Survey on the fatty acids profile of fluid goat milk

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Abstract

Fluid goat milk submitted to thermal treatment has interesting nutritional properties and a potential expanding market. The present study was aimed to conduct fatty acids profile characterisation of goat milk placed on market. Forty-nine fluid milk samples were collected: 12 pasteurised, 12 pasteurised at high temperature, 11 ultrahigh temperature (UHT) whole milk and 14 UHT semi-skimmed milk. Milk samples were collected at retail level from 7 different companies and from different production batches. After extraction and methilation, fatty acids (FAs) profile was determined on each sample using a gas chromatograph with flame ionisation detector (GC-FID) with high-polarity capillary column. The concentration (g/100mL) of saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs), polyunsaturated fatty acids (PUFAs), *trans* fatty acids (*t*-FAs), and isomers of conjugated linoleic acid (CLA) was determined. N-6/n-3 ratio, atherogenic index (AI) and thrombogenic index (TI) were also assessed. Fluid goat milk lipid profile was characterised by SFAs (68.4% of total FAs), PUFAs (5.3%), MUFAs (21.3%), *t*-FAs (3.6%) and CLA (0.8%). The most represented fatty acids were: 16:0 (24.5%), 9*cis*-18:1 (18.2%), 18:0 (9.6%), 14:0 (9.5%), 10:0 (9.3%) and 12:0 (4.5%). Nutritional indices were 2.8-6.8 for n-6/n-3 ratio; 2.3-2.9 for AI; and 2.7-3.2 for TI. Milk produced by small scale plants, with no milk fat standardisation, showed greater differences in fatty acid profile as compared to industrial plants milk. Large scale production is characterised by commingled bulk tank milk of different origins and then is more homogeneous. The whole goat milk supply chain should be controlled to obtain milk with fatty acids of high nutritional value.

Introduction

Fluid goat milk is a dairy product with a market of potential increasing relevance. Among milk constituents, fat has a great interest for human nutrition (Ervin *et al.*, 2004), therefore it is essential the evaluation of milk fatty acids profile. Dietary fat intake of specific FAs is believed to affect human health and the occurrence of acute and chronic diseases (Huth *et al.*, 2006). Several investigations studied the impact of milk fat in the prevention of cardiovascular disease (CVD) (Ulbricht and Southgate, 1991) and some types of cancers (Huth *et al.*, 2006; Parodi, 2003). Whether saturated fatty acids (SFAs) play a positive or negative (Ulbricht and Southgate, 1991) role on human health is still debated. Some authors emphasise an holistic approach (Astrup *et al.*, 2011). In fact, lauric (12:0), myristic (14:0) and palmitic (16:0) acids are considered responsible for the increase of plasmatic low density lipoprotein (LDL) and cholesterol levels, thereby increasing the risk of coronary heart disease (CHD) (Ulbricht and Southgate, 1991). On the contrary, unsaturated fatty acids (UFAs) of milk fat, especially some monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs), are considered having a positive influence on human health. Among MUFAs, oleic acid (OA) (9*cis*-18:1) seems to have a protective effect against cancer (Menendez *et al.*, 2006). PUFAs, such as the essential fatty acids (EFAs) linoleic acid (LA) (9*cis*, 12*cis*-18:2) and α-linolenic acid (ALA) (9*cis*, 12*cis*, 15*cis*-18:3), affect platelet aggregation and the risk of CVD (Haug *et al.*, 2007). The dietary intake of long chain PUFAs (LC-PUFAs), and especially of n-3 such as eicosapentaenoic acid (EPA) (5*cis*, 8*cis*, 11*cis*, 14*cis*, 17*cis*-20:5) and docosahexaenoic acid (DHA) (4*cis*, 7*cis*, 10*cis*, 13*cis*, 16*cis*, 19*cis*-22:6) is proven to be effective in reducing the risk of CHD (Kris-Etherton *et al.*, 2003). The importance of nutritional intake of these FAs must be evaluated considering the complex compensation mechanisms that occur in the human organism. In case of deficient diet in EPA and DHA or LA, EPA production is carried out through elongation of ALA (Defilippis and Sperling, 2006). A parameter for the determination of nutritional value of milk is the n-6/n-3 fatty acid ratio. The low intake of n-3 as compared to n-6, observed in western countries diet may promote the onset of chronic diseases such as CVD, cancer, autoimmune and inflammatory diseases (Simopoulos, 2002).

