FATTY ACID COMPOSITION AND CONJUGATED LINOLEIC ACID CONTENT OF COW AND GOAT CHEESES FROM NORTHWEST ARGENTINA

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ABSTRACT

In this study, we evaluated chemical characteristics, fatty acid composition and conjugated linoleic acid (CLA) content of cow and goat cheeses from Northwest Argentina. Similar chemical and fatty acid composition were determined in milk and cheese of both species. Palmitic, oleic and myristic acids were the most abundant fatty acids in dairy products. CLA level averaged 0.85 and 0.96 in milk and 0.76 and 1.04 g/100 g of fatty acids in cheese of cow and goat, respectively. Cis-*9,*trans-*11 was the major isomer present in both species. Significant differences in CLA desaturase activity were observed, showing a value of 0.068 and 0.064 in milk, and 0.077 and 0.071 in cheese of cow and goats, respectively. Good nutritional properties were determined for cheeses of both species, which are fed on natural pasture during spring and summer seasons. Goat's cheese represents a higher source of CLA for human consumers than cow's cheese, offering from 156.6 to 222.6 mg/ 100 g of sample.*

PRACTICAL APPLICATIONS

The present work shows the fatty acid composition and chemical characteristics of two fresh cheeses manufactured with cow and goat milk. Animals were fed on natural pasture during summer and spring seasons. It is known that pasture increases conjugated linoleic acid (CLA) concentration in milk fat, and the content in cheese is directly related to it. The CLA content of dairy

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products for the human consumers was analyzed, showing goat cheese with high polyunsaturated fatty acid content, including CLA. Cow and goat fresh cheese offer CLA as many ripening products of different countries, as cheddar or hard cheeses. Lipid composition of food is related to many illnesses, but some compounds are beneficial to human health. The main sources of CLA are milk and cheeses, and in Northwest of Argentina, no data are reported about it, where artisanal cheeses are consumed by the population. Therefore, the atherogenicity index was determined as well.

INTRODUCTION

Milk fat plays an important role in the nutritional quality and technological properties of milk, and its composition is directly involved in the health of human consumers. Milk fat is a high source of saturated fatty acids, which are associated with the development of cardiac illnesses.

It is widely recognized that diet plays a primordial role in modulating fatty acid composition of ruminants' milk, and this fact was previously reported for cattle (Jensen 2002), goats (Chilliard *et al.* 2003) and sheep (Bocquier and Caja 2001). In Northwest Argentina, milk produced in small regional farms is exclusively used for artisanal cheese manufacture, and final products are used for population consumption. Cow and goat are the main ruminants of the region and are fed on grazing pasture during summer and spring seasons. There are no data available about milk or cheese fatty acid composition on these ruminants. There are only a few studies about fatty acid composition of buffalo milk and cheese (Van Nieuwenhove *et al.* 2004, 2007).

Many components of fat are related to beneficial health properties, such as conjugated linoleic acid (CLA), which is the generic name for a mixture of positional and geometrical isomers of linoleic acid (C18:2) with conjugated double bonds. CLA is present in meat and milk fat of ruminants, being dairy products as the main source for humans. It has important biological functions like anticarcinogenic properties (Shultz *et al.* 1992; Lee *et al.* 2005), hypocholesterolemic (Nicolosi *et al.* 1992) and antioxidant effects (Pariza *et al.* 2001). Among individual CLA isomers, the greatest attention has been focused on *cis*-9, *trans*-11 and *trans*-10, *cis*-12, both biologically active isomers.

Considerable efforts have been made to increase CLA content in milk and in this context, animals fed on pasture have shown the highest CLA levels (Dhiman *et al.* 1999; Lock *et al.* 2005).

The aim of this work was to determine chemical characteristics and fatty acid composition of cow and goat dairy products, obtained after a feeding based on natural pasture. We also evaluated each product as a natural source of CLA for human consumption.

