatments (weeks 2 and 3). Thirty multiparous Turcana ewes (BW = 44.6 ± 1.12 kg) in mid lactation (60–80 day of lactation and 3 months postpartum) were divided in 3 homogeneous groups (10 ewes/group), balanced for milk yield, BW, days postpartum, number of lactation and number of lambs born. The three groups were allocated randomly to one of three feeding treatment. The feeding treatments were as follows: P - grazed grass, without supplementation; PC - grazed grass, supplemented with standard concentrate (500 g/d) and PCs - grazed grass, supplemented with fat-enriched concentrate (500 g/d). Camelina seed (Cs - *Camelina sativa* L), were used as source of fat which contains 38.2% crude fat and has a high supply of polyunsaturated FA (65.8% of total fatty acids methyl esters) [16]. Camelina seeds were included in the concentrate mixture in 20% proportion, that is, 100 g/head/day, which provided a fat supplement of approximately 38 g/d for the ewes in the corresponding group. Ingredients of the concentrate and the chemical composition of the experimental concentrate are given in table 1. The concentrate mixtures were isoenergetic and isoproteic and were administered in equal parts twice a day during milking.

During weeks 2 and 3, the ewes were gradually switched to experimental diets: week 2 was for adaptation to the

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Item		Standard concentrate	Fat-enriched concentrate
Ingredients concentrate mixture (g/kg)			
	Maize grain	605	215
	Triticale grain	190	435
	Soybean meal	155	100
	Camelina seed	-	200
	Minerals and vitamins	50	50
Nutritional value			
	PDIE[1] (g/kg DM)	131.5	130.8
	PDIN[1] (g/kg DM)	123.2	124.7
	NE_L[2] (kcal/kg DM)	2032	2086

Table 1
INGREDIENTS AND NUTRITIONAL VALUES OF CONCENTRATE MIXTURE

[1]Calculated values [17] PDIN and PDIE = Digestible CP in the intestine from microbial protein synthesis when availability of fermentable N in the rumen is limiting, and from microbial protein synthesis when availability of energy in the rumen is limiting, respectively.
[2]NE_L = Net Energy for lactation [17]

supplement of standard concentrate and week 3 was for adaptation to fat-enriched concentrate (concentrate mix with Cs).

All ewes were grazed together 12 h /day on a mountain pasture (1248 m altitude), consisting of a mixture of *Festuca rubra*, *Phleum pratense*, *Poa pratensis*, *Dactylis glomerata* and *Trifolium repens*. The ewes had access to water and vitamin-mineral blocks all the time.

Measurement, sampling and analysis

Ewes were milked twice daily (at 07:00 and 20:00 o'clock), individual milk production being recorded daily. Milk fat content, crude protein (N x 6.38) and lactose were determined weekly. At week 6 and 10 of experimental period, milk samples were taken from two consecutive milking, in order to determine the FA profile of milk fat.

Feed samples were collected in weeks 3, 5, 7 and 10 of the experiment period (n=4), stored at -20°C, and then used for chemical composition analysis. Pasture samples were collected by using a quadrant of 200 cm^2 on 50 plots, by cutting to 2 cm above the ground, using metal shears. Feed samples were analyzed for dry matter (DM) [18], NDF (Neutral Detergent Fiber) and ADF (Acid Detergent Fiber) (on a Fibersac analyzer Ankom Technology, Fairport, NY) [19], crude fat and crude protein (CP) [20]. DM content of pasture samples was determined by drying in a freeze drier (Labconco Freeze Dry System, Labconco). Samples (n=2) of feeds (camelina seed, pasture, and concentrates) were collected on weeks 6 and 10 for the determination of FA profile. These samples were immediately stored at -20°C, later lyophilized and ground until analysis.

Milk samples were preserved with 2 tablets of Bronopol® (BroadSpectrum Micro-tabs II, D&F Control Systems Inc., USA). The samples were refrigerated at 4°C before being analysed for fat and protein content by infrared analysis (Milk Analyser System 4000, Foss Electric, Hillerod, Denmark). Monohydrate lactose content was measured on these samples using an enzymatic method [21].

