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A comparative study of the fatty acid profiles in commercial sheep cheeses

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SUMMARY: The present study was carried out to characterize the FA profile of sheep cheese marketed in Chile. Fifty-eight cheeses were collected from supermarkets of 5 different Chilean cities including 34 sheep cheeses, 7 from goat's milk, 11 from cow's milk, 4 from a mixture of sheep, goat and cow's milk and 2 from a mixture of sheep and cow's milk. Compared to the cow and goat cheese (3.4 and 2.5 g·100g^{-1}), the sheep cheese (3.8 g·100g^{-1}) contained higher contents of C18:1t. The saturated and polyunsatured FA contents were greater in goat cheese than in sheep and cow cheese. The n6/n3 ratio was greater in goat (6.1) cheese than in sheep and cow cheese (3.8 and 5.2). The atherogenicity index was unaffected by cheese type, however, the thrombogenic index was lower in sheep cheese (2.8) than in goat and cow cheese (3.1 and 2.9). The n6/n3 ratio and thrombogenic index were lower in Chilean sheep cheese than in those imported from Europe. The fatty acid profile of cheese can be used to differentiate animal species from which the cheese is made and to some extent the geographical origin that may give some insight as to animal feed and production management.

KEYWORDS: *Cheese; Fatty acids; Milk; Sheep*

RESUMEN: ***Estudio comparativo del perfil de ácidos grasos de quesos de oveja comerciales***. Este estudio fue llevado a cabo para caracterizar el perfil de AG de quesos de oveja que se comercializan en Chile. Cincuenta y ocho quesos fueron recogidos de supermercados de 5 ciudades de Chile de los cuales 34 fueron de oveja, 7 de cabra, 11 de vaca, 4 de mezcla de leche de oveja, cabra y vaca y 2 de mezcla de leche de oveja y vaca. Comparado con quesos de vaca y cabra (3.4 y 2.5 g·100g^{-1}), los quesos de oveja (3.8 g·100g^{-1}) presentaron mayor contenido de C18:1t. Los AG saturados y poliinsaturados tuvieron concentraciones más altas en los quesos de cabra que en los quesos de oveja y vaca. La relación n6/n3 fue más alta en quesos de cabra (6.1) que en quesos de oveja y vaca (3.8 y 5.2). El índice aterogénico no fue afectado por el tipo de queso, sin embargo, el índice trombogénico fue menor en quesos de oveja (2.8) que en quesos de cabra y vaca (3.8 y 5.2). La relación n6/n3 y el índice trombogénico fueron menores en quesos chilenos que en quesos importados de Europa. El perfil de AG de quesos puede ser usado para diferenciar entre especies animales de las cuales proviene el queso y hasta cierto grado, el origen geográfico, ofreciendo indicios sobre el tipo de alimento y sistema productivo animal del cual provienen los quesos.

PALABRAS CLAVE: *Ácidos grasos; Leche; Oveja; Queso*

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1. INTRODUCTION

In Chile there has been a significant growth in cheese production (ODEPA, 2012) and at the same time, there has been an incipient market for sheep cheese because it is considered a gourmet product whose production is expected to increase in the forthcoming years. In Chile, cardiovascular diseases are the leading cause of death among adults and the prevalence of cardiovascular risk factors is similar to that of European and North American populations (Bunout and Escobar, 2000). In the last decade, consumers have become more concerned about the fat content of dairy products and this has led to the development of different nutritional strategies to improve the FA composition of dairy products such as cheese (Vera *et al*., 2009; Toro-Mujica *et al*., 2011). Producing cheese with an improved fatty acid (FA) composition could significantly increase economic returns to farmers (Vera *et al*., 2009). Ruminant cheeses have some FA that have beneficial effects on human health such as vaccenic (VA; C18:1t11) and conjugated linoleic acids (CLA; C18:2 c9, t11) (Aldai *et al*., 2013). It has been demonstrated that the modulation of dairy ewe diets (Vargas-Bello-Pérez *et al*., 2013 a,b) results in sheep cheese with reduced atherogenic and thrombogenic indices and low saturated FA contents.