Trans fatty acids (*t*-FAs) are naturally present in ruminant's milk fat. Their total content is lower and with different composition of isomers as compared to partially hydrogenated oils (Destaillats *et al.*, 2008). High *t*-FAs intake has been associated with an increased risk of CHD and myocardial infarction (Ascherio *et al.*, 1994). Vaccenic acid (VA) (11*trans*-18:1) is the most represented *t*-FAs in ruminant milk (Park *et al*., 2007). VA is the main precursor of rumenic acid (RA) (9*cis*, 11*trans*-18:2), the principal isomer of conjugated linoleic acid (CLA) in milk. The isomer 9*cis*, 11*trans*-18:2 positively affects the plasmatic lipid profile, reducing the risk of CHD and the onset of cancers (Bhattacharya *et al.*, 2006). Ruminant milk and meat represent almost the exclusive source of CLA in human diet (Parodi, 2003). Characteristics of goat milk composition and their effects on human nutrition have been investigated in several reports (Park *et al*., 2007; Ceballos *et al*., 2009). Most of milk composition studies have been carried out on individual or bulk tank samples collected at farm level, while little information exist on fluid milk at retail level. Moreover, only few studies investigated goat's milk lipid composition (Barnes, 1951; Merlo, 2001). The objective of the present study was to evaluate the nutritional characteristics of fluid goat milk available on the market with regard to major fatty acids profile and concentration.

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Key words: Fatty Acids, Fluid goat milk, GC-FID.

Conflict of interests: the authors declare no potential conflict of interests.

Received for publication: 28 March 2013.
Revision received: 3 May 2013.
Accepted for publication: 3 May 2013.

Italian Journal of Food Safety 2013; 2:e33
doi:10.4081/ijfs.2013.e33

Materials and Methods

The survey was conducted between April and May 2012 on fluid goat milk samples marketed in Sardinia. A total of 49 samples, belonging to 7 different dairy plants, were collected at retail level. Milk samples originated from the same dairy plant were of different batches (Table 1). Milk samples were frozen at -20°C until analysis. Lipid extraction was performed by a liquid/liquid technique with chloroform-methanol-water, according to Bligh and Dyer's modified method (1959). The methylation of FAs was obtained using sodium methoxide in methanol according to the procedure described by Cruz-Hernandez *et al.* (2004). The separation of the methyl esters of FAs (FAME) was performed by gas chromatograph Shimadzu GC-2010 (Shimadzu Italy, Milan, Italy) equipped with a flame ionisation

detector (FID) and ionic liquid capillary column SLB-IL111 (100 m, 0.25 mm, thickness 0.2 μm) (Supelco, Bellefonte, PA, USA) (Delmonte *et al.*, 2011).

The oven temperature was set at 80°C for 2 min, then at 168°C with a rate of 15°C/min, kept constant for 18 min, increased to 5°C/min up to 186°C and maintained constant for 33 min. The injector was maintained at 250°C and the detector at 280°C. The injection port was used in split mode with a ratio of 100:1, with 1 mL injection volume. The carrier gas was H_2 at a flow rate of 1.36 mL/min, while the gas for the detector were H_2 at 30 mL/min, ultrapure air at 400 mL/min and make-up gas N_2 at 30 mL/min. The tritridecanoin (triglyceride 13:0) was used as internal standard (IS) and was added to milk before lipids extraction. The IS amount added to milk was about 0,0036 mg per mg milk. The individual identification of FAs was carried out through a comparison of the retention times determined throught the use of reference standard or those reported in the literature.

Total fat and FAs mean concentration were calculated as g/100mL of milk. FAs profile was also determined and expressed as % of total FAs in milk. The atherogenic index (AI) and thrombogenic index (TI) were calculated according to Ulbricht and Southgate (1991).

Results

The dairy plants location, number and types of fluid milk collected are summarised in Table 1. Total fat content and main lipid fractions profile of fluid goat milk produced in the seven plants are reported in Table 2. Fresh pasteurised milk (plant A and B) showed a higher fat content as compared to the other types of fluid milk. Moreover, in fresh milk the higher absolute values for almost all the FAs were detected (Table 2). Goat milk average FAs profile was characterised by 68.4% of SFAs, 5.3% of PUFAs, 21.3% of MUFAs and 3.6% of *t*-FAs. The complete profile of analysed fatty acids is reported in Table 3. The most represented FAs were 16:0 (24.5%), 9*c*-18: 1 (18.2%), 18:0 (9.6%), 14:0 (9.5%), 10:0 (9.3%) and 12:0 (4.5%). Pasteurised milk collected from dairy A was characterised by the higher content of ALA (0.7%) and the lower content of *t*-FAs (3.1%), in particular isomer 10*t*-18:1 (0.2%). These samples showed the highest value of TI (3.2). Pasteurised milk from dairy plant B showed the highest fat content and was characterised by the lowest concentration of SFAs (66.4%), in particular myristic (8.5%) and palmitic (23.3%) acids. The FAs profile showed a concentration of short chain saturated fatty acids (SCFAs) of 19.3%, while MUFAs 18:1 accounted for 20.7 and 16:1 for 0.7%. Pasteurised milk of the dairy plant B also showed the lowest level of n-3 as compared to milk of other establishments. In particular ALA was 0.2%, while the content of LA was 2.7%. In this milk the highest value (6.8) for the nutritional index n-6/n-3 and the lowest for the AI (2.3) were observed.

