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Chemical and fatty acid composition of Manchego type and Panela cheeses manufactured from either hair sheep milk or cow milk

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ABSTRACT

This study compared the chemical composition and fatty acid (FA) profile of Manchego type cheese and Panela cheese made from hair sheep milk and compared these with both types of cheese manufactured with cow milk as a reference. In addition, this study aimed to determine differences in sensory characteristics between Manchego type cheeses manufactured with either hair sheep milk or cow milk. A total of 25 and 14 Manchego type cheeses from hair sheep milk and cow milk were manufactured, respectively. In addition, 30 and 15 Panela cheeses from hair sheep milk and cow milk were manufactured, respectively. The chemical composition and FA profile were determined in all cheeses. In addition, a sensory analysis was performed in Manchego type cheeses manufactured from either hair sheep milk or cow milk. Moisture content was lower in Manchego type cheeses (37.5 ± 1.26 and 37.5 ± 1.26 g/100 g in cheeses manufactured from hair sheep milk and cow milk, respectively) than in Panela cheeses (54.0 ± 1.26 and 56.1 ± 1.26 g/100 g in cheeses manufactured from hair sheep milk and cow milk, respectively). Ash, protein, and sodium contents were higher in Manchego type cheeses than in Panela cheeses. Manchego type cheese manufactured from hair sheep milk contained more C4:0, C6:0, C8:0, C10:0, C12:0, C14:0, C18:2 *cis*-9,*cis*-12, total saturated FA, total short-chain FA, total medium-chain FA, total polyunsaturated FA, and de novo FA than Manchego type cheeses from cow milk. Total content of short-chain FA was higher in hair sheep cheeses (24.4 ± 1.30 and 19.6 ± 1.30 g/100 g in Manchego type and Panela cheeses, respectively) than in cow cheeses (8.89 ± 1.30 and 8.26 ± 1.30 g/100 g in Manchego type and Panela cheeses, respectively). Manchego type cheeses from hair sheep milk obtained higher scores for odor (7.05), texture (6.82), flavor (7.16), and overall acceptance (7.16) compared with those made from cow milk (6.37, 6.12, 6.17, and 6.83, respectively). In conclusion, both Manchego type cheese and Panela cheese manufactured with hair sheep milk had a similar chemical composition and contained higher levels of short-chain FA, total polyunsaturated FA, and de novo FA than those manufactured with cow milk.
Key words: sheep, cheese, milk, innovation, tropical

INTRODUCTION

Milk produced by dairy cows represents approximately 81% of global dairy production, followed by milk produced by buffaloes, goats, sheep, and camels, which represents 15, 2, 1, and 0.5% of the milk produced worldwide, respectively (FAO, 2020). The high content of protein, fat, and total solids in sheep milk makes it particularly suitable for cheese manufacturing (Albenzio et al., 2016).

Both the global sheep dairy industry and its associated cheese industry are markedly regionalized (FAO, 2020). Unlike the original Manchego cheese manufactured from sheep milk in Spain, Manchego type cheese in Mexico is manufactured from pasteurized whole cow milk and calf rennet extract (González-Córdova et al., 2016). This type of cheese represents one of the most important ripened cheeses in Mexico (Salazar-Montoya et al., 2018), with a high economical value in the Mexi-

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can retail sector. On the other hand, consumption of fresh cheeses represents approximately 80% of the total cheese consumed in Mexico, with Panela cheese being one of the most purchased products (Jiménez-Guzmán et al., 2009). Panela cheese is a white soft cheese produced by enzymatic or acid coagulation of pasteurized whole milk (Ramírez-López and Vélez-Ruiz, 2018).

In Mexico, particularly in the tropical regions, hair sheep breeds such as Pelibuey are typically bred for meat production because milk production from this breed is currently not relevant for farmers (Castellanos and Valencia, 1982). However, Chay-Canul et al. (2019) reported that milk yields in Pelibuey sheep can reach 1.4 kg/d, suggesting the potential of using the milk from this hair breed for cheese manufacturing in tropical regions.