MATERIALS AND METHODS

Milk Samples and Cheese Manufacture

Milk samples were obtained from small regional farms during summer season (February–March). Holando-Argentino cows' ($n = 11$) and Anglo-Nubian goats' ($n = 10$) milk were collected weekly for a month. All animals were fed on pasture *ad libitum* without forage supplement. Samples were delivered by refrigerated transport (4C) to our laboratory, pasteurized at 65C for 30 min and maintained at −20C until analysis or use for cheese manufacture. Four batches of cow and goat milk were used to elaborate fresh cheeses according to the regional manufacture process. Pasteurized milk was heated at 42C and starter culture (1%, v/v) was added. Starter culture was compounded by *Lactobacillus delbruekii* spp. *bulgaricus* CRL 423 and *Streptococcus thermophillus* CRL 728 (CRL: Centro de Referencia para Lactobacilos culture collection, Tucumán, Argentina). Bovine rennet (0.04%, v/v) was added after 2 h to accelerate milk coagulation, and cutting was started 40 min later using a 12 mm knife. Curd was molded and pressed for 2 h. Cheeses were salted by immersion in 25% (w/v) NaCl solution, pH 5.2, maintained for 1 day at 4C (1-day-old) and frozen at −20C until fatty acid analysis.

Chemical Analysis

Milk and cheese samples were analyzed for protein and fat content by micro-Kjeldahl technique (Case *et al.* 1985) and according to International Dairy Federation standards (1997), respectively. Cheeses were also analyzed for dry matter content according to International Dairy Federation standards (1982), and pH was measured with Metrohm pH-meter (model 692, Herisau, Switzwerland).

Lipid Analysis

Lipids were extracted using chloroform/methanol solution (2:1, v/v) according to Folch *et al.* (1957). Fatty acid methyl esters analyses were performed according to Chin *et al.* (1992), using HCl methanolic solution. All reagents and solvents used were purchased from Merck (Darmstadt, Germany).

One microliter of fatty acids methyl esters, dissolved in hexane, was injected to an Agilent Technologies gas chromatograph (Model 6890N, Wilmington, DE) equipped with a flame ionization detector and automatic injector (Model 7683, Agilent Technologies) into an HP-88 capillary column (100 m × 0.25 mm × 0.20 μm, Agilent Technologies). Gas chromatograph conditions were: injector temperature, 255C; the initial oven temperature of

75C was increased to 165C at 8C/min and held there for 35 min; increased to 210C at 5.5C/min and held for 2 min; and then increased to 240C at 15C/min and held for 3 min. Detector temperature was 280C. Oxygen-free nitrogen was used as carrier gas at a flow rate of 18 mL/min, at 38 psi. Fatty acids were identified by comparison of retention times with methylated standards (99% purity; Sigma, St. Louis, MO). CLA and fatty acids methyl esters were identified and quantified by comparison with the retention times and peak areas of Sigma standards. Results were expressed as g/100 g of fatty acids.

Statistical Analysis

All samples were analyzed in triplicate. Results were expressed as mean ± standard deviation, and data were statistically evaluated by analysis of variance test (Minitab® Release 14 Statistical Software, 2003 Minitab Inc., State College, PA). Differences were considered significant at $P < 0.05$.

RESULTS AND DISCUSSIONS

Cow and Goat Milk

The chemical properties and fatty acid composition of cow and goat milk are shown in Table 1. Protein level and fat content were similar among milks, having an average value of 3.3 and 3.4% for protein and 3.0 and 3.2% for fat, respectively.

Fatty acid composition was slightly different according to milk origin. Saturated fatty acids were the major fatty acids determined, reaching a value of 68.2 and 69.6 g/100 g of fatty acids in cow and goat milk, respectively. Among these, palmitic (C16:0), stearic (C18:0) and myristic (C14:0) acids were the most abundant fatty acids. The monounsaturated fatty acids were 26.6 and 27.4 g/100 g of fatty acids, respectively, with oleic acid (*cis*-9, C18:1) as the most abundant. Goat's milk showed high polyunsaturated fatty acid (PUFA) content with respect to cow's milk (4.7 and 3.0 g/100 g of fatty acids, respectively). The main differences among these were based on linoleic and linolenic acid concentrations, being both fatty acids of dietary origin. The concentration of linoleic and linolenic acid in milk fat depends on the amount that flow out of the rumen.

Milk fatty acid composition is related to the feeding of cattle and it is very different among species and regions, but the ratio of saturated and unsaturated fatty acids remains similar among milks.

CLA value was 0.96 g/100 g of fatty acids in goat milk, while in cow milk the value was 0.85 g/100 g of fatty acids. *Cis*-9, *trans*-11 was the major CLA isomer in both, being *trans*-10, *cis*-12 as the other isomer determined.

