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Meat quality in suckling kids reared by different production systems

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Summary
The effect of grazing on pasture or feeding with concentrates was evaluated on the concentration of Conjugated Linoleic Acid (CLA) in goat milk and in meat obtained from suckling kids fed only on maternal milk. The study used twenty male Ionica kids born as singletons from mature goats. The kids were reared with their dams, suckling ad libitum only maternal milk throughout the whole experimental period. Two groups of 10 kids each were formed according to their mothers' feeding treatment. One group of kids was raised under dams reared by an intensive production system (Group I - Intensive), while the other group of kids was raised under dams grazing on pasture (Group E – Extensive). The goats were milked once a week in order to assess milk chemical composition, fatty acid profile and CLA concentration. Kids were slaughtered when 45 days old. Meat quality was evaluated on samples of the Longissimus lumborum (Ll) and Quardriceps femoris (Qf) muscles. On the whole, suckling kids raised under grazing goats showed a higher concentration of total CLA in both raw (2.57 vs 2.25%) and cooked meat (1.85 vs 1.44%), although the differences were not significant.

Riassunto
Lo scopo del lavoro è stato quello di valutare l'influenza del sistema alimentare e di allevamento sulle caratteristiche qualitative del latte di capra, con particolare riferimento al contenuto di acido linoleico coniugato (CLA), e su quelle delle carni del capretto lattante. La prova è stata condotta su 20 capretti maschi di razza Ionica, nati da parto singolo da capre mature. I capretti sono stati allevati con le proprie madri e nutriti esclusivamente con latte materno assunto *ad libitum* per l'intera durata della prova. Sono stati costituiti due gruppi di 10 capretti in relazione al sistema alimentare e di allevamento delle madri: un gruppo "estensivo" (Gruppo E) in cui le capre sono state alimentate al pascolo su erbaio; un gruppo "intensivo" (Gruppo I) in cui le capre sono state stabulate ed alimentate con fieno e concentrato. Le capre sono state munte una volta a settimana al fine di analizzare la composizione chimica, acidica e in CLA del latte. I capretti sono stati macellati all'età di 45 giorni. Le caratteristiche qualitative delle carni sono state valutate su campioni dei

muscoli *Longissimus lumborum* (Ll) e *Quardriceps femoris* (Qf). Complessivamente la carne dei capretti allevati con le madri alimentate al pascolo ha mostrato una maggiore concentrazione totale di CLA, sia nei campioni crudi (2.57 vs 2.25%) che in quelli cotti (1.85 vs 1.44%), anche se le differenze non attingono i livelli di significatività statistica.

Introduction

In South Italy's marginal areas, sheep and goat farming is traditionally performed using authocthonous breeds, well adapted to the environmental conditions and able to exploit the poor feed resources available. The animals usually graze on natural pastures and receive supplementary feeding at housing based on concentrates formulated in relation to their productive and physiological requirements. However, natural pastures are in decline due to the dry climatic conditions and to the continuous human interference with the environment, and so they are often unable to fulfil animal needs. This leads breeders to make a difficult choice between two possible solutions: sowing herbages or changing to more intensive breeding systems. The former solution has the advantage of being cheap, respectful of eco-sustainability and in line with the EU Common Agricultural Policy despite moderate profitability, while the latter increases farm management expenses in turn of higher productivity.

According to the local traditional rearing system, lambs and kids are raised with their mothers and suckle only maternal milk *ad libitum* until weaning, which occurs generally within 45 days of age, so that milk may be used for cheese-making. At this age lambs and kids may be slaughtered, especially during particular seasons of the year, providing meat which is greatly appreciated for its organoleptic features.

Previous research has focused on the quality of meat obtained from suckling animals (1-4). There is general agreement that during the pre-ruminant stage of life the fatty acid composition of the muscular and adipose tissues reflects that of the milk consumed (5-9).

On the other hand, the nutritional properties of ruminant milk are largely affected by diet (10, 11) and by season (12). Feeding is also the main factor influencing the Conjugated Linoleic Acid (CLA) content of ruminant milk (10, 11, 13-17).