Samples of milk collected on weeks 6 and 10 for FA analysis were frozen at - 20°C without preservatives. To determine FA in feeds, FA methyl esters (FAME) were prepared by the one-step extraction-methylation method of Sukhija and Palmquist [22]. Quantification of FA was done using 4 mg of C17:0 as the internal standard. In order to determine the composition of fatty acids in milk, the fat was extracted according to the international standard ISO 15884/IDF [23]. Fatty acid methyl esters were prepared according to the method proposed by Christie [24] and Chouinard et al. [25]. FAME were determined by gas chromatography using a Varian GC 3600 equipped with FID and a fused silica capillary column (SP 2560 Supelco), 100 m × 0.25 mm i.d., film thickness 0.20 μm. Helium was used as the carrier gas at a flow of 1 mL/min. The split ratio was 1:100 [26]. The oven temperature was programmed at 70°C and held for 1.50 min, then increased to 190°C at a rate of 8C/min, held for 25 min, increased to 230°C at 15°C/min, held for 7 min. The temperatures of the injector and of the detector were set at 270°C.

The identification of FAs was based on external standards, and calculation of the distribution (in weight percentage) was based on the area of each fatty acid ester corrected for the response factors for the individual FAs. Internal standards were used to determine percentage of recovery. The percentage of each fatty acid was calculated by dividing the area under the FA peak by the sum of the areas under total reported FA peaks.

Calculations and statistical analysis

The atherogenic index (AI) was calculated according to Chilliard et al. [27] as follows: AI = (C12:0 + 4 x C14:0 + C16:0)/(MUFA + PUFA), whereas the thrombogenic index (TI) was calculated in accordance with Ulbricht and Southgate [28] using the formula: TI = (C14:0 + C16:0 + C18:0)/(0.5 x MUFA + 0.5 x n-6 PUFA + 3 x n-3 PUFA + n-3/n-6 PUFA).

The obtained data were subjected to variance analysis by using the General Linear Models procedure of SAS, Version 9.1 (SAS Institute, Cary, NC, USA) [29]. Data for milk production and composition, fatty acids profile and health lipid indices of milk were analysed using ANOVA model with factorial term for diet composition. Comparison among means was carried out using Duncan's multiple range test. The difference in treatment means were considered significant at $p < 0.05$.

Results and discussions

Experimental diets

Chemical composition and FA contents of feeds (camelina seed, pasture and concentrates) are presented in table 2. As expected, camelina seeds had the highest CP content, while pasture had the highest content of cell wall components (NDF and ADF).

All feeds, and the concentrate mixture in particular, were good sources of linoleic acid (C18:2 n-6), but camelina seeds and the pasture were richer in α-linolenic acid (C18:3 n-3) (44.12% and 44.58% of the total FAME respectively). Though *Camelina sativa* L is a species of the cruciferous family, the linoleic acid (LA, C18:2 n-6) and the α-linolenic

acid (ALA, C18:3 n-3) contents of its seeds were similar to those of linseed [1, 13]. Adding camelina seeds to the concentrate mix increased content of total PUFA, in particular for C18:3 n-3, by approximately five times compared with standard concentrate (14.35 *vs.* 2.98% of FAME).

Milk yield and milk composition

The average daily milk yield was higher ($p < 0.01$) for PC and PCs ewes (764.6 and 788.2 ml/d respectively), fed supplemental with concentrates, than for P ewes (621.3 mL/d) (table 3). Milk yield was not affected by supplementing the diet with fat-enriched concentrates, though PCs ewes tended to the have higher milk yield, than for PC ewes.

Supplementary feeding of ewes with fat-enriched concentrates (PCs groups) increased milk fat content, milk fat yield, as well as ECM (Energy Corrected Milk) and FPCM [Fat (6.5%) and Protein (5.8%) Corrected Milk] production ($p < 0.01$). It can be assumed that the slow release of unsaturated FA from the camelina seeds in rumen decreased the amount of trans FA and in this way milk fat depression was avoided [30].