The milk fatty acid profile of ruminants can be affected by different factors such as animal species, lactation stages, feeding, and genetics (Vargas-Bello-Pérez and Garnsworthy, 2013). Cheese fat from dairy ewes is characterized by high concentrations of FA made-up with 6–10 atoms of carbon (Partidário *et al*., 2008). Also, compared to bovines and goats, the CLA contents in sheep milk are greater (Shingfield *et al*., 2010).

Given that sheep cheese has fatty acids that may have positive effects on human health and its production could signify economic profits, the objective of the present study is to analyze the FA profile of commercial sheep cheese in Chile. The results could become the basis for developing benchmarking tools and strategies aiming at *improving* the nutritional characteristics of sheep cheese.

2. MATERIALS AND METHODS

2.1. Cheese samples

Fifty-eight cheeses were collected from supermarkets of 5 different Chilean cities (Santiago, Rancagua, Melipilla, Viña del Mar and Puerto Natales) including 34 sheep cheeses, 7 from goat's milk, 11 from cow's milk, 4 from a mixture of sheep, goat and cow's milk and 2 from a mixture of sheep and cow's milk. The sheep cheeses were produced in Chile (23 cheeses) and imported from France (2 cheeses) and Spain (9 cheeses). After collection, the cheeses were cut in four sections at which time two cores of each cheese were obtained and stored in re-sealable bags at –80 °C for one month until further analysis.

2.2. Fatty acid analysis

Two cores of each cheese were used for the FA analysis. The lipids from the cheese were extracted according to a chloroform/methanol (2:1, v/v) by Folch *et al*. (1957) method and methylated with the modifications of Sukhija and Palmquist (1988) using hexane as an organic solvent instead of benzene. Analyses of fatty acid methyl esters (FAME) were performed using a gas chromatograph (GC; Shimadzu Scientific Instruments AOC-20s, Columbia, MD, USA) equipped with a flame ionization detector, an autoinjector and an Rtx column (30 m × 0.32 mm × 0.20 μm column). The GC conditions were similar to those reported by Vargas-Bello-Pérez *et al*. (2013b). FA peaks were identified by using two FAME standards (GLC 60; Nu-Check-Prep, Elysan, MN, USA), and the Food Industry 37 FAME mix, 35077 Restek Co, Bellefonte, PA, USA). C18:1 *trans* isomers were detected by comparing retention times as reported by Ledoux *et al*. (2000).

2.3. Statistical analysis

The samples were assigned to four groups: cow, sheep, goat and mixtures. The samples were analyzed using ANOVA and multiple comparisons of means. In order to determine which FA was responsible for the differentiation between cheeses that were made from different animal species and geographical origin a multivariate analysis was carried out using a correlation matrix between individual FA to discard those that showed very high correlations ($r = >0.9$) as well as those without correlations. Bartlett's test of sphericity was applied to examine the hypothesis that the variables were uncorrelated in the population and the Kaiser-Meyer-Olkin index was used to measure sampling adequacy. Hierarchical clustering was then performed and a discriminant analysis was used to verify the extent to which samples were correctly assigned to the clusters identified in the previous analysis. To check for possible differences among cheeses associated with country of origin (Chile, Spain and France) an individual analysis of variance and multiple means comparison were performed. The SPSS statistical software for Windows was used (version 15.0.0; SPSS Inc., Chicago IL, USA).

3. RESULTS AND DISCUSSION

3.1. Fatty acid profile of cheeses

From the cheese samples analyzed, only C17:0 was not different among animal species (Table 1). Regardless of cheese type, C10:0, C14:0, C16:0,

TABLE 1. Fatty acid profile (mean ± standard deviation) of cheese from different animal species ($g \cdot 100g^{-1}$ of total FAME)