CLA is produced by rumen biohydrogenation of linoleic acid and is defined as a mixture of geometric and positional isomers of linoleic acid with conjugated double bonds (13), naturally occurring in food products from ruminants (18). The concentration of CLA in milk depends on the amount of CLA escaped from the rumen and on the endogenous synthesis in the mammary gland by desaturation of vaccenic acid, an intermediate in the ruminal biohydrogenation of polyunsaturated fatty acids such as linoleic and linolenic acids (19). The CLA content in milk and meat depends on many factors, such as animal genotype, age and diet (20, 21). Although CLA accounts for a relatively small amount of the total fatty acid composition of foods, it is very important for human health (22, 23). Its main isomer, C18:2 cis-9, trans-11, is effective against cancer and atherogenic diseases (24-27) and also has positive effects on diabetes and on the immune system (24).

Many attempts have been made to improve the CLA content in ru-

minant products (28-30). A significant increase in the CLA concentration of milk was found in ewes (16, 31), goats (32) and cows (33) grazing on lush pastures. Feeding based on linseed, fresh forage or fish oil as rich sources of linolenic acid causes an increase of the intramuscular C18:2 cis-9, trans-11 concentration (34-37), although the results seem quite controversial (38).

So far there is only limited information as to how the goat diet and rearing system by affecting milk characteristics may influence the quality features and the CLA content of suckling kid meat.

The aim of this study was to evaluate whether goat rearing by extensive (grazing on pasture) or intensive production systems (feeding with concentrates and rearing indoors) affects growth performances, carcass characteristics, meat quality and CLA content in suckling kids fed only on maternal milk.

Materials and methods

Animals, diets and management

The trial was carried out on a private farm ("Azienda Bruno") in Laterza (40°37'30"N; 16°47'51"E; 340 m above the sea level), in the province of Taranto (Apulia, South Italy) during February-March 2005. All the procedures concerning animal handling and experimentation were performed in the respect of animal welfare according to the International Guidelines.

The study used twenty male Ionica-breed kids born as singletons from mature goats. The kids were reared with their dams, suckling only maternal milk *ad libitum* throughout the whole experimental period. Two groups of 10 kids each were formed according to their mothers' feeding treatment. One group of kids (Group I - Intensive) was raised under dams reared by an intensive production system, i.e. kept indoors in boxes and fed a diet based on hay *ad libitum* and concentrated feed (500 g/head/d), while the other (Group E - Extensive) was raised under dams grazing on pasture and receiving supplementary hay and concentrated feed (300 g/head/d) at housing.

The herbage used (4000 kg/ha) did not represent a limiting factor for goats' feeding. It consisted mainly of oats (*Avena sativa* L., 70%), vetch (*Vicia sativa* L., 20%) and red clover (*Trifolium incarnatum* L., 10%). The hay used for supplementation was produced the year before on a pasture with approximately the same floristic composition as the herbage described above. The concentrated feed contained (on as fed basis) crushed and hot-steamed corn (35%), faba beans (*Vicia faba* L. *minor*, 25%), barley (35%) and crushed carobs (5%). The chemical composition of the pasture, hay and concentrate was assessed (39) and the results are reported in table 1.

Milk sampling and analysis

The dams were hand milked once a week, for a total of 6 samplings during the experiment, twice daily (12 h apart). Per each day of col-

Table 1 - Chemical composition of pasture, hay and concentrated feed (% of as fed basis)

	Pasture grass	Hay	Concentrate
Moisture	64.20	15.40	14.00
Crude protein	6.00	5.30	12.50
Ether extract	1.80	1.50	2.20
NDF	20.64	64.50	25.30
ADF	12.35	40.80	17.40
Ashes	3.50	5.40	3.10