The fatty acid (**FA**) profile differs between cheeses manufactured with either sheep or cow milk, especially short-chain FA (**SCFA**; Aguilar et al., 2014) and odd- and branched-chain FA (Ha and Lindsay, 1991), which in turn plays a major role in the cheese sensory characteristics. Based on these facts, studies to characterize and differentiate cheeses manufactured from hair sheep and cow milk are necessary. Therefore, this study aimed to compare the chemical composition and FA profile of Manchego type and Panela cheeses manufactured with hair sheep milk and to compare them to those cheeses manufactured with cow milk. In addition, this study aimed to determine differences in sensory characteristics between Manchego type cheeses manufactured with either hair sheep milk or cow milk.

MATERIALS AND METHODS

Experimental Site and Animal Management

Animals were handled according to the guidelines and regulations for animal experimentation of the Academic Division of Agricultural Sciences, Universidad Juárez Autónoma de Tabasco (UJAT-DACA-2015-IA-02). The study was carried out at the Sheep Integration Center of the Southeastern (Villahermosa-Teapa, Tabasco, Mexico).

Thirty-six Pelibuey ewes (60 ± 3 DIM) were confined in 6 raised-floor pens (6 × 4 m). Animals were fed a diet consisting of grass hay (i.e., *Cynodon nlemfuensis*; 60% DM), ground corn (20% DM), soybean meal (15% DM), molasses (3% DM), and a premix of vitamins and minerals (2% DM). Crude protein represented 15% of DM, and the diet contained ME equivalent to 12 MJ/kg of DM according to the guidelines for sheep feed rations (AFRC, 1993). Hair sheep were hand-milked once daily at 0700 h. The whole milk from all animals was pooled for cheese manufacturing.

Twenty crossbreed cows (Holstein × Zebu; 103 ± 20 DIM) were used. The cows were kept in a paddock and allowed to graze stargrass (i.e., *Cynodon nlemfuensis*) and humidicola grass (i.e., *Brachiaria humidicola*) and were supplemented during milking with a commercial concentrate (2 kg/d) with 18% CP (DM basis) and 12 MJ of ME/kg of DM (NRC, 2001). The concentrate consisted of soybean meal (33% DM), ground corn (60% DM), molasses (5% DM), and a premix of vitamins and minerals (2% DM). Cows were hand-milked once daily at 0700 h. The whole milk from all animals was pooled for cheese manufacturing.

Manchego Type Cheese Manufacturing

Cheeses were manufactured at the Dairy Products Technology Laboratory (Academic Division of Agricultural Sciences, Universidad Juárez Autónoma de Tabasco, Mexico). Milk from hair sheep and cows was obtained during the dry season between May and August 2015.

Two batches (75 L each) of hair sheep milk and 2 batches (75 L each) of cow milk were used for Manchego type cheese manufacturing. Both hair sheep milk and cow milk were processed using the protocol from Lobato-Calleros et al. (2001). Briefly, milk was pasteurized for 30 min at 63°C and cooled to 35°C. Immediately after, a mix of *Lactococcus lactis* ssp. *lactis* and *Lactococcus lactis* ssp. *cremoris* (French Bioprox M 195) was inoculated and allowed to ferment for 30 min. After fermentation, 50% (wt/vol) $CaCl_2$ was added at a proportion of 21 mL/100 L of milk followed by the addition of a commercial rennet (Cuamex) at a proportion of 30 mL/100 L and kept at 35°C and allowed to coagulate for 45 min. The obtained curd was heated, shaken, cut into 1-cm^3 pieces, and salted with NaCl (2.5 g/L of milk) and then dried and placed in stainless steel molds (1-kg capacity, 20-cm diameter, and 8-cm height). Cheeses (1 per vat) were pressed for 24 h at 20°C and then vacuum-packed and ripened (10°C and 85% relative humidity) for 60 d until analysis. A total of 25 hair sheep cheeses (900 g each) and 14 cow cheeses (900 g each) were manufactured.