Fatty acid	Cow (n = 11)	Sheep (n = 34)	Goat (n = 7)	Mixture (n = 6)	P-value
C4:0	1.32±0.15^{c}	1.18±0.17^{b}	1.01±0.07^{a}	1.18±0.07^{b}	0.001
C6:0	1.08±0.05^{a}	1.36±0.19^{bc}	1.44±0.11^{c}	1.21±0.11^{ab}	<0.001
C8:0	0.81±0.05^{a}	1.62±0.29^{c}	2.06±0.24^{d}	1.29±0.25^{b}	<0.001
C10:0	2.17±0.23^{a}	5.92±1.06^{c}	8.44±1.22^{d}	4.47±1.07^{b}	<0.001
C12:0	2.93±0.38^{a}	3.99±0.59^{b}	4.46±0.82^{b}	3.18±0.54^{a}	<0.001
C14:0	11.1±0.62^{ab}	11.43±1.15^{b}	10.53±0.82^{a}	10.23±1.01^{a}	0.028
C14:1c9	1.62±0.17^{c}	0.84±0.13^{b}	0.49±0.04^{a}	0.91±0.22^{b}	<0.001
C15:0	1.35±0.25^{b}	1.34±0.25^{b}	1.01±0.12^{a}	1.05±0.21^{a}	0.001
C16:0	31.84±3.08^{b}	28.55±2.33^{a}	29.88±1.1^{ab}	30.9±1.87^{b}	<0.001
C16:1c9	2.01±0.14^{c}	1.4±0.39^{b}	0.74±0.25^{a}	1.37±0.36^{b}	<0.001
C17:0	0.73±0.12	0.76±0.14	0.69±0.10	0.69±0.17	0.418
C17:1n3(c10)	0.34±0.05^{b}	0.36±0.07^{ab}	0.29±0.07^{a}	0.32±0.07^{ab}	0.047
C18:0	12.12±1.39^{ab}	11.64±1.91^{ab}	11.08±1.33^{a}	13.12±1.53^{b}	0.159
C18:1t	3.36±1.65^{ab}	3.77±1.21^{b}	2.47±1.26^{a}	2.7±0.65^{ab}	0.050
C18:1n9c	22.52±1.52^{b}	19.64±1.92^{a}	19.75±2.93^{a}	22.68±1.35^{b}	<0.001
C18:2n6(t9,12)	0.41±0.07^{a}	0.58±0.13^{b}	0.52±0.23^{ab}	0.41±0.10^{a}	0.001
C18:2n6(c9,12)	2.15±0.41^{a}	2.22±0.42^{a}	3.22±0.43^{b}	2.2±0.33^{a}	<0.001
C18:3n6(c6,9,12)	0.06±0.07^{a}	0.34±0.07^{c}	0.24±0.07^{b}	0.29±0.08^{bc}	<0.001
C18:3n3(c9,12,15)	0.63±0.27^{a}	0.96±0.34^{b}	0.77±0.47^{ab}	0.55±0.33^{a}	0.009
C20:1n9(c11)	1.26±0.67^{ab}	1.49±0.59^{b}	0.74±0.29^{a}	0.86±0.29^{a}	0.005
Others	0.95±0.15^{a}	0.6±0.24^{b}	0.18±0.10^{a}	0.39±0.11^{a}	<0.001
Short chain FA	2.40±0.15	2.53±0.33	2.44±0.15	2.39±0.05	0.434
Medium chain FA	5.91±0.65^{a}	11.53±1.89^{c}	14.96±2.06^{d}	8.93±1.75^{b}	<0.001
Short + medium chain FA	5.39±0.29^{a}	8.14±1.34^{b}	10.07±1.62^{c}	12.94±1.53^{d}	<0.010
Long chain FA	57.13±2.23^{b}	53.72±1.83^{a}	53.19±1.21^{a}	55.99±1.63^{b}	<0.001
Saturated FA	65.45±2.57^{a}	67.78±2.14^{b}	70.6±1.84^{c}	67.32±2.09^{ab}	<0.001
Monounsaturated FA	31.11±2.61^{c}	27.51±1.93^{b}	24.47±2.2^{a}	28.83±1.85^{b}	<0.001
Polyunsaturated FA	3.25±0.28^{a}	4.11±0.61^{b}	4.75±0.77^{c}	3.45±0.51^{a}	0.009
PUFA n3	0.63±0.27^{a}	0.96±0.34^{b}	0.77±0.47^{ab}	0.55±0.33^{a}	<0.001
PUFA n6	2.62±0.43^{a}	3.15±0.49^{b}	3.98±0.46^{c}	2.9±0.37^{ab}	<0.001
PUFA n6/ PUFA n3	5.17±2.82^{ab}	3.79±1.81^{a}	6.09±1.79^{b}	6.45±2.78^{b}	<0.007
PUFA/SFA	0.049±0.005^{a}	0.061±0.009^{b}	0.067±0.011^{b}	0.051±0.009^{a}	<0.001
Atherogenicity index[1]	2.33±0.35	2.49±0.35	2.63±0.29	2.34±0.32	0.226
Thrombogenic index[2]	2.94±0.44^{ab}	2.81±0.28^{a}	3.1±0.28^{b}	3.09±0.34^{ab}	0.070