TABLE 1.
CHEMICAL CHARACTERISTICS OF COW AND GOAT'S MILK

	Cow	Goat
Protein (%)	3.3 ± 0.5^a	3.4 ± 0.6^a
Fat (%)	3.0 ± 0.8^a	3.2 ± 0.4^a
Fatty acids†		
C4:0	1.1 ± 0.3^a	0.9 ± 0.2^a
C6:0	2.4 ± 0.7^a	3.3 ± 0.3^b
C8:0	1.8 ± 0.4^a	3.2 ± 0.5^b
C10:0	3.4 ± 0.7^a	5.2 ± 0.8^b
C12:0	2.4 ± 0.3^a	2.5 ± 0.4^a
C14:0	12.5 ± 1.8^a	11.8 ± 2.2^a
C14:1	0.9 ± 0.2^a	0.9 ± 0.3^a
C15:0	3.0 ± 0.4^a	2.2 ± 0.6^a
C16:0	27.9 ± 4.0^a	27.2 ± 3.9^a
C16:1	1.2 ± 0.7^a	1.4 ± 0.4^a
C17:0	0.3 ± 0.1^a	0.4 ± 0.1^a
C18:0	12.8 ± 2.4^a	12.0 ± 1.5^a
C18:1 *trans*-11	3.5 ± 0.5^a	3.3 ± 0.7^a
C18:1 *cis*-9	20.8 ± 2.9^a	21.5 ± 2.5^a
C18:2	1.2 ± 0.4^a	2.1 ± 0.7^b
C18:3	0.8 ± 0.1^a	1.1 ± 0.3^b
CLA *cis*-9,*trans*-11	0.8 ± 0.1^a	0.9 ± 0.1^a
CLA *trans*-10,*cis*-12	0.05 ± 0.01^a	0.06 ± 0.01^a
C20:0	0.6 ± 0.3^a	0.9 ± 0.2^a
C20:1	0.2 ± 0.1^a	0.4 ± 0.2^a
C22:4	0.2 ± 0.1^a	0.4 ± 0.3^a
Saturated	68.2 ± 11.4^a	69.6 ± 10.7^a
Monounsaturated (%)	26.6 ± 4.4^a	27.4 ± 4.2^a
Polyunsaturated (%)	3.0 ± 0.8^a	4.7 ± 1.4^a
Δ^9-desaturase index	0.068 ± 0.001^a	0.064 ± 0.001^a
CLA desaturase index	0.18 ± 0.01^a	0.21 ± 0.01^b
Atherogenicity index	2.71 ± 0.58^a	2.40 ± 0.65^a

† Fatty acids content was expressed as g/100 g of fatty acids.
Different superscript letters indicate significant differences ($P < 0.05$).
Values were expressed as mean ± standard deviation.
CLA, conjugated linoleic acid.

Δ^9-Desaturase Activity in Mammary Gland and Atherogenicity Index

The mammary gland of ruminants has substantial Δ^9-desaturase activity, enzyme that can be measured indirectly by comparing the product: substrate ratio of certain fatty acids. Therefore, C14:1/C14:1+C14:0 ratio is the best indicator of this activity because all C14:0 in milk fat comes from *de novo* synthesis in the mammary gland (Lock *et al.* 2005).

In the present study, the C14:1/C14:1+C14:0 and *cis*-9, *trans*-11/*cis*-9, *trans*-11 + *trans*-11 C18:1 were determined as Δ^9 and CLA desaturase index, respectively (Table 1). Δ^9-Desaturase index (C14) was 0.068 and 0.064 for cow and goat milk, respectively. Lock and Garnsworthy (2003) reported an average value of 0.062 in cows, showing during summer months an average of 0.072. Significant differences were observed in CLA desaturase index, showing a value of 0.18 and 0.21 for cow and goat milk, respectively. Higher values for goat milk were reported by Nudda *et al.* (2006), which found a CLA desaturase index of 0.48. Kelsey *et al.* (2003) reported higher CLA desaturase index for cow milk as well, showing an average of 0.28.

The discrepancy between both desaturase indexes for cow and goat milk could be due to the fact that specific desaturase activity in the mammary gland depends on animal species.