Panela Cheese Manufacturing

Two batches (50 L each) of hair sheep milk and 2 batches (50 L each) of cow milk were used for Panela cheese manufacturing. Both hair sheep milk and cow milk were processed using the same protocol. Milk was pasteurized at 72°C for 15 s. Then, 50% (wt/vol) $CaCl_2$ was added at a proportion of 21 mL/100 L of milk followed by the addition of a commercial rennet (Cuamex) at a proportion of 30 mL/100 L of milk, kept at 35°C, and allowed to coagulate for 45 min. The curd was cut into 1-cm^3 pieces, shaken for 30 s, and allowed to settle for 15 min. The curd was salted with NaCl (4.5 g/L of milk) and placed in plastic molds (1-kg capacity, 20-cm diameter, and 8-cm height). After 1 h, cheeses were removed from the molds and were vacuum-packed and stored at 6°C until analysis. A total of 30 hair sheep cheeses (950 g each) and 15 cow cheeses (960 g each) were manufactured.

Chemical Composition

Four cheeses per type (i.e., hair sheep Manchego type, cow Manchego type, hair sheep Panela, and cow Panela) were used to determine cheese chemical composition. Analyses were carried out following procedures from AOAC International (2005) to determine moisture (method 948.12), ash (method 935.42), fat (method 933.05), and Kjeldahl N (method 991.20). Crude protein was calculated as N × 6.38. Sodium content was determined by spectrophotometry (Corning 410) following method 966.16 of AOAC International (2000). The relative intra-assay variation for determination of moisture, ash, fat, protein, and sodium was below 4%.

FA Analysis

Four cheeses per type were used for FA analysis. Lipids were extracted with chloroform/methanol (2:1, vol/vol) and methylated (transesterified with sodium methoxide) as described previously by Vargas-Bello-Pérez et al. (2017). Methyl *cis*-13-docosenoate was used as the internal standard. A GC system (Perkin Elmer AutoSystem XL) with flame-ionization detector equipped with a capillary column [100 m × 0.32 mm × 0.20 μm; Rt-2560, Restek; highly polar phase and biscyanopropyl polysiloxane–not bonded (fused silica)] was used to determine the FAME profile. The GC conditions were as follows: oven temperature was initially set at 50°C and then increased to 195°C at 20°C/min, increased to reach 205°C at 3°C/min, and held for 7 min until a final temperature of 220°C, which was held for 24 min. Inlet and flame ionization detector temperatures were set at 205 and 250°C, respectively. The split ratio was 15:1, and a 2-mL injection volume was used. Hydrogen was the carrier gas, and nitrogen was the makeup gas. Peaks were identified using a FAME standard (37 Component FAME mix; Supelco) and comparison with retention times of FA and equivalent chromatograms (de la Fuente et al., 2015). Fatty acid profiles were not corrected for potential losses of the SCFA. To get more insight into the nutritional benefits from cheese FA profiles, atherogenicity and thrombogenicity indices were determined using the formulas proposed by Ulbricht and Southgate (1991), where C12:0, C14:0, and C16:0 are considered atherogenic FA and C14:0, C16:0, and C18:0 are considered thrombogenic FA.

Sensory Analysis of Manchego Type Cheese Manufactured with Either Hair Sheep Milk or Cow Milk

For sensory analysis, 3 kg of each Manchego type cheese was used (n = 4 cheeses/type). The sensory panel comprised 92 untrained judges. Judges were not informed about the samples in any of the testing sessions. Evaluations considered the following attributes: color, odor, texture, flavor, and overall acceptance. The sensory descriptors and definitions have been previously described by Vargas-Bello-Pérez et al. (2015). Judges evaluated all samples (2 cm^3) in a monadic sequential way, scoring attributes on a continuous unstructured line intensity scale ranging from 0 (none) to 9 (very high) and anchored at both ends with extremes for each attribute.