Short-chain FA = C4:0-C6:0; Medium-chain FA = C8:0-C12:0; Short- + medium- chain FA = C4:0-C10:0; Long-chain FA = ≥C14:0;^{a,b,c} Means in the same row with different superscripts are different ($P<0.05$). [1]Atherogenicity index = [(12:0 + 4(14:0) + 16:0] /[(n6 + n3) PUFA + 18:1 + ΣMUFA] (Ulbricht and Southgate, 1991); [2]Thrombogenic index = (14:0 + 16:0 + 18:0)/ [(0.5×18:1) + 0.5(ΣMUFA) + 0.5(n6PUFA) + 3(n3PUFA) + (n3PUFA/n6PUFA)] (Ulbricht and Southgate, 1991).

C18:0, C18:1 t11 and C18:1c9 represented around 78% of the total FA, and these results agree with those reported previously (Partidário *et al.*, 2008; Walther *et al.*, 2008). As reported by Park *et al.* (2007), sheep and goat cheese contained higher contents of caproic (C6:0), caprylic (C8:0), capric (C10:0) and lauric (C12:0) acids than cow cheese. Fatty acids which are formed by 4 to 14 carbons arise chiefly from *de novo* synthesis whereas FAs with more than 16 carbons are derived from the uptake of circulating lipids. Ruminants utilize acetate produced by the ruminal fermentation of carbohydrates (contained in dietary fiber) as the major carbon source (Bauman and Griinari, 2003). Fatty acids with less than 12 carbons are associated with the typical flavors of small ruminant cheese and

can also be used to detect mixtures of milk from different species (Park *et al*., 2007).

Compared with cow and goat, sheep cheese had higher contents of C18:1 *trans* isomers. In ruminant fat, vaccenic acid (VA; C18:1 t11) is the most common C18:1 *trans* isomer accounting for 60 to 80% of the total trans FA (Vargas-Bello-Pérez and Garnsworthy, 2013). VA can be converted to C18:2 c9, t11 (rumenic acid; RA) through the action of stearoyl coenzyme A desaturase and it has been estimated that 20% of VA can be converted to RA in humans. The RA has been identified as anti-carcinogenic, anti-atherosclerotic, antioxidant, and immunomodulator (Young *et al*., 2013). The C18:1 *trans* isomer contents in sheep cheese are similar to those reported in Italian (Nudda *et al*., 2005) and Spanish (Luna *et al*., 2005) cheeses. This may be due to the feeding practices.It is possible that those cheeses came from farms where the sheep were fed with fresh pastures or supplemented with oilseeds. When pasture inclusion increases in the total diet, linear increases in C18:3n3, C18:1 t11 and C18:2 c9t11 and decreases in C10:0–C16:0 are observed (Chilliard *et al*., 2007). On the other hand, oilseeds are rich sources of polyunsaturated fatty acids (PUFA), which, after being biohydrogenated in the rumen, can increase the concentrations of health promoting FA such as linolenic (C18:3n3) and rumenic acids (Zhang *et al*., 2006).

Interestingly, the C18:1 *trans* isomers and C18:3n3 contents were higher in Chilean sheep cheese than in the French and Spanish cheese (Table 2). As mentioned before, those FA can be improved when the ewe diet is based mostly on pastures. In Chile, sheep production is based largely on grazing systems, however, in Spain for example, sheep cheese is produced throughout the year leading to an intensification of reproductive management, and a reduction in grazing periods (Riedel *et al*., 2007). This type of system results in a substitution of on-farm natural resources (forages and pastures) with external inputs (conserved forages and concentrates) (Vera *et al*., 2009). No differences were observed between French and Spanish sheep cheese so it is possible that these countries have similar conditions among their production systems including feeding, breeds and level of intensification of farm management (Riedel *et al*., 2007).