lection the morning and evening samples were mixed together in order to obtain a pool of milk for each group that was analysed for the chemical and fatty acid composition including CLA content.
The milk pool was split into two sub-samples: one was analysed fresh for fat, protein, lactose and total solids by using a Milkoscan equipment, while the other one was stored at -80°C until fatty acid analysis was performed.
Lipid extracts were prepared according to the method suggested by Folch et al. (40) using a chloroform/methanol 2:1 (v/v) solution. Fatty acids were methylated using a BF_3/methanol solution (12% v/v) and analysed by gas chromatography (Chrompack CP 9000) using a 50 m silicate glass column with a 0.25 mm internal diameter and 0.2 µm film thickness (9).
The CLA content in milk was determined by high performance liquid chromatography (HPLC) according to the method suggested by Banni et al. (41) preparing free fatty acids by a mild saponification (41). Briefly, aliquots (3 mg) of lipid extracts were dissolved in 5 ml of ethanol and 100 µl of desferal (25 mg/ml H_2O), to which 1 ml of a 25% water solution of ascorbic acid and 0.5 ml of 10N KOH was added. The solutions were left in the dark at room temperature for 14 h. After addition of 10 ml of n-hexane and 7 ml of H_2O, samples were acidified with 0.35 ml of HCl (37% v/v) to a pH of 3-4 and were then centrifuged for 1 h at 900 g. The hexane phase containing free fatty acids was collected, the solvent evaporated and the residue dissolved in 0.5 ml of CH_3CN 0.14% of CH_3COOH (v/v). Aliquots (8 µl) of the latter were injected into the HPLC Waters 600E multisolvent delivery system equipped with a 996 photodiode array detector. A C-18 Alltech Adsorbosphere column, 5 µm particle size, 250 x 4.6 mm, was used with a mobile phase of $CH_3CN/H_2O/CH_3COOH$ (70/30/0.12, v/v/v) at a flow rate of 1.5 ml/min. Conjugated diene fatty acids were detected at 234 nm. All solvents used were of HPLC grade. Hydroperoxy-octadecadienoic acid (HPODE) and desferal (deferoxamine methanesulfonate), an iron chelator, were purchased from Sigma Aldrich (Milan, Italy). A mixture of standard CLA was obtained from NU Chek Prep. Inc. (Elysian, MN, USA). All the other reagents and chemicals were the purest available.

Slaughtering procedures and carcass measurements

Individual kid weights were recorded weekly. At 45 days of age, kids were fasted for 12 h, submitted to body measurements and weighed before being slaughtered.
All the procedures involved in slaughter and carcass sectioning, dissection and evaluation were carried out according to the ASPA methods (42). After refrigeration at 0-4°C for 24 h, the carcasses were measured and cut into two halves. The right half-carcass was sectioned into commercial cuts, and of these the pelvic limb and the lumbar region were dissected in order to evaluate the tissue composition (percentage of lean, fat and bone).

Meat quality assessments

The pH values of the muscles *Longissimus lumborum* (Ll) and *Quadriceps femoris* (Qf) were recorded within 45 minutes after slaughter ($pH_{45\ m}$) and after 24 h refrigeration at 0-4 °C ($pH_{24\ h}$) using a penetrating glass electrode attached to a portable pH-meter. A colorimeter (HunterLab, Miniscan XE™, illuminant D65/10°) was used to assess meat colour on Ll and Qf samples by the Lab system (L = Lightness, a = redness and b = yellowness). Hue (h) and Chroma (C) were also calculated. Representative sub-samples were taken from Ll and Qf muscles and split into two pieces; one was used raw, while the other was cooked in a normal ventilated electric oven at 180°C until an internal endpoint temperature of 75°C was reached in the geometric centre of the meat

cut, as recorded by a thermocouple (Hanna Instruments, model HI 935005, Sarmeola di Rubano, PD, Italy) inserted into a meat sample placed in the centre of the wire rack (43). Cooking losses were calculated by weighing the meat samples before and after cooking. Raw and cooked meat samples taken from both the muscles examined were assessed for tenderness using a Warner Bratzler Shear (WBS) testing machine (Instron, model No. 5544, Canton, MA, USA). On raw meat, three cylindrical cores of 1.25 cm diameter were removed from each muscle, while cooked meat was cut in order to obtain three 1 cm^2 section parallelepipeds. All the meat cores were sheared perpendicularly to their long axis. Peak force was expressed as kg/cm^2. Raw and cooked meat samples obtained from the Ll muscle were homogenised in a grinder in order to perform chemical analysis and lipid extraction as described in the section above (40). The CLA content of raw and cooked meat samples was assessed according to the method suggested by Banni et al (33) as described above.

