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SUMMARY – A survey was carried out on three Sarda goat herds (A, B and C) during the milking period, with the aim to investigate the effect of different feeding systems on milk composition, with particular emphasis to fatty acid (FA) and volatile compound contents. Herd A was stall-fed with hay and concentrate whereas herds B and C were fed at pasture, with woody and herbaceous species in B and only herbaceous species in C. Milk yield and composition including FA and volatile compounds, as well as feeding behaviour were measured monthly. Individual milk yield and composition were different in the three herds (P<0.05), as well as the bulk milk FA composition, particularly the long chain fatty acids (C17:0-C18:3). The levels of CLA (C18:2 *c-9, t-11*) and vaccenic acid (C18:1 *t-11*) were higher in B (11.10±0.9 and 23.01±1.9 g/kg of fat respectively; P<0.05) as compared to the other herds. When pooling all data, a relationship was found between CLA and vaccenic acid (Y=0.38X+1.90, R^2=0.79, P<0.05). The profile of total volatile compounds in the bulk milk of the three herds was different, probably as a consequence of dietary factors.

Keywords: Goats, milk, CLA, fatty acids, volatile compounds.

RESUME – *"Effet de différents régimes alimentaires sur la composition en acides gras et la teneur en composés volatils du lait de chèvre". Trois troupeaux de chèvres Sardes (A, B et C) ont été suivis afin d'évaluer l'effet de différents systèmes alimentaires sur la production et la composition du lait, en particulier en acides gras et en composés volatils. Le troupeau A était alimenté en stabulation avec du foin et du concentré, alors que les troupeaux B et C s'alimentaient au pâturage, constitué d'espèces ligneuses et herbacées en B et d'espèces exclusivement herbacées en C. La production et la composition du lait, y compris les acides gras et les composés volatils, ainsi que le comportement alimentaire des animaux, furent mesurés une fois par mois. Une différence significative (P<0,05) de production et de composition du lait a été observée entre les trois troupeaux ainsi qu'au niveau de la composition en acides gras, en particulier ceux à longue chaîne (C17:0-C18:3). Les niveaux de CLA (C18:2 c-9, t-11) et d'acide vaccénique (C18:1 t-11) étaient plus élevés pour le troupeau B (respectivement 11,10±0,9 et 23,01±1,9 g/kg de matière grasse; P<0,05). Enfin, une bonne relation entre teneur en CLA et acide vaccénique a été trouvée (Y=0,38X+1,90,* R^2*=0,79, P<0,05). La différence de profil des composés volatils totaux entre les trois troupeaux est probablement due à l'effet de différents régimes alimentaires.*

Mots-clés : *Chèvres, lait, CLA, acides gras, composés volatils.*

Introduction

It is known that the feeding regimen affects the composition of ruminant milk. In particular some nutraceutical components, like conjugated linoleic acid (CLA) reach higher levels in cows and ewes grazing sward at vegetative stage (Chouinard *et al*., 1999; Cabiddu *et al*., 2003). An important effect of the forage species was found not only on CLA level (Addis *et al*., 2002; Cabiddu *et al*., 2004) but also on the presence of some volatile compounds like terpenes in sheep (Moio *et al*., 1996; Viallon *et al*., 1999) and goat milk (Fedele *et al*., 2004). These compounds could play an important role as feeding regimen markers because they can pass from the ingested plants to the dairy products. These aspects are less studied in goat extensive systems with animals browsing on bushland. For this reason a survey was carried out in three goat farms, with different level of intensification, with the aim of evaluating the effect of the feeding system on milk fatty acids (FA) composition and volatile compound content.