3.2. Nutritional value of total lipids in cheeses

Nutritional recommendations are based on different ratios such as PUFA n6/ PUFA n3 and PUFA/SFA; these values are used to evaluate the nutritional value of fat for human consumption. The values for PUFA/SFA found in our cheese samples were below the recommended amount (above 0.45) for the human diet whereas only the values for sheep cheese were below the recommended level (less than 4.0) for the PUFA n6/PUFA n3 ratio (British Department of Health, 1994). Compared to cow and goat, sheep cheese had a lower thrombogenic index and intermediate concentrations of SFA, MUFA and PUFA (Table 1). Saturated FA are known to increase the risk of coronary heart disease (CHD; Williams *et al*., 2000), on the contrary, milk MUFA and PUFA (e.g., C18:2 c9, t11) can reduce the risk of CHD and prevent some types of cancer (Mohammadzadeh *et al*., 2013). However, there is a lack of scientific evidence that other SFA such as C4:0-C10:0 (short- and medium- chain FA; SMFA) have an effect on blood cholesterol and CHD risk (Astrup *et al*., 2011). In this study, compared to cow and sheep, goat cheese had higher contents of SMFA.

From the human health perspective, in this study, Chilean sheep cheese could be considered healthier than those imported from Europe; this is supported by the higher PUFA n3 and lower PUFA n6 contents (consequently lower PUFA n6/ PUFA n3 ratio) found in the Chilean sheep cheese (Table 2). The PUFA n3 play an important role in the prevention and control of coronary artery disease, hypertension, diabetes, arthritis, autoimmune disorders and cancer (Simopoulos, 2000).

3.3. Multivariate analysis

The correlation matrix of FA discarded C4:0, C6:0, C18:0 and C20:1n9 (c11). The principal component analysis (PCA) carried out on the 16 remaining FA resulted in 4 principal components (PCs) which explained 0.84 of the overall variance in the data. PC1 and PC2 explained 0.34 and 0.28 of the variation in FA contents (Table 3). The KMO index was 0.62, whereas the Bartlett's test of sphericity showed the suitability ($P<0.001$) of those variables selected for analysis.

Three groups were found after PCA was carried out in order to obtain data clusters related to the fatty acid profiles of the cheeses. Group I was formed by 26 samples from which 23 were Chilean sheep cheeses, 2 were Chilean mixture cheeses (90% sheep and 10% cow milk) and 1 Chilean goat cheese. Group II was composed of 13 samples from which 11 were Chilean cow cheeses and 2 were Spanish mixture cheeses (proportion of milks was not found in the label). Finally, Group III was formed by 19 samples from which 9 were Spanish sheep cheeses, 2 were French sheep cheeses, 2 were Spanish mixture cheeses and 6 were Chilean goat cheeses.

PC1 consisted of the typical FA that can be found in the milk of small ruminants (C8:0 and C10:0) (Partidário *et al*., 2008) whereas C14:1c9 and C16:1c9 are usually detected in the milk and cheeses of cows (O'Donnell *et al*., 2010). Figure 1 shows a clear difference among animal species particularly

TABLE 2. Fatty acid profile (mean ± standard deviation) of sheep cheese from different geographical origins (g·100g^{-1} of total FAME)