The decreased milk urea-N percentage when supplementing the diet of pasture-fed ewes may be attributed to the improved energy balance of PC and PCs ewes and to a more efficient use of nitrogen in the microbial protein sythesis in rumen [31]. This improvement in bacterial protein synthesis can be the result of a higher supply of unsaturated fats in the feed, but also of a decrease in the number of protozoa in the rumen, which reduces intraruminal recycling of bacterial protein or increases urea - N transfer from blood to rumen [32].

Absolute milk production and composition showed the lowest values in treatment P, which may be related to a likely lower energy and protein intake together with

Table 2
CHEMICAL COMPOSITION AND FATTY ACID PROFILE OF FEEDS CONSUMED BY EWES[1]

Item	Pasture	Camelina seed	Standard concentrate	Fat-enriched concentrate
Chemical composition (g/kg of DM)				
Dry matter (DM)	210	889	879	881
Crude protein (CP)	162	270	189	190
Crude fat	32	386	34	95
NDF	519	274	127	173
ADF	254	169	34	68
Fatty acid composition (% of FAME)				
C12:0	0.45	0.26	0.05	0.05
C14:0	0.52	0.19	0.14	0.12
C16:0	17.05	5.12	15.31	13.53
C16:1	0.14	0.18	0.14	0.12
C18:0	1.72	2.47	4.21	3.72
C18:1	3.07	14.74	20.68	17.01
C18:2 n-6	27.83	23.06	52.27	44.78
C18:3 n-3	44.58	44.12	2.98	14.35
C20:1	0.88	4.17	0.52	1.27
C22:1	0.09	2.21	ND	0.76
SFA	19.74	8.04	19.71	17.42
MUFA	4.18	21.30	21.34	19.16
PUFA	72.41	67.18	55.25	59.13
Others	3.67	3.48	3.70	4.29

[1]Data presented are least square means (n = 4), except for FA (fatty acid) profile (n = 2 samples per feeds). DM = dry matter; NDF = Neutral Detergent Fiber; ADF = Acid Detergent Fiber; FAME: fatty acid methyl esters; ND = not detected. SFA = saturated FA; MUFA = monounsaturated FA; PUFA = polyunsaturated FA.

Table 3
MILK PRODUCTION AND MILK COMPOSITION

Parameters	Dietary treatment			SEM	p-values
	P	PC	PCs		
Milk yield (ml/day)	621.3^{b}	764.6^{a}	788.2^{a}	22.17	<0.01
ECM[1] (kg/day)	0.581^{b}	0.739^{a}	0.772^{a}	0.087	<0.01
FPCM[2] (kg/day)	0.632^{b}	0.808^{a}	0.844^{a}	0.073	<0.01
Milk composition:					
Fat (%)	6.72^{b}	6.91^{b}	7.52^{a}	0.098	<0.05
Protein (%)	5.04	5.37	5.18	0.067	0.21
Urea N (mg/dl)	73.81^{a}	52.86^{b}	50.38^{b}	1.54	<0.01
Lactose (%)	4.76	4.82	4.80	0.092	0.38
Milk production (g/day):					
Fat	42.24^{c}	52.83^{b}	59.27^{a}	2.07	<0.01
Protein	33.17^{b}	38.76^{a}	40.82^{a}	1.83	<0.01
Lactose	29.57^{b}	36.85^{a}	37.83^{a}	1.09	<0.05

^{a,b,c} In the some row, mean values with different letters differ significantly;
P: pasture, PC: pasture + standard concentrate, PCs: pasture + fat-enriched concentrate;
SEM: standard error of mean; [1]Energy Corrected Milk: ECM = Milk Yield (kg/d) x (0.071 x Fat % + 0.043 x Protein % + 0.2224) [6]; [2]Fat (6.5%) and Protein (5.8%) Corrected Milk, estimated: FPCM (1047 kcal/kg) = Milk Yield, kg x (0.25 + 0.085 x fat % + 0.035 x protein %) [6].