Materials and methods

The survey was carried out with three Sarda goat herds (A, B and C) at the same DIM on average, in the NW of Sardinia during the milking period (from March to June). In herd A, goats (n=32) were stall-fed with lucerne hay and commercial concentrate whereas in herds B (n=41) and C (n=40), goats were fed at pasture and received supplements (lucerne hay, concentrate and maize). The botanical composition of the pastures was different between B (woody and herbaceous species) and C (only herbaceous species). Goats were machine milked twice a day. The B and C herds were penned during the night. Individual milk yield and milk composition (fat, protein, lactose, milk urea) were measured every month. At the same time bulk milk samples were collected to determine fatty acid composition and volatile compounds. Fatty acids were measured, after fat extraction, according to Röse-Gottlieb method (using isopropanol and hexane as extraction solvent mixture), and transmethylation (Chin *et al*., 1992) by gas-cromatograph. Each fatty acid was identified with reference to the retention time of the standards and quantified respect internal standards. The volatile compounds were extracted by dynamic headspace method ("Purge & Trap", Larrayoz *et al*., 2001). The compounds were separated and identified by a gas-cromatograph coupled with mass-spectrometry (MSD) and a flame ionisation detector (FID). Data on forages and concentrates offered to the animals were recorded each month. Feeding behaviour of the animals at pasture (time spent grazing and resting) was measured by direct observation. Hand plucked bite-like samples of the main species grazed or browsed by the goats were collected. These samples were freeze-dried and analysed for chemical composition (AOAC, 1990). The fatty acid composition (after lipid extraction according to a modified Folch method; Christie, 1989) and volatile compounds of these samples were also measured using the same methods as for the milk. Data of milk yield and milk composition content were analysed by GLM with sampling period and herd as fixed effects. Milk volatile compounds were analysed by canonical discriminant analysis.

Results and discussion

The chemical composition of the feedstuffs used by the three goat herds are showed in Table 1. In herd A the goats were fed with lucerne hay and commercial concentrate according to their requirements (Jarrige, 1989). In B the supplementation represented 55% of goat energy requirements. These goats spent 52% of the total observation time grazing (16% in the bushland and 36% in the herbaceous vegetation). In this herd the woody species browsed for a longer time was *Mirtus communis* L. and the herbage sward grazed contained besides grasses also legumes and forbs. In C herd the goat energy requirements were covered up to 51% by the supplements. The goats grazed for 59% of the observation time.

Table 1. Chemical composition of hay and concentrate given to goat herd A and of hand-plucked samples of main herbaceous and woody species fed by goat herds B and C

	Phenological phase	DM	OM (%)	EE (%)	CP (%)	NDF (%)	Linoleic acid (g/kg DM)	Linolenic acid (g/kg DM)
Herd A								
Alfalfa hay		87.27	91.83	1.80	18.38	53.00	-	-
Concentrate		88.66	89.44	4.02	18.77	31.60	-	-
Herd B								
Arbutus unedo L.	First ripe fruit	47.42	94.73	7.36	8.41	38.76	0.82	3.28
Urginea marittima L.	Vegetative	17.61	91.20	3.75	15.84	28.39	1.69	4.47
Mirtus communis L.	Vegetative	43.94	93.75	3.20	9.13	35.85	1.00	2.94
Pirus spp.	Early-flowering	31.33	93.81	3.35	15.00	40.34	2.49	6.21
Pistacia lentiscus L.	Early-flowering	48.39	94.54	3.45	8.12	38.79	2.58	2.71
Quercus ilex L.	Early-flowering	35.35	95.45	1.90	10.86	47.72	2.52	2.84
Ryegrass, oat, barley	Early-headings	22.02	91.83	2.86	15.12	48.37	2.18	8.99
Mirtus communis L.	Flowering	38.85	94.83	2.06	8.75	37.79	1.39	3.74
Herd C								
Oat, barley	Vegetative	16.97	87.92	4.18	24.57	38.36	1.90	12.41

Milk yield was higher in A than B and C herds, and the milk composition was different in the three herds (Table 2). In particular the milk urea level was high in stall fed goats, as a consequence of a higher CP level of the feedstuff than what expected (Table 1). Differences between herds were found for the medium chain fatty acids (C16:0; C16:1 *c-9*) and long chain fatty acids (C17:0; C18:0; C18:1 *t-11;* C18:3 *c-9 c12 c15;* C18:2 *c-9 t-11;* CLA) (Table 3). The level of CLA was higher in the herds fed at pasture as compared to the stall-fed ones, in agreement to what observed in cows and ewes (Kelly *et al*., 1998; Antongiovanni *et al*., 2004). In particular the B herd showed the highest value of CLA and vaccenic acid, probably because the diet of these goats included not only grass but also species belonging to other botanical families, as already observed in sheep (Cabiddu *et al*., 2005).