The atherogenicity index, which characterizes the atherogenic potential of dietary fat, was calculated by using the following formula: $C12{:}0 + 4 \times C14{:}0 + C16{:}0/MUFA + PUFA$ (Chilliard *et al.* 2003). Foods with high atherogenicity index are considered more detrimental to human health. In the present study, this index for cow milk averaged 2.71, and lower value was determined in goat milk (2.40). Our results are coincident with those reported by Chilliard *et al.* (2003) for goat milk, which informed similar values according to feeding.

Cheese Composition

Chemical composition of fresh cheeses (1-day-old) is shown in Table 2. No statistical differences were determined among components of evaluated cheeses. Protein content in cow cheese was 18.8% and was 19.1% in goat cheese. Fat level was 20.6 and 21.4%, respectively. Slightly higher dry matter content was determined in cow than goat cheese, having a value of 40.1 and

TABLE 2.
CHEMICAL CHARACTERISTICS OF COW AND GOAT CHEESES

	Cow	Goat
Protein†	18.8 ± 2.2^a	19.1 ± 2.1^a
Fat†	20.6 ± 1.3^a	21.4 ± 1.8^a
Dry matter†	40.1 ± 2.1^a	39.3 ± 2.4^a
pH	5.3 ± 0.1^a	5.2 ± 0.1^a

† Results are expressed as percentage (mean ± standard deviation). Different superscript letters indicate significant differences ($P < 0.05$).

39.3%, respectively. Similar pH value was determined in both cheeses (5.3 and 5.2, respectively).

Table 3 shows the fatty acids composition of fresh cheeses. As in milk, saturated fatty acids were predominant in dairy products, reaching a value of 67.6 and 69.1 g/100 g of fatty acids for cow and goat cheese, respectively. Of the saturated fatty acid, C16:0 was found at the highest level, followed in turn by C18:0 and C14:0. Monounsaturated fatty acid content was 27.3 and 25.5 g/100 g of fatty acids, respectively, where the main fatty acid was *cis*-9 C18:1.

TABLE 3.
FATTY ACIDS COMPOSITION OF COW AND GOAT CHEESES

Fatty acids†	Cow	Goat
C4:0	1.1 ± 0.2^a	0.9 ± 0.2^a
C6:0	2.0 ± 0.3^a	3.2 ± 0.9^a
C8:0	1.7 ± 0.2^a	2.4 ± 0.6^b
C10:0	3.5 ± 0.7^a	5.2 ± 0.6^b
C 12:0	2.6 ± 0.4^a	2.9 ± 0.7^a
C14:0	12.0 ± 2.7^a	11.7 ± 2.0^a
C14:1	1.0 ± 0.4^a	0.9 ± 0.3^a
C15:0	3.0 ± 1.2^a	2.5 ± 0.5^a
C16:0	28.0 ± 3.2^a	27.0 ± 3.4^a
C16:1	1.2 ± 0.3^a	1.1 ± 0.4^a
C17:0	0.4 ± 0.1^a	0.6 ± 0.1^a
C18:0	12.3 ± 2.5^a	11.8 ± 2.0^a
C18:1 *trans*-11	3.8 ± 0.9^a	2.5 ± 0.8^a
C18:1 *cis*-9	21.0 ± 1.9^a	20.6 ± 2.3^a
C18:2	1.1 ± 0.3^a	2.0 ± 0.5^b
C18:3	0.7 ± 0.2^a	0.8 ± 0.1^a
CLA *cis*-9,*trans*-11	0.71 ± 0.3^a	0.95 ± 0.2^a
CLA *trans*-10,*cis*-12	0.05 ± 0.01^a	0.09 ± 0.02^b
C20:0	0.8 ± 0.2^a	0.9 ± 0.3^a
C20:1	0.3 ± 0.1^a	0.4 ± 0.1^a
C22:4	0.4 ± 0.1^a	0.5 ± 0.2^a
Saturated	67.6 ± 12.3^a	69.1 ± 11.3^a
Monounsaturated	27.3 ± 3.6^a	25.5 ± 3.9^a
Polyunsaturated	3.0 ± 0.9^a	4.3 ± 1.0^a
Δ^9-desaturase index	0.077 ± 0.026^a	0.071 ± 0.010^a
CLA desaturase index	0.16 ± 0.04^a	0.27 ± 0.06^b
Atherogenicity index	2.59 ± 0.62^a	2.57 ± 0.63^a

† Values were expressed as g/100 g of fatty acids (mean ± standard deviation).

Different superscript letters indicate significant differences ($P < 0.05$).