Fatty acid	Dietary treatment			SEM	p-values
	P	PC	PCs		
C4:0	3.02	2.91	2.77	0.252	0.194
C6:0	2.87	2.58	2.69	0.109	0.086
C8:0	1.85^{b}	2.05^{b}	2.43^{a}	0.117	<0.05
C10:0	6.65^{a}	6.96^{a}	5.21^{b}	0.283	<0.01
C12:0	3.22^{a}	3.45^{a}	2.07^{b}	0.202	<0.001
C14:0	8.76^{a}	8.57^{a}	6.67^{b}	0.330	<0.001
C14:1	0.13	0.10	0.10	0.024	0.076
C15:0	0.91^{a}	0.71^{a}	0.64^{b}	0.045	<0.05
C16:0	24.19^{a}	24.80^{a}	21.65^{b}	1.191	<0.01
C16:1	0.52	0.48	0.42	0.168	0.061
C17:0	0.64	0.58	0.51	0.188	0.082
C18:0	10.27^{c}	12.16^{b}	15.25^{a}	0.394	<0.001
C18:1 *trans*-9	0.59	0.60	0.77	0.114	0.079
C18:1 *trans*-11 (VA)	3.44^{b}	2.15^{c}	5.05^{a}	0.171	<0.001
C18:1 *cis*-9	22.62	23.91	22.07	0.527	0.242
C18:1 *cis*-11	0.50^{b}	0.46^{b}	0.73^{a}	0.064	<0.05
C18:2 n6*t*	0.31	0.22	0.32	0.042	0.078
C18:2 n6c (LA)	1.87^{b}	2.32^{a}	2.42^{a}	0.085	<0.01
Total CLA	2.12^{b}	1.26^{c}	2.88^{a}	0136	<0.001
cis-9, *trans*-11 CLA	2.01^{b}	1.08^{c}	2.68^{a}	0.141	<0.001
trans-10, *cis*-12 CLA	0.11^{b}	0.18^{a}	0.20^{a}	0.041	<0.01
C18:3 n-3 (ALA)	2.09^{a}	1.04^{b}	2.12^{a}	0.203	<0.001
C20:0	0.29	0.31	0.31	0.027	0.41
C20:4	0.18	0.17	0.22	0.036	0.23
C20:5 n-3 (EPA)	0.30^{b}	0.11^{c}	0.43^{a}	0.094	<0.01
C22:6 n-3 (DHA)	0.37^{b}	0.18^{c}	0.54^{a}	0.017	<0.001
Others	2.40	2.10	1.93	0.154	0.271
Saturated FA	62.85^{b}	66.08^{a}	60.42^{c}	0.796	<0.001
Unsaturated FA	34.75^{b}	31.82^{c}	38.05^{a}	0.509	<0.01
Monounsaturated FA	27.80^{b}	27.70^{b}	29.54^{a}	0.391	<0.05
Polyunsaturated FA	6.95^{b}	5.12^{c}	8.51^{a}	0.176	<0.001
PUFA n-6	2.36^{b}	2.71^{a}	2.96^{a}	0.112	<0.05
PUFA n-3	2.76^{b}	1.33^{c}	3.09^{a}	0.097	<0.001
DI (18:2 *c*9,*t*11)[1]	36.88^{a}	33.44^{b}	34.67^{b}	0.371	<0.05

Table 4
FATTY ACIDS PROFILE OF SHEEP RAW MILK (% of FAME)

[a,b,c] In the some row, mean values with different letters differ significantly ($p < 0.05$).

P: pasture, PC: pasture + standard concentrate, PCs: pasture + fat-enriched concentrate;

FAME: fatty acid methyl esters; SEM: Standard error of mean; FA: fatty acid; VA: vaccenic acid; LA: linoleic acid;

CLA: conjugated linoleic acid (RA: rumenic acid); ALA: α-linolenic acid; EPA: eicosapentaenoic acid; DHA: docosahexaenoic acid;

[1]DI (18:2 c9,t11): Ä9-desaturase (c9,t11 CLA) index=100(c9,t11 CLA)/(c9,t11 CLA + 18:1 t11), calculated according to Pilarczyk et al. [41].

interactions among several nutritional factors (such as source of dietary non-fibre carbohydrates, and energy concentration of the diets) [6, 33].