Table 2. Goat milk yield and composition (least square means)

	N	Herds			Effects	
		A	B	C	Herd	Period
Milk yield (ml)	397	1258	1065	975	*	*
Fat (%)	"	4.06	4.52	4.29	*	*
Protein (%)	"	3.36	3.33	3.54	*	*
Lactose (%)	"	4.46	4.35	4.26	*	*
Urea (mg/dl)	360	62.89	36.70	32.51	*	*

*P<0.05.

In herds B and C, the supplementation level expressed as the percentage of energy requirement was negatively correlated with CLA (R = -0.65; P<0.05). Pooling all the data, a good relationship was found between vaccenic acid and CLA (Y = 0.38X+1.90, R^2 = 0.79, P<0.05). Vaccenic acid and CLA content in milk fat tended to decrease during the period probably as a consequence of lowest levels of precursors C18:2 *c9, c12* (linoleic acid) and C18:3 *c-9, c-12, c-15* (linolenic acid) in the diet. Regarding the poly-unsaturated fatty acids, the herd B showed also the highest value of linolenic acid, an ω3 fatty acid with a cardiovascular protective effect. In general high content of C18:3 has been observed in the milk from animals fed at pasture compared to the silage and concentrate feeding (Christa *et al*., 2004). Considering the $\omega 3/\omega 6$ ratio, represented in this case by linolenic/linoleic, the herds at pasture showed the highest values (0.49, 0.45 and 0.21 in C, B and A respectively, P<0.05). In general a $\omega 3/\omega 6$ ratio > 0.20 is considered highly valuable from a nutritional point of view (Collomb *et al*., 2004).

Concerning volatile compounds, differences were observed between the three herds (Fig. 1). The milk from the herds fed at pasture showed higher levels of total volatile compounds as already observed in cows (Carpino *et al*., 2004). In particular, in herd B, the highest level of volatile compounds was found in April when the goats were browsing mainly *Mirtus communis*, *Pistacia lentiscus* and *Pirus* spp. Overall the volatile compounds most represented in milk were the ketones. No terpenes were found in bulk milk although they were detected in some woody species. The canonical discriminant analysis of volatile compounds, using the herd as classification factor, generates two discriminant functions. The first one explained 97% of variance and discriminated the herd C from the others (Fig. 2). The compounds that contributed the most to the first function were alcohols (ethanol, 3-penthanol and 1-butanol).

Conclusions

The feeding system based on pasture confirmed its positive effect on CLA content in milk, in particular when the pasture is characterised by a high proportion of herbage with high botanical variability. The high heterogeneity of goats' diet while feeding on bushland makes it very difficult the understanding of its effect on milk FA composition. Further research is needed to better investigate the relationship between diet composition and milk content in volatile compounds.

Table 3 Goat milk fatty acid composition (least square means)

Fatty acids†	N	Herds			Effects	
		A	B	C	Herd	Period
C4:0 (g/kg fat)	12	22.97	25.89	24.65	*	*
C6:0 (g/kg fat)	12	20.93	21.65	20.40	ns	*
C8:0 (g/kg fat)	12	20.51	20.49	18.81	ns	0.08
C10:0 (g/kg fat)	12	106.54	104.06	92.12	ns	ns
SCFA (g/kg fat)	12	170.96	172.09	155.98	ns	ns
C12:0 (g/kg fat)	12	40.68	37.42	34.66	ns	ns
C14:0 (g/kg fat)	12	76.80	74.41	80.33	ns	ns
C14:1 *cis-9* (g/kg fat)	12	1.21	0.90	1.19	ns	ns
C15:0 (g/kg fat)	12	11.09	9.51	10.39	ns	*
C16:0 (g/kg fat)	12	221.61	197.25	207.04	*	ns
C16:1 *cis-9* (g/kg fat)	12	3.43	2.28	2.57	*	ns
MCFA (g/kg fat)	12	354.81	321.77	336.17	*	*
C17:0 (g/kg fat)	12	9.20	6.49	7.42	*	*
C18:0 (g/kg fat)	12	82.53	105.80	106.44	*	*
C18:1 *cis-9* (g/kg fat)	12	207.49	204.86	231.33	ns	0.09
C18:1 *trans-11* (g/kg fat)	12	10.70	23.01	9.70	*	0.09
C18:2 *c-9, c-12* (g/kg fat)	12	30.55	22.93	17.66	*	ns
C18:3 *c-9, c-12, c-15* (g/kg fat)	12	6.49	10.25	8.69	*	0.09
CLA (C18:2 *c-9, t-11*) (g/kg fat)	12	4.74	11.10	6.61	*	ns
LCFA (g/kg fat)	12	351.69	384.45	387.84	0.07	*
Total (g/kg fat)	12	877.46	878.31	880.00	ns	ns
SFA (g/kg fat)	12	612.85	602.96	602.26	ns	ns
MUFA (g/kg fat)	12	222.83	231.05	244.79	ns	0.07
PUFA (g/kg fat)	12	41.76	44.28	32.96	*	*
UFA (g/kg fat)	12	264.61	275.33	277.75	ns	ns
C14:1/C14:0	12	0.016	0.012	0.015	ns	ns
CLA/Vac	12	0.47	0.49	0.63	0.10	ns
Atherogeniticy index	12	2.17	1.96	2.04	ns	0.06