The results obtained in samples originated from plants with higher production volume (C-G) where more homogeneous. The milk pasteurised at high temperature (C) is characterised by a limited amount of PUFAs (4.7%), in particular of LA (2.2%). There is also the lowest value for the n-6/n-3 nutritional index (2.8). High temperature pasteurised milk (plant D) showed the highest content of palmitic acid (25.9%). UHT milk (plant E) had the lowest values of SCFAs (16.8%), LCFAs (9.9%), rumenic acid (0.4%) and vaccenic acid (0.7%). Higher values of 10*t*-18:1 and AI (2.9) were also observed.

In semi-skimmed milk samples (dairy F and G), the fat content was 1.6 and 1.5 mg/100 mL of milk. Milk obtained from dairy F showed higher concentration of PUFAs (6.7%) and EFAs metabolism products n-6 (3.1%) and n-3 (1.1%). There was also the highest quantity of *t*-FAs (4.2%) and CLA (1.1%), while the TI showed its lowest value (2.7). Partially skimmed milk samples (dairy G) showed lower concentrations of MUFAs (19.7%) and particularly of oleic acid (16.6%), while the values of

Table 1. Types of 49 fluid goat milk samples collected from different dairy plants.

Dairy plant	Location	Type of milk	Samples (n)
A	Sardinia	Fresh pasteurised	6
B	Sardinia	Organic fresh pasteurised	6
C	Sardinia	Whole pasteurised at high temperature	6
D	Campania	Whole pasteurised at high temperature	6
E	Sardinia	Whole UHT	11
F	France	Semi-skimmed UHT	10
G	France	Semi-skimmed UHT	4

UHT, ultrahigh temperature.

Table 2. Total fat and lipids profile (g/100 mL of milk) of 49 fluid goat milk samples.

	Dairy plant						
	A	B	C	D	E	F	G
Fat	3.90±0.23	5.04±0.69	3.42±0.07	3.05±0.02	3.32±0.28	1.60±0.16	1.51±0.08
SFAs	2.77±0.18	3.35±0.51	2.39±0.04	2.09±0.02	2.28±0.18	1.07±0.07	1.05±0.05
SCFAs	0.73±0.05	0.97±0.18	0.64±0.03	0.52±0.01	0.56±0.04	0.30±0.05	0.29±0.03
MCFAs	1.54±0.12	1.83±0.28	1.33±0.03	1.23±0.02	1.39±0.14	0.60±0.03	0.60±0.02
LCFAs	0.50±0.03	0.54±0.07	0.42±0.02	0.34±0.01	0.33±0.03	0.17±0.01	0.16±0.01
c-MUFAs	0.77±0.04	1.20±0.21	0.70±0.05	0.65±0.01	0.72±0.08	0.34±0.03	0.30±0.01
PUFAs	0.19±0.01	0.25±0.03	0.16±0.01	0.16±0.01	0.16±0.01	0.11±0.05	0.09±0.01
n-6	0.10±0.00	0.15±0.02	0.08±0.01	0.08±0.00	0.09±0.01	0.05±0.01	0.04±0.00
n-3	0.04±0.00	0.02±0.01	0.03±0.00	0.03±0.00	0.02±0.01	0.02±0.01	0.01±0.00
CLA	0.02±0.00	0.04±0.01	0.02±0.00	0.02±0.00	0.02±0.00	0.02±0.01	0.02±0.00
t-FAs	0.12±0.01	0.18±0.02	0.11±0.01	0.10±0.00	0.12±0.02	0.07±0.02	0.05±0.00

SFAs, saturated fatty acids; SCFAs, short chain fatty acids (SFAs with C=4-10); MCFAs, medium chain fatty acids (SFAs with C=11-16); LCFAs, long chain fatty acids (SFAs with C=17-24); *c*-MUFAs, *cis*-mono-unsaturated fatty acids; PUFAs, poli-unsaturated fatty acids; n-6, 18:2+18:3c6,c9,c12+20:3HOMO-G+20:4+22:4+20:2; n-3, 18:3c9,c12,c15+20:5+22:5+22:6; CLA, conjugated linoleic acid; *t*-FAs, *trans*-fatty acids.

rumenic (0.6%) and vaccenic acid (1.1%) were higher.