Fatty acid composition and health lipid indices of milk

Supplimenting the diet of pasture-fed ewes caused changes in milk fatty acids (FA) composition accordingly (table 4). Pasture intake (P group) increased the α-linolenic acid (C18:3 n-3, ALA) and decrease in the linoleic acid (C18:2 n-6, LA) content of milk fat, in agreement with FA composition of the diets (table 2) and with data reported by other authors in dairy ruminants [34-37]. When the pasture based diet was supplemented with standard concentrates increased the content of milk fat in C18:0 (+16.7%) and reduced the CLA (- 46.3%), VA (- 37.5%) and ALA (- 49.8%) concentrations. Increased concentrations of C18:0 in the milk from ewes' PC group could be explained by the supply through diet of linoleic acid (C18:2 n-6), which is hydrogenated into VA and thereafter C18:0 in the rumen [38]. The same applies to the increases in oleic acid (c9 C18:1), due to its synthesis from C18:0 via mammary gland Δ^{9}- desaturase [6]. This negative effect of supplementation of grazing dairy ewes with concentrates on milk fat CLA, VA and ALA content has been previously found not only in dairy cows [39] but also in dairy sheep and goats [6, 40].

Supplementary feeding of ewes with standard concentrates (PC group) decreased the milk fat polyunsaturated FA content ($p < 0.001$) compared with grazing ewes receiving no supplement (P treatment), which suggests an intensification of ruminal hydrogenation processes of FA from feed.

In the case of pasture-fed ewes whose diet was supplemented with fat-enriched concentrates (PCs group) the milk had a lower content in de novo synthesized FA in the mammary gland (C10:0 - C16:0) from acetate and β-hidroxybutirate. This is explained by the fact that long-chain FA (18 or more carbon atoms) from feed inhibit acetyl-CoA carboxylase synthesis, reducing in this way FA synthesis in the mammary gland [38]. Indirectly, the camelina seed could have had a negative effect on the de novo FA synthesis in the mammary gland by changing ruminal fermentation and reducing the amount of acetate and β-hidroxybutirate, which are precursors for FA synthesis in the mammary gland [38, 41].

Increased concentrations of C18:0 and VA in the milk from ewes whose diet was supplemented with fat-enriched concentrates (PCs group) could be explained by the supply of α-linolenic acid, which is hydrogenated into VA and thereafter C18:0 in the rumen.

Supplementary feeding of ewes with fat-enriched concentrates (PCs groups) generated higher amounts of

Parameter	Dietary treatment			SEM	p-values
	P	PC	PCs		
PUFA/SFA	0.11[b]	0.08[c]	0.14[a]	0.002	<0.001
n-6/n-3 FA	0.86[b]	2.03[a]	0.95[b]	0.013	<0.001
AI	1.80[b]	1.97[a]	1.32[c]	0.031	<0.01
TI	1.54[b]	2.05[a]	1.40[c]	0.018	<0.001
h/H	1.05[b]	0.97[b]	1.31[a]	0.011	<0.001
LA/ALA	0.89[c]	2.23[a]	1.14[b]	0.015	<0.001

Table 5
HEALTHLIPID INDICES IN SHEEP PAW MILK

P: pasture, PC: pasture + standard concentrate, PCs: pasture + fat-enriched concentrate;
PUFA: polyunsaturated fatty acid; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids;
AI: index of atherogenity = (12:0 + 4 ×14:0 + 16:0)/(MUFA + PUFA) calculated according to Chilliard et al. [27];
TI: index of thrombogenity= (12:0 + 16:0 + 18:0)/[(0.5 × MUFA) + (0.5 × n-6 PUFA) + (3 × n-3 PUFA) + (n-3 PUFA/n-6 PUFA)];
h/H: hypocholesterolemic/Hypercholesterolemic ratio = (C18:1 + PUFA)/(C14:0 + C16:0); calculated according to Ulbricht & Southgate [28]