Statistical Analysis

All statistical analyses were performed using SAS (version 9.0; SAS Institute Inc.). Data on chemical composition of cheeses were analyzed using a completely randomized design by ANOVA considering the treatment as fixed effects. Differences among treatments were explored through preplanned orthogonal contrasts: between species (hair sheep vs. cow), between cheeses (Manchego type vs. Panela), and between Manchego type (hair sheep Manchego type vs. cow Manchego type). Significance was set at $P < 0.05$.

Additionally, a multivariate analysis was performed using R 0.100.54 (R Core Team, 2019) to determine the capability of the FA profile to differentiate cheeses by animal species and type of cheese. The analysis included 4 stages: variable selection, factor analysis, cluster analysis, and a test for identification capacity (Vargas-Bello-Pérez et al., 2018). The selection of variables was made through the determination of the coefficient of variation and a correlation matrix. To carry out the factor analysis, the variables were standardized and the factorization methodology by principal components (**PC**) was used. In the cluster analysis, the agglomeration methods of the nearest neighbor, farthest neighbor, centroid, and Ward were evaluated, with the Euclidean distance and Euclidean distance squared metrics. The identification capacity test was carried out through the comparison of groups obtained from the cluster analysis with the analyzed groups of cheeses.

Differences between sensory evaluations of hair sheep Manchego type and cow Manchego type cheeses were also used to analyze which of the evaluated sensory characteristics received the highest value. In addition, differences in satisfaction between hair sheep Manchego type and cow Manchego type cheeses for each sensory characteristic were evaluated using contingency tables and a chi-squared test. Thus, positive values indicated preference for hair sheep Manchego type cheese over cow Manchego type cheese, values equal to zero indicated indifferences between both Manchego type cheeses, and negative values indicated preference for cow Manchego type cheese over hair sheep Manchego type cheese.

RESULTS AND DISCUSSION

Animal Conditions

One of the challenges in our methodological approach was to supply diets with similar ingredients to determine the effect of animal species and avoid dietary effects on chemical composition, FA profile, and sensory characteristics. The diets used for sheep and cows were typical for the tropical region where the study was done and were formulated to meet the energy requirements described for both species. These diets were based on tropical grass and in both species were supplemented with similar concentrate during milking.

Chemical Composition

Regarding the chemical composition of the cheeses manufactured in this study (Table 1), moisture was lower in Manchego type cheese manufactured with either hair sheep milk or cow milk than in Panela cheeses ($P < 0.001$). This was expected because Panela cheese is a fresh cheese and therefore contains less DM (Jiménez-Guzmán et al., 2009). This is the first study reporting the chemical composition of Panela cheese manufactured with hair sheep milk. The protein content reported in this study is similar to that described for other sheep cheeses such as such as feta, Terrincho, and Robiola delle Langhe (15, 21, and 18% protein, respectively; Raynal-Ljutovac et al., 2008).

No differences in the chemical composition were detected between Manchego type cheeses made from either hair sheep or cow milk. Fat, protein, ash, and sodium contents were higher in Manchego type cheese manufactured with either hair sheep milk or cow milk than Panela cheeses ($P < 0.027$). Protein and fat contents were lower in Manchego type cheeses manufactured with cow milk compared with those reported by Salazar-Montoya et al. (2018). Those authors described 23% protein and 28% fat in Manchego type cheeses manufactured with cow milk at 60 d of ripening. It is important to highlight that in this study, cow milk was obtained from a cross between Holstein and Zebu cattle, which produces milk with lower protein and fat contents than milk produced from pure *Bos taurus* breeds (Teodoro and Madalena, 2003). Overall, changes observed in the chemical composition reflected the type of cheeses evaluated, where Panela cheeses (i.e., fresh cheese) contained higher moisture and lower solids compared with Manchego type cheeses (ripened cheese).