Statistical analysis

Data referring to the chemical and fatty acid composition of goat milk, to the physical and chemical features of kid meat and to the dissection of the lumbar region and pelvic limb were analysed by ANOVA using the GLM procedure of SAS (1999/2000), taking into consideration only the goat production system effect in a mono-factorial model. Means were compared using Student's T test.
Data concerning the parameters assessed on raw and cooked meat were processed by analysis of variance according to the following model: $y_{ijk} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \varepsilon_{ijk}$ where μ is the overall mean, α_i the effect of the goat production system (intensive or extensive), β_j the effect of cooking (raw or cooked meat), $\alpha\beta_{ij}$ the interaction of the production system with cooking and ε_{ijk} the residual experimental error. Student's T test was used to analyse differences between means.

Results and discussion

The mean chemical composition, main fatty acid classes and CLA concentration of goat milk are shown in table 2. Grazing on pasture significantly improved the total CLA concentration of goat milk compared to goats fed with only with concentrates (2.80 vs 2.45%; $P<0.05$). On the whole

Table 2 - Chemical and fatty acid composition and CLA content of goat milk

		Goat production system		
		Intensive (Group I)	Extensive (Group E)	SEM (DF = 18)
Fat	(%)	4.89	4.46	0.16
Protein	(%)	3.72	3.62	0.13
Lactose	(%)	4.49	4.65	0.09
Total solid	(%)	13.65	12.95	0.15
(% on total fatty acids)				
MUFA		21.67	23.90	0.59
PUFA		3.89	4.95	0.14
SFA		74.44	71.15	0.65
Total ω3		0.65	1.03	0.04
Total ω6		2.61	2.53	0.08
C18:3 ω3		0.46	0.72	0.05
C18:2 ω6		2.13	1.99	0.08
Total CLA		2.45b	2.80a	0.15

milk obtained from the grazing goats showed better dietetic properties since higher amounts of MUFA (23.90 vs 21.67), PUFA (4.95 vs 3.89%), ω-3 fatty acids (1.03 vs 0.65%) and C18:3 ω-3 were also found. These results are in general agreement with the findings obtained by Tsiplakou et al. (17) who reported that sheep and goats kept indoors had constantly lower levels of milk CLA. This evidence may be probably attributable to the lower amount of CLA precursors present in concentrates in comparison with fresh grass as well as to the ability of fresh grass to alter the rumen environment, by changing pH and/or affecting biohydrogenation pathways.

Data referring to the kids' weight gain during the experiment and to the yield of the commercial meat cuts at slaughtering have not been reported, since no significant differences were found between groups.

The physical and chemical features of the *Longissimus lumborum* and *Quadriceps femoris* muscles are shown in table 3.

Table 3 - Physico-chemical features of the *Longissimus lumborum* and *Quadriceps femoris* muscles of suckling kids

	Goat production system		SEM (DF = 18)
	Intensive (Group I)	Extensive (Group E)	
Longissimus lumborum			
$pH_{45\ min}$	6.73a	6.53b	1.4836
$pH_{24\ h}$	5.98	5.99	1.3383
L	48.86	50.63	4.0985
a	5.98	6.43	1.1303
b	11.93b	13.42a	1.6764
C (Chroma)	13.45b	14.92a	1.3555
h (hue angle)	62.75	64.34	6.2739
Cooking loss (%)	26.89b	31.51a	4.7300
Quadriceps femoris			
$pH_{45\ min}$	6.73	6.71	1.5026
$pH_{24\ h}$	6.09	6.01	1.3528
L	51.74	51.54	3.2491
a	5.56	5.97	1.3300
b	12.68	13.55	1.4990
C (Chroma)	13.96	14.84	1.3108
h (hue angle)	65.88	66.30	6.1619
Cooking loss (%)	21.75	22.93	3.7814