*P<0.05.
†SCFA: small chain FA; MLFA: medium chain FA; LCFA: long chain FA; SFA: saturated FA; MUFA: mono-unsaturated FA; PUFA: poly-unsatuaretd FA; UFA: unsaturated FA.

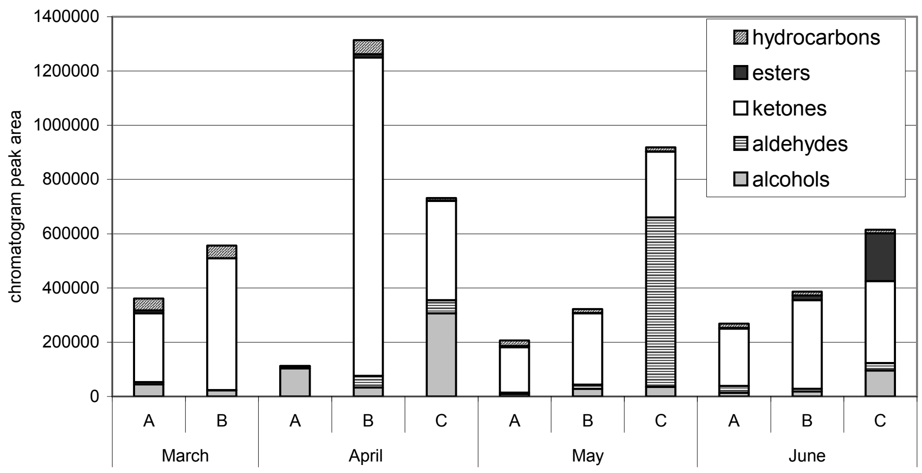
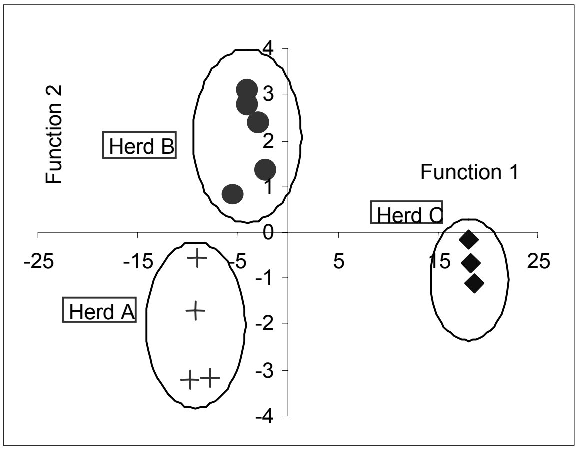


Fig. 1. Total volatile compounds in goat milk.



Standardized Canonical Discriminant Function Coefficients

	Functions	
	1	2
Acetone	-2.05	1.05
3-Hydroxy -2-butanone	-2.70	-2.06
Ethanol	6.91	1.69
1-Butanol	3.36	-0.42
3-Pentanol	5.88	-0.45
Pentane	1.17	0.28

Fig. 2. Canonical discriminant functions for volatile compounds in goat milk.

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