FA Profile

Manchego type cheese manufactured from hair sheep milk contained more ($P < 0.05$) C4:0, C6:0, C8:0, C10:0, C12:0, C14:0, C18:2 *cis*-9,*cis*-12, total SFA, total SCFA, total medium-chain FA, total PUFA, and de novo FA than Manchego type cheeses from cow milk (Table 2). Total content of SCFA was higher ($P < 0.001$) in hair sheep cheeses (i.e., Manchego type and Panela cheeses) than in cow cheeses. This was expected because sheep cheeses contain higher levels of caproic (C6:0), caprylic (C8:0), capric (C10:0), and lauric (C12:0) acids than cow cheeses (Aguilar et al., 2014). Odd- and branched-chain FA (C15:0, C15:1 *cis*-9, C17:0, and C17:1 *cis*-9) were lower ($P < 0.001$) in hair sheep cheeses (i.e., Manchego type and Panela cheeses) than in those from cows, whereas de novo FA were higher ($P < 0.001$) in hair sheep cheeses than in those manufactured with cow milk. Fatty acids within 4 to 14 carbons are mainly derived from de novo synthesis, whereas FA with more than 16 carbons are obtained

Table 1. Chemical composition (g/100 g unless otherwise noted) of Manchego type and Panela cheeses manufactured with either hair sheep milk or cow milk

	Manchego type		Panela			P-value[1]		
Item	Sheep	Cow	Sheep	Cow	SEM	C1	C2	C3
Moisture	37.5	37.5	54.0	56.1	1.26	0.419	<0.001	0.979
Ash	4.19	3.93	3.41	2.60	0.18	0.015	<0.001	0.320
Fat	22.7	22.8	17.3	17.6	1.54	0.888	0.027	0.961
Protein	23.4	22.0	16.9	14.4	0.72	0.028	<0.001	0.216
Sodium (mg/g)	4.01	3.80	3.26	2.04	0.14	0.001	<0.001	0.355

[1]C1 = sheep vs. cow; C2 = Manchego type vs. Panela; C3 = hair sheep Manchego type vs. cow Manchego type.

Table 2. Fatty acid profile (g/100 g of total FAME) of Manchego type and Panela cheeses manufactured with either hair sheep milk or cow milk

	Manchego type		Panela			*P*-value[2]		
Fatty acid[1]	Sheep	Cow	Sheep	Cow	SEM	C1	C2	C3
C4:0	4.69	3.63	3.60	2.97	0.312	0.026	0.022	0.042
C6:0	3.79	2.08	3.40	1.94	0.242	<0.001	0.303	0.001
C8:0	3.95	1.12	3.54	1.11	0.234	<0.001	0.389	<0.001
C10:0	11.97	2.05	9.12	2.24	0.554	<0.001	0.042	<0.001
C12:0	6.62	2.30	4.70	2.55	0.159	<0.001	0.001	<0.001
C14:0	11.88	8.95	9.19	10.16	0.215	0.001	0.001	<0.001
C14:1 *cis*-11	0.22	0.94	0.16	0.98	0.012	<0.001	0.449	<0.001
C14:1 *cis*-9	0.32	0.46	0.25	0.44	0.025	0.001	0.113	0.001
C14:1 *cis*-7	0.55	0.70	0.43	0.72	0.042	0.001	0.285	0.039
C15:0	0.78	1.28	0.64	1.33	0.019	<0.001	0.030	<0.001
C15:1 *cis*-9	0.20	0.35	0.22	0.40	0.002	<0.001	<0.001	<0.001
C16:0	24.39	27.43	21.46	28.59	0.580	<0.001	0.167	0.006
C16:1 *cis*-11	0.58	1.51	0.61	1.40	0.017	<0.001	0.048	<0.001
C16:1 *cis*-9	0.27	0.45	0.42	0.39	0.012	0.001	0.005	<0.001
C16:1 *cis*-7	0.35	0.52	0.48	0.47	0.014	0.001	0.010	<0.001
C17:0	0.46	0.88	0.58	0.83	0.019	<0.001	0.135	<0.001
C17:1 *cis*-9	0.15	0.43	0.20	0.37	0.020	<0.001	0.937	<0.001
C18:0	9.81	12.96	13.71	12.40	0.274	0.010	0.003	<0.001
C18:1 *cis*-9	16.77	30.19	24.47	27.68	0.986	<0.001	0.030	<0.001
C18:2 *cis*-9,*cis*-12	1.83	0.51	2.46	1.68	0.074	<0.001	<0.001	<0.001
C18:3 *cis*-9,*cis*-12,*cis*-15	0.34	1.20	0.30	1.31	0.020	<0.001	0.144	<0.001
ΣSFA	77.59	61.42	69.31	62.80	0.969	<0.001	0.007	<0.001
ΣMUFA	19.44	35.57	27.27	32.88	0.954	<0.001	0.027	<0.001
ΣPUFA	2.18	1.72	2.77	2.98	0.075	0.134	<0.001	0.002
ΣSCFA	24.41	8.89	19.66	8.26	1.305	<0.001	0.073	<0.001
ΣMCFA	20.60	15.00	15.61	16.58	0.332	0.001	0.001	0.001
OBCFA	1.60	2.96	1.65	2.93	0.040	<0.001	0.778	<0.001
DNFA	55.12	33.86	44.29	35.27	1.218	<0.001	0.004	<0.001
Unidentified	0.78	1.28	0.64	1.33	0.019	<0.001	0.030	<0.001
Atherogenicity index[3]	1.95	0.95	1.06	1.03	0.103	0.001	0.001	0.001
Thrombogenicity index[3]	2.32	1.26	1.57	1.42	0.126	0.001	0.050	0.001