Differences between groups: a, b: $P<0.05$

Compared to the kids reared under grazing dams, meat obtained from the kids raised by the intensively reared goats showed a significantly higher pH value at 45 min after slaughtering (6.73 vs 6.53; $P<0.05$), and hence a greater reduction in pH from 45 min to 24 h. This may have affected meat colour, which was slightly darker in Group I kids. Moreover, in this group both the yellowness index and the Chroma value were significantly lower ($P<0.05$). Altogether the Group E kids displayed meat colour features ranging within values considered acceptable in terms of visual appearance. Grazing on pasture is well known to influence the colour of meat, making it generally darker than that obtained from concentrate-fed animals (35, 45), as a consequence of the greater physical exercise performed by animals grazing on pasture and of the higher myoglobin content of the muscles (46). However, in this study kids were fed only on maternal milk, so the meat colour featu-

res observed may depend only on the characteristics of the milk consumed, which may have been influenced by goat feeding. It may be hypothesised that since lush pastures are rich in natural antioxidants (47) these substances may have been transferred to goat milk and from the suckled milk to kid tissues.

A greater cooking loss (P<0.05) was recorded in Group E *Longissimus lumborum* than in Group I (31.50 vs 26.98%). Adversely, no significant differences arose between treatments for any of the parameters evaluated on the *Quadriceps femoris* muscle (Table 3).

Whether goats were fed at pasture or on concentrated feed did not affect the tissue composition of the meat cuts, as evidenced by the results reported in table 4. The dissection data of the lumbar region and of the pelvic limb were quite similar in the two treatment groups.

Table 4 - Dissection data of the lumbar region and pelvic limb (% of weight) of suckling kids

	Goat production system		
	Intensive (Group I)	Extensive (Group E)	SEM (DF = 18)
Pelvic limb (g)	820.00	868.00	188.7200
Lean	53.54	54.64	3.5673
Fat	11.23	11.03	3.5926
Bone	35.23	34.33	2.3959
Lumbar region (g)	282.00	298.00	64.8459
Lean	42.27	42.74	5.1351
Fat	15.55	15.25	5.6896
Bone	42.18	42.01	4.8807

The tenderness of raw meat in kids reared under goats grazing on pasture (Group E) was significantly better than Group I (Tab. 5), as evidenced by the lower peak force needed to shear meat (2.86 vs 3.58 kg/cm^2; P<0.05). After cooking, the meat samples obtained from the two groups displayed a different trend: tenderness of the meat from Group I was significantly improved following cooking (2.68 vs 3.58 kg/cm^2; P<0.01) while Group E cooked samples showed a greater peak force (3.28 vs 2.86 kg/cm^2), although the difference was not significant. The effects of cooking on tenderness

Table 5 - Tenderness of raw and cooked meat of the *Longissimus lumborum* and *Quadriceps femoris* muscles of suckling kids

Peak force (kg/cm^2)	Group I		Group E		SEM (DF = 116)	Significance of main effects and their interaction		
	Raw	Cooked	Raw	Cooked		Production system (P)	Cooking (C)	P x C
Ll	3.58aC	2.68D	2.86b	3.28	0.7224	ns	ns	**
Qf	2.07	2.19	1.50	2.11	0.7387	ns	ns	ns

Differences between groups: a, b: P<0.05; differences between raw and cooked samples within each group: C, D: P<0.01
**: P<0.01; ns: not significant

are probably attributable to the cooking loss which, as previously said, was greater in Group E in comparison with Group I.

The chemical composition of raw and cooked samples did not differ between groups (Tab. 6). Cooking significantly (P<0.01) affected the contents of moisture, protein and ether extract in both groups.

The results concerning the CLA content of meat are reported in table 7. The kids reared under goats grazing on pasture showed a higher total CLA content in raw (2.57 vs 2.25% of total fatty acids) and in cooked (1.85 vs 1.44%) meat, although the differences were not significant. In particular, raw meat samples from Group E contained a slightly better content of both the cis-9, trans-11 (2.08 vs 1.85%) and trans-10, cis-12 (0.49 vs 0.40%) CLA isomers. The cooked meat samples in Group E contained a higher content of the cis-9, trans-11 CLA isomer (1.52 vs 1.10%), but the differences were not significant. The CLA content in raw meat and meat products has been investigated in various animal species including lamb, beef, pork, chicken and turkey and also in other species less common in human diets, as recently reviewed by Schmid et al. (48). Moreover, the findings reported in various studies on meat CLA content are not easily comparable, due