CLA, conjugated linoleic acid.

PUFA content was higher in goat (4.3 g/100 g of fatty acids) than cow cheese (3.0 g/100 g of fatty acids).

Different levels of CLA were obtained for cow (0.76 g/100 g of fatty acids) and goat (1.04 g/100 g of fatty acids) cheese, and this fact is directly related to its content in raw milk.

Higher Δ^9-desaturase index was observed in cow (0.077) than goat cheese (0.071). However, CLA desaturase index was lower in cow than goat cheese, having a mean value of 0.16 and 0.27, respectively. Atherogenicity index was similar in both cheeses, having an average of 2.59 and 2.57 for cow and goat cheese, respectively.

The *cis*-9, *trans*-11 is produced either as an intermediate product of the ruminal biohydrogenation of linoleic acid or in tissues, such as the mammary gland, by Δ^9-desaturase activity from vaccenic acid (Griinari *et al.* 2000). In the present study, CLA desaturase index was higher in goat than cow dairy products, and this fact could explain the higher CLA level in these products.

Previous studies reported CLA content in a variety of cheeses from several countries (Parodi 1999). CLA content in dairy products ranged from 0.27 to 1.44 g/100 g of fat, our results included in the interval informed. Our results for goat cheese showed similar CLA values to those reported for feta cheese manufactured with sheep and goat milk (Zlatanos *et al.* 2002). On the other hand, cow cheese from Northwest Argentina showed similar CLA content to that informed for Spanish cheese (Luna *et al.* 2005).

To determine the CLA level available in each dairy product, results were expressed as mg/100 g of sample (Table 4). Cow milk represents a lower source of CLA (25.5 mg/100 g of sample) than goat milk (30.7 mg/100 g of sample). In both species, *cis*-9, *trans*-11 represent more than 90% of total CLA in milk. Lower value was reported for this isomer in goat dairy products (Chung *et al.* 2005). The *trans*-10, *cis*-12 is mainly involved in lipid metabolism and has been shown to reduce body fat (Chung *et al.* 2005). However, in the present study, its content in dairy products is very low, accounting for less than 10%.

TABLE 4.
CONJUGATED LINOLEIC ACID (CLA) CONTENT IN COW AND GOAT DAIRY PRODUCTS

CLA content (mg/100 g of sample)	Milk		Cheese	
	Cow	Goat	Cow	Goat
Cis-9,*trans*-11	24.0	28.8	146.3	203.3
Trans-10,*cis*-12	1.5	1.9	10.3	19.2
Total CLA	25.5	30.7	156.6	222.6

CLA content was calculated by using mean value.

TABLE 5.
CONJUGATED LINOLEIC ACID (CLA) OFFERED FOR HUMAN CONSUMPTION BY DIFFERENT CHEESES

	Milk origin	CLA values (mg/100 g of sample)	Author
Mozzarella	Buffalo	152–227	Bergamo *et al.* (2003)
Cheddar	Cow	148–170	Shanta *et al.* (1995)
Swedish	Cow	190	Jiang *et al.* (1998)
Hard cheeses	Goat-Sheep	260	Zlatanos *et al.* (2002)

As in milk, cow cheese offers less CLA than goat cheese (156.6 and 222.6 mg/100 g of sample, respectively).

There are few data available about CLA content and isomers present in cheeses from different ruminants from Northwest Argentina (Van Nieuwenhove *et al.* 2004, 2007). However, CLA content in different fermented products has been reported by many authors.

The CLA level offered by each product is dependent on its fat content. Therefore, our results are compared with fresh and ripening cheeses (Table 5). CLA offered by cheeses manufactured in the present study (156.6 and 222.6 mg/100 g of sample) are similar to levels reported for other fresh cheese such as mozzarella (152–227 mg/100 g of sample). Ripening cheeses showed higher CLA content than fresh products, offering 170–260 mg/100 g of sample to the consumer.

CONCLUSION

In the present study, the concentration of *cis*-9, *trans*-11 and *trans*-10, *cis*-12- CLA were measured in cow and goat dairy products form Northwest Argentina. Milks were obtained during summer season after animal feeding on natural pasture. Milk and cheese from cow and goat presented good nutritional properties and a high CLA level. The main isomer determined in both was *cis*-9, *trans*-11. Therefore, both products represent a good source of CLA for human nutrition, with CLA being higher in goat milk and cheese.

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