[1]SCFA = short-chain fatty acids (C4:0–C10:0); MCFA = medium-chain fatty acids (C12:0–C15:1 *cis*-9); OBCFA = odd- and branched-chain fatty acids (C15:0, C15:1 *cis*-9, C17:0, and C 17:1 *cis*-9); DNFA = de novo fatty acids (C4:0, C6:0, C8:0, C10:0, C12:0, C14:0, and half of C16 content).

[2]C1 = sheep vs. cow; C2 = Manchego type vs. Panela; C3 = hair sheep Manchego type vs. cow Manchego type.

[3]Calculated according to Ulbricht and Southgate (1991).

from the diet (Vargas-Bello-Pérez and Garnsworthy, 2013). Odd- and branched-chain FA (i.e., C15:0 and C17:0) are exclusively detected in ruminant products (dairy and beef), and they have not been associated with mortality in patients with coronary heart disease (Astrup et al., 2020).

In this study, differences between FA profiles in hair sheep cheese (i.e., Manchego type and Panela cheeses) and those in cow cheese are probably caused by the specific rumen microbiome in each of the species used in this study. Sheep and cows have different relative abundances of fibrolytic ruminal microbes such as protozoa, anaerobic fungi, and bacteria (Huws et al., 2018). Different abundance of those microorganisms leads to the formation of different FA in the rumen, which are then absorbed and later secreted into milk (Vargas-Bello-Pérez and Garnsworthy, 2013). Thus, rumen microbes, mainly bacteria, are the major source of odd- and branched-chain FA in ruminant milk (Vlaeminck et al., 2006).

As described by Sánchez-Macías et al. (2011), the greater lipase activity in ripened cheeses (i.e., Manchego type cheese) compared with fresh cheeses (i.e., Panela cheese) could explain the differences in the FA profiles observed in the present study. Lipases are produced in plants and animals, and they have specificity, regiospecificity, and stereospecificity for substrates and FA, which results in hydrolysis of all ester bonds regardless of their position or type of FA (Kontkanen et al., 2011). Lipases are also important for the production of flavors during ripening (Kendirci et al., 2020). In addition, the use of starter cultures in Manchego type cheese could have influenced the differences in the FA profile compared with Panela cheeses. During cheese ripening, lactic acid bacteria can lead to different FA profiles by the activity of hydratase, dehydrogenase, isomerase, and reductase enzymes (Santiago-López et al., 2018).