Table 6 - Chemical composition of raw and cooked meat from the *Longissimus lumborum* muscle (% of dry matter) of suckling kids

	Group I		Group E		SEM	Significance of main effects and their interaction		
	Raw	Cooked	Raw	Cooked	(DF = 36)	Production system (P)	Cooking (C)	P x C
Moisture	74.40C	67.78D	75.40C	66.71D	0.2577	ns	**	*
Protein	75.20D	82.40C	76.48D	82.06C	3.0111	ns	**	ns
Ether extract	16.21C	8.67D	14.68C	9.17D	2.9907	ns	**	ns
Ashes	4.39	4.45	3.99d	4.64c	0.6068	ns	ns	ns

Differences between raw and cooked samples within each group: C, D: P<0.01; c, d: P<0.05;
**: P<0.01; *: P<0.05; ns: not significant

Table 7 - CLA content of raw and cooked meat samples of the *Longissimus lumborum* muscle (% of total fatty acids) of suckling kids

	Group I		Group E		SEM	Significance of main effects and their interaction		
	Raw	Cooked	Raw	Cooked	(DF = 36)	Production system (P)	Cooking (C)	P x C
$CLA_{c9,t11}$	1.85C	1.10D	2.08c	1.52d	0.5385	ns	**	ns
$CLA_{t10,c12}$	0.40	0.34	0.49c	0.33d	0.1752	ns	*	ns
CLA_{total}	2.25C	1.44D	2.57	1.85	0.6731	ns	*	ns

Differences between raw and cooked samples within each group: C, D: P<0.01; c, d: P<0.05;
**: P<0.01; *: P<0.05; ns: not significant

to the different units of measurement used to express concentration (mg CLA/g lipid; mg CLA/g FAME - Fatty Acid Methyl Ester; % CLA of total fatty acids). So far, to our knowledge, the scientific literature available is lacking in information about the CLA concentration in raw and cooked kid meat. The qualitative and quantitative assessment of the change in CLA isomer concentrations after cooking has been investigated in beef (49) and lamb (50). Shanta et al. (49) reported that the CLA concentration in broiled beef steaks cooked to an internal temperature of 80 °C was in general only slightly higher than in raw steaks, while Badiani et al. (50) found a significant increase of the CLA concentration in lamb after cooking. In this study, regardless of the goat production system, cooked meat contained lower amounts of CLA, which unfortunately is not really a desirable result since the healthy properties of an edible portion of kid meat are reduced after cooking.

Several Authors have found a seasonal variation of the CLA content in milk in grazing animals. Di Trana et al. (51) found that the CLA content of milk in grazing goats declined from Winter to Summer but it was always significantly greater than that of goats kept indoors. Tsiplakou et al. (17) reported that grazing sheep and goat milk contained the highest amount of CLA in April-May, i.e. during the early growth stage of grass. On the other hand Jahreis et al. (20) found that milk obtained from goats grazing on pasture had always a higher content of CLA than goats reared indoors throughout the year, except for March, that was the same period we carried out the experiment. Indeed, though we found more CLA in the grazing goats respect to those kept indoors an fed with concentrate, it may be assumed that the influence of season on the CLA content of goat milk may have levelled out the differences between extensively and intensively reared goats; consequently the CLA content in suckling kid meat did not differ markedly between the two groups, thus confirming the lack of rumen development and function at this stage of life.

Conclusion

Suckling kids raised under goats grazing on pasture and under goats fed on concentrate-based diet displayed similar meat quality features, except for colour and tenderness, which were generally more acceptable in kids suckling from extensively reared goats, while meat cooking loss was higher in this group. No significant differences arose between groups for the cis-9, trans-11 and trans-10, cis-12 CLA isomers investigated. Goat grazing on pasture slightly enhanced the total CLA concentration in suckling kid raw and cooked meat when compared to kids raised under goats reared according to an intensive production system. In conclusion, when goats graze on pasture, meat quality and CLA content in suckling kids fed only on maternal milk is improved, but the slight effect found is probably attributable to the influence of season on goat milk characteristics.

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