Fatty acid	Chile (n=23)	France (n=2)	Spain (n=9)	P-value
C4:0	1.09±0.16^{a}	1.18±0.19^{ab}	1.32±0.10^{b}	0.003
C6:0	1.3±0.21^{a}	1.54±0.10^{a}	1.42±0.13^{a}	0.122
C8:0	1.53±0.31	1.94±0.19	1.7±0.19	0.087
C10:0	5.61±1.13	7.15±0.29	6.23±0.71	0.072
C12:0	3.84±0.60	4.67±0.07	4.13±0.45	0.090
C14:0	11.6±1.25	11.81±0.10	10.85±0.64	0.215
C14:1c9	0.92±0.09^{b}	0.69±0.01^{a}	0.7±0.06^{a}	<0.001
C15:0	1.46±0.21^{b}	1.08±0.01^{a}	1.09±0.08^{a}	<0.001
C16:0	28.88±2.79	28.25±0.55	27.8±1.20	0.527
C16:1c9	1.52±0.40	1.3±0.02	1.19±0.27	0.090
C17:0	0.8±0.15^{b}	0.66±0.02^{ab}	0.67±0.04^{a}	0.037
C17:1n3(c10)	0.39±0.07^{b}	0.29±0.04^{a}	0.30±0.02^{a}	0.001
C18:0	11.14±2.09	12±0.47	12.81±1.22	0.093
C18:1t	4.26±1.18^{b}	2.84±0.48^{ab}	2.95±0.59^{a}	0.007
C18:1n9c	19.1±1.89^{a}	19.27±0.07^{ab}	21.38±1.14^{b}	0.007
C18:2n6(t9,12)	0.59±0.10	0.41±0.08	0.56±0.12	0.075
C18:2n6(c9,12)	1.98±0.26^{a}	2.46±0.05^{b}	2.69±0.29^{b}	<0.001
C18:3n6(c6,9,12)	0.34±0.08	0.3±0.03	0.35±0.05	0.628
C18:3n3(c9,12,15)	1.1±0.25^{b}	0.78±0.09^{ab}	0.59±0.14^{a}	<0.001
C20:1n9(c11)	1.86±0.42^{b}	0.93±0.19^{a}	0.83±0.15^{a}	<0.001
Others	0.68±0.24^{b}	0.48±0.05^{ab}	0.43±0.13^{a}	0.014
Short chain FA	2.39±0.33^{a}	2.72±0.08^{ab}	2.74±0.23^{a}	0.019
Medium chain FA	10.98±1.97	13.76±0.55	12.05±1.33	0.070
Short + medium chain FA	9.54±1.7	10.67±1.09	11.81±0.4	0.050
Long chain FA	53.88±2.03	53.8±1.15	53.22±1.49	0.676
Saturated FA	67.25±2.15	70.27±0.68	68.01±1.21	0.097
Monounsaturated FA	28.05±1.93	25.30±0.63	27.37±1.06	0.091
Polyunsaturated FA	4.02±0.57	3.95±0.10	4.2±0.48	0.678
PUFA n3	1.09±0.25^{b}	0.78±0.10^{ab}	0.59±0.14^{b}	<0.001
PUFA n6	2.92±0.36^{a}	3.17±0.03^{ab}	3.61±0.37^{b}	<0.001
PUFA n6/ PUFA n3	2.76±0.61^{a}	4.1±0.51^{b}	6.41±1.27^{c}	<0.001
PUFA/SFA	0.059±0.009	0.056±0.002	0.062±0.008	0.703
Atherogenicity index[1]	2.49±0.37	2.74±0.1	2.39±0.17	0.380
Thrombogenic index[2]	2.71±0.25^{a}	3.09±0.18^{b}	2.96±0.19^{b}	0.019

Short-chain FA = C4:0-C6:0; Medium-chain FA = C8:0-C12:0; Short- + medium- chain FA = C4:0-C10:0; Long-chain FA = ≥C14:0; ^{a,b,c} Means in the same row with different superscripts are different ($P<0.05$). [1]Atherogenicity index = [(12:0 + 4(14:0) + 16:0] /[(n6+n3)PUFA + 18:1 + ΣMUFA] (Ulbricht and Southgate, 1991); [2]Thrombogenic index = (14:0 + 16:0 + 18:0) / [(0.5×18:1) + 0.5(ΣMUFA) + 0.5(n6PUFA) + 3(n3PUFA) + (n3PUFA/n6PUFA)] (Ulbricht and Southgate, 1991).

between Groups I and II. PC2 comprised C16:0, C18:1t, C18:3n3 and C18:2n6, and therefore, the cheese in this PC may have a high MUFA/SFA ratio. Group I (mainly Chilean cheeses) had higher proportions of these FA.

The different data clusters obtained in this study showed that some FA vary depending on animal species, however, there are some confounding factors related to the type of feed, production system and breed of animals (Carta *et al.*, 2008). For example, in Group III, where most of the European cheeses were grouped, most of the production systems may be intensive and their feeding management relies on high-concentrate diets (Sanz Sampelayo *et al.*, 2007).