Discussion

Whole fresh pasteurised milk originated from small or very small establishments (A, B), where no standardisation of fat content is performed, showed a higher fat content (>3.5%) as compared to larger dairies. Regulation EC No. 1234/2007 (European Commission, 2007) sets fat content limits for standardised milk ≥3.5% for whole milk and of 1.5-1.8% for semi-skimmed milk. Whole milk samples (C-E) were lower than the limits, while semi-skimmed milk samples (F and G) were always within the defined range.

The relation between dietary SFAs and CVD is a topic of great public interest. The SFAs mean content was 68.4% of total milk FAs, which is lower than previously reported in raw goat milk, 76.8% by Luna *et al.* (2008) and 70.4% by Ceballos *et al.* (2009). The SFAs content of fluid goat milk samples was comparable to heat treated fluid cow milk ranging between 62.4 and 74.1% (O'Donnell *et al.*, 2010; O'Donnell-Megaro *et al.*; 2011; Butler *et al.*, 2011). The SCFAs content of fluid goat milk was 18.1%, which is higher than fluid cow's milk (5.26-10.06%) (O'Donnell *et al.*, 2010; O'Donnell-Megaro *et al.*, 2011; Butler *et al.*, 2011). The MCFAs mean content was 39.3%, lower than observed in raw goat milk (40.7-44.4%) and fluid bovine milk (40.9-53.0%) (Park *et al.*, 2007; Luna *et al.*, 2008; Ceballos *et al.*, 2009; O'Donnell *et al.*, 2010; O'Donnell-Megaro *et al.*, 2011; Butler *et al.*, 2011). The presence of higher content in SCFAs and lower in MCFAs observed in the present study supports the benefic effect of goat milk in the reduction of plasma cholesterol levels (Krauss *et al.*, 2000). The mean content of *t*-FAs, mainly represented by 11*trans*-18:1, was 3.6% of total milk FAs within the range for ruminants, from 2.5 to 5.0% of total FAs (Park *et al.*, 2007). *T*-FAs are considered to be harmful to human health because associated with the risk of coronary heart disease and myocardial infarction (Ascherio *et al.*, 1994). However, CHD risk is associated with consumption of *t*-FAs tipically from industrial sources characterised by a high content of 9*trans* and 10*trans*-18:1 (Destaillats *et al.*, 2008). The possible indication on the label of *trans* fatty acids content, as already adopted by Canada and United States, is considered by Regulation EU No. 1169/2011 (European Commission, 2011). The importance of the 11*trans*-18:1 is also linked to its role as a precursor of 9*cis*,11*trans*-18:2 CLA, studied for its many positive effects (Bhattacharya *et al.*, 2006). Total CLA in the samples analysed in this study showed a mean content of 0.8%. Park *et al.* (2007) reported a mean content of 0.65% of total CLA in goat raw milk. Available information refers to bovine commercial milk, with a total CLA content of 1.89% (Precht and Molkentin, 2000).

The average values of the nutritional indices were 2.71 and 2.95 for AI and TI, respectively, in agreement with previous stud-

Table 3. Fatty acid composition (g/100 g total fatty acids) and nutritional indices of 49 fluid goat milk samples.