c9,t11-CLA (rumenic acid, RA) in milk fat than the pasture-only diet (and so, much higher content than animals on treatment PC), which indicates that supplementing the diet of ewes with sources rich in C18:2 and C18:3 (camelina seed) can further increase the content of c9,t11-CLA in milk fat for pasture-fed ewes. The increase in the content of c9,t11-CLA in milk fat from ewes PCs was also the result of the increase in the content of t11-C18:1 in milk, as VA is converted in endogenous RA in the mammary gland by desaturation via the enzyme Δ^9-desaturase [41]. Similar results were obtained by Addis et al. [34] by supplementing the diet of pasture-fed ewes with a concentrate rich in linseed. In addition, it was demonstrated that fats rich in C18:3 n-3 included in diet are more efficient than fats rich in C18:1 or C18:2 as far as increasing the content of c9,t11-CLA in milk fat is concerned [43].

The higher amounts of c9,t11-CLA in the milk fat of PCs group ewes as compared with those from the P group, without an increase in the Δ^9-desaturase activity (DI) (table 4), suggests an decrease ruminal biohydrogenation of PUFA from camelina seeds. A decrease in the Δ^9-desaturase activity was reported by Malgorzata et al. [43] when the diet of ewes was supplemented with a mixture of flaxseed oil and fish oil.

The higher t11-C18:1 content in milk fat from PCs treatment ewes has a practical significance for dairy producers, as VA can be converted to c9,t11-CLA in the human body, providing in this way the health benefits associated with CLA [45].

FA with more than 20 atoms were detected in small quantities in milk fat, with a difference between treatments for the content in C20:5 n-3 (eicosapentaenoic acid; EPA) and C22:6 n-3 (docosahexaenoic acid; DHA). The highest content by EPA and DHA was being recorded for ewes fed PCs diet, as reflects the higher content of C18:3 n-3 in fat-enriched concentrates. Including camelina seeds in the diet of ewes increased the content of EPA and of DHA in milk fat, even against ewes fed pasture without any diet supplementation.

The PUFA/SFA, n-6/n-3 FA and h/H (hypocholesterolemic/ Hypercholesterolemic acids) ratios, atherogenity index (AI) and thrombogenity index (TI) are commonly used to assess the nutritional value and consumer health of animal fat [46, 47]. In general, a ratio of PUFA to SFA above 0.45 and a ratio of n-6/n-3 below 4.0 are required in the diet to combat lifestyle diseases such as coronary heart disease and cancers [48]. In the present study, the PUFA/SFA ratios (0.08 - 0.14) were considerably lower than the recommended values, whereas the n-6/n-3 ratios (0.86 - 2.03) were within the recommended levels (table 5). Supplementary feeding of ewes with fat-enriched concentrate (PCs group) provided the most beneficial ratios of PUFA/SFA in milk fat, these being higher that those reported in dairy cows fed with a pasture-based diet [46].

The atherogenic index (AI) and thrombogenic index (TI) take into account the effects that single FAs might have on human health and, in practice, on the probability of increasing the incidence of pathogenic phenomena such as atheroma and/or thrombus formation [45, 46]. In the present study, the AI and TI in the milk from grazing ewes receiving no supplement (P treatment) was lower compared with the milk of ewes fed the pasture was supplemented with standard concentrate (PC treatment). Much lower values of AI and TI were obtained by dietary supplementation with fat-enriched concentrates (PCs group). Supplementary feeding of ewes with with camelina seed-enriched concentrates (PCs group) increase the h/H ratio which improves human health because of the beneficial effect on the cardiovascular system.

Conclusions

The nutritional quality of the milk obtained by grazing without any diet supplementation is deemed more favourable by consumers than that of the milk from supplementary feeding of animals with standard concentrate. Under the conditions of this study, supplementation of grazing ewes with standard concentrate increased milk production, but compromises the FA profile of milk fat. When pasture cannot sustain a high milk yield, it is preferable to supplement the diet of ewes with fat-enriched concentrates (camelina seeds-based concentrate). In this way, not only the negative impact on milk fat FA profile is avoided, but it is even possible to increase the milk fat content in FA beneficial to human health.

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