TABLE 3. Principal component (PC) analysis related to the fatty acid profile of cheese

PC	Eigenvalue	Variables	Correlation
1	5,1	C8:0	0,90
	33,7[1]	C10:0	0,92
	(33,7)[2]	C14:1c9	−0,94
		C16:1c9	−0,85
2	4,1	C16:0	−0,67
	27,5	C18:1t	0,92
	(61,2)	C18:2n6(t9,12)	0,72
		C18:3n3(c9,12,15)	0,76
3	2,0	C15:0	0,74
	13,1	C17:0	0,88
	(74,3)	C17:1n3(c10)	0,91
4	1,4	C14:0	0,93
	9,3	C18:1n9c	−0,81
	(83,6)		

[1]Proportion of variance explained; [2]Variance accumulated.

These particular characteristics of production systems, animals, feedstuffs, etc., are closely related to the organoleptic characteristics of cheese that lead to the creation of the Protected Denomination of Origin (PDO) or Protected Geographical Identification (PGI) regimes (Martínez *et al*., 2011) and therefore become useful tools for creating strategies aiming at improving the nutritional characteristics of sheep cheese in Chile.

4. CONCLUSIONS

The results indicated that the FA profiles of Chilean cheese were desirable from a human health standpoint. The fatty acid profile of cheese can be used to differentiate the animal species from which the cheese is made and to some extent the geographical origin that may give some insights into animal feed and production management. The data from this study could be used to develop benchmark tools and strategies aiming at improving the nutritional characteristics of sheep cheese.

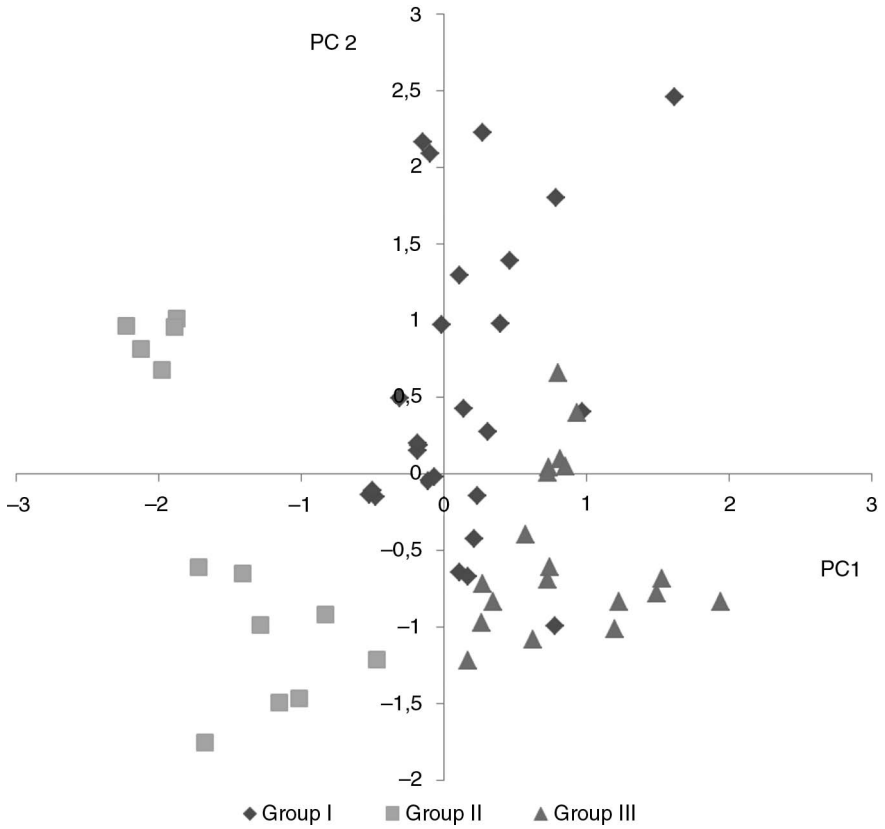

FIGURE 1. Positioning of the cheeses according to the scores obtained for PC 1 and PC 2.
Three groups were found after PCA was carried out in order to obtain data clusters related to the fatty acid profiles of the cheese. Group I: 26 samples from which 23 were Chilean sheep cheeses, 2 were Chilean mixture cheeses (90% sheep and 10% cow milk) and 1 Chilean goat cheese. Group II: 13 samples from which 11 were Chilean cow cheeses and 2 were Spanish mixture cheeses (proportion of milks was not found in the label). Group III: 19 samples from which 9 were Spanish sheep cheeses, 2 were French sheep cheeses, 2 were Spanish mixture cheeses and 6 were Chilean goat cheeses.

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