FA	Dairy plant						
	A	B	C	D	E	F	G
4:0	2.91±0.12	2.79±0.08	2.92±0.07	2.78±0.08	2.68±0.16	2.94±0.54	2.78±0.19
6:0	2.97±0.13	3.04±0.15	2.93±0.12	2.67±0.06	2.64±0.14	2.90±0.38	2.93±0.13
8:0	3.00±0.12	3.24±0.28	2.98±0.20	2.68±0.05	2.65±0.14	2.89±0.17	3.02±0.10
10:0	9.82±0.37	10.05±1.24	9.64±0.62	8.89±0.16	8.69±0.29	9.15±0.27	9.98±0.12
12:0	3.86±0.18	3.93±0.61	3.94±0.23	4.03±0.03	5.91±1.42	4.10±0.28	4.49±0.14
14:0	8.98±0.15	8.48±0.60	9.27±0.18	9.56±0.07	10.61±0.74	9.15±0.73	9.82±0.23
15:0	0.76±0.03	0.56±0.05	0.84±0.02	0.85±0.01	0.79±0.08	0.75±0.06	0.79±0.04
16:0	25.78±0.66	23.33±0.56	24.81±0.33	25.89±0.43	24.45±1.78	23.67±2.21	24.23±0.50
17:0	0.55±0.03	0.47±0.05	0.60±0.02	0.55±0.01	0.45±0.11	0.50±0.02	0.55±0.05
18:0	11.35±0.24	9.57±0.51	10.83±0.31	9.60±0.27	8.73±0.82	8.91±0.98	9.43±0.26
20:0	0.36±0.02	0.28±0.05	0.38±0.04	0.34±0.04	0.26±0.04	0.26±0.12	0.25±0.02
22:0	0.12±0.02	0.10±0.02	0.12±0.01	0.11±0.01	0.11±0.01	0.17±0.11	0.17±0.04
24:0	0.14±0.02	0.19±0.02	0.14±0.02	0.12±0.02	0.15±0.02	0.20±0.11	0.14±0.04
9c-14:1, MA	0.09±0.00	0.12±0.01	0.09±0.00	0.12±0.01	0.17±0.04	0.13±0.02	0.13±0.02
9c-16:1, PA	0.44±0.03	0.68±0.06	0.45±0.03	0.54±0.03	0.66±0.11	0.51±0.07	0.47±0.06
9c-18:1, OA	17.51±0.52	20.67±2.86	18.05±1.33	18.40±0.46	18.61±0.60	17.08±1.65	16.65±0.38
18:2, LA	2.35±0.19	2.66±0.07	2.16±0.16	2.23±0.06	2.17±0.13	2.38±0.25	2.36±0.06
18:3, ALA	0.73±0.05	0.24±0.03	0.67±0.04	0.66±0.02	0.44±0.16	0.54±0.10	0.55±0.02
20:4, AA	0.14±0.02	0.19±0.02	0.14±0.02	0.12±0.02	0.15±0.02	0.20±0.11	0.14±0.04
20:5, EPA	0.06±0.02	0.08±0.05	0.08±0.05	0.09±0.03	0.08±0.03	0.16±0.12	0.10±0.03
22:6, DHA	0.06±0.03	0.06±0.02	0.06±0.02	0.09±0.05	0.08±0.03	0.16±0.09	0.10±0.03
9c,11t-18:2, RA	0.41±0.03	0.55±0.05	0.41±0.03	0.55±0.02	0.40±0.06	0.56±0.05	0.62±0.05
10t-18:1	0.20±0.02	0.40±0.02	0.21±0.01	0.23±0.01	0.55±0.26	0.39±0.06	0.27±0.03
11t-18:1, VA	0.88±0.06	1.02±0.06	0.84±0.10	0.97±0.04	0.69±0.12	1.03±0.12	1.09±0.07
n-6/n-3	2.81±0.25	6.82±1.42	2.79±0.31	2.77±0.16	3.79±0.80	3.19±0.89	3.39±0.26
AI	2.80±0.13	2.27±0.38	2.76±0.20	2.74±0.05	2.91±0.16	2.55±0.24	2.90±0.06
TI	3.20±0.13	2.78±0.27	3.09±0.14	2.97±0.09	3.01±0.12	2.70±0.39	3.07±0.11

FA, fatty acid; MA, myristoleic acid; PA, palmitoleic acid; OA, oleic acid; LA, linoleic acid; ALA, α-linolenic acid; AA, arachidonic acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid; RA, rumenic acid; VA, vaccenic acid; AI, atherogenic index; TI, thrombogenic index.

ies performed on goats milk (Bouattour *et al.*, 2008; Osmari *et al.*, 2011). Low values of these indices are usually observed in foods that provide a low intake of undesirable fats and are therefore associated with a reduced risk of cardiovascular disease (Ulbricht and Southgate, 1991).

Conclusions

Based on the quantity of fatty acids, small scale productions, where no standardisation of milk fat content was applied, showed the greatest variability, while industrial plants resulted more homogeneous and undifferentiated. Considering the increasing importance of goat milk on the international market, further research is needed in order to characterise the lipids profile of heat treated milk. Special attention should be paid on the fatty acids which have an impact on human nutrition and health. In order to have a commercial milk with a natural high content of such benefic fatty acids, it is essential to standardise the production system. Fluid milk market also require to put in place a reorganisation of goat milk supply chain to be able to support the demand of large scale distribution.

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