From a human health perspective, the FA profiles of either Manchego type or Panela cheeses manufactured with hair sheep milk represent healthier alternatives to cheeses manufactured with cow milk because SCFA were higher in sheep cheeses. Short-chain FA such as those between C4:0 and C12:0 have been reported to have antiviral and antibacterial properties (Knutsen et al., 2018). In fact, C12:0 has been proposed as part of preventive interventions against COVID-19 because monolaurin, a metabolite from C12:0, is able to disrupt the envelope of single-stranded RNA viruses (Tan-Lim and Martinez, 2020). It is important to highlight that coconut and dairy products are the most important sources of C12:0 in human diets (Lieberman et al., 2006).

Manchego type cheese had higher atherogenicity and thrombogenicity indices than Panela cheese. In addition, cheeses manufactured with hair sheep milk had a higher thrombogenicity index than those manufactured with milk from cows. Manchego type cheese manufactured with hair sheep milk had a higher thrombogenicity index than those manufactured from cow milk. As mentioned earlier, Ulbricht and Southgate (1991) formulas for both indices are based SFA such as C12:0, C14:0, C16:0, and C18:0 but do not consider the SCFA; thus, estimations for hair sheep cheeses may not completely reflect their nutritional quality compared with cow cheeses. Although total SFA were higher in cheeses manufactured from hair sheep milk, this was mainly because hair sheep cheeses had higher contents of SCFA. Therefore, information regarding the atherogenicity and thrombogenicity indices obtained in this study needs to be considered carefully as individual FA can exert positive benefits on human health. Recently, it has been reported that SCFA plays a special role in human nutrition because they have been shown to have antiobesogenic properties by sustaining a balance between lipogenesis and oxidative degradation of FA (Schönfeld and Wojtczak, 2016). Moreover, myristic acid (C14) is now recognized as playing an important role in modification of several cellular signaling pathways implicated in both carcinogenesis and immune function through its participation in myristoylation of proteins in human cells (Thinon et al., 2014). In addition, SCFA in the human hind gut are reported to be important for preserving colonic health (Pakiet et al., 2019).

Multivariate Analysis

The variable selection process, through the determination of the coefficients of variation and correlation matrix, allowed us to select 12 FA for the development of the factor analysis. Three main PC were selected, which were able to explain 96.2% of the variance of the data (Table 3): PC1 (63.1% of variance) consisted of SFA (C14:0, C18:0) and MUFA (C16:1 *cis*-9, C19:1 *cis*-7, C18:1 *cis*-9), PC2 (25.0% of variance) consisted of SFA (C8:0 and C16:0) and UFA (C14:1 *cis*-7, C14:1 *cis*-11, C17:1 *cis*-7, and C18:2 *cis*-6), and PC3 (8.1% of variance) consisted of C4:0.

Table 3. Principal component (PC) analysis related to the fatty acid profile of Manchego type and Panela cheeses manufactured with either hair sheep milk or cow milk

PC	Eigenvalue	Variance (%)	Fatty acid	Correlation
1	7.6	63.1 (63.1)[1]	C14:0	−0.96
			C16:1 *cis*-9	0.94
			C16:1 *cis*-7	0.89
			C18:0	0.95
			C18:1 *cis*-9	0.80
2	3.0	25.0 (88.1)	C8:0	−0.76
			C14:1 *cis*-11	0.89
			C14:1 *cis*-7	0.94
			C16:0	0.83
			C17:1 *cis*-7	0.80
			C18:2 *cis*-6	−0.90
3	1.0	8.1 (96.2)	C4:0	−0.82

[1]Variance accumulated.

The 3 PC were used for the development of the cluster analysis, which allowed the identification of the 4 groups of cheeses (3 cheeses per group). Cluster analysis allowed the correct classification of the 12 cheeses evaluated. However, one of the Manchego type cheeses manufactured with cow milk was located close to the Panela type cheeses because 1 Manchego type cheese manufactured with cow milk presented a different FA profile than the other 2 Manchego type cheeses. Specifically, Manchego type cheese from cow milk had lower contents of C10:0, C12:0, C14:0, and C18:2 *cis*-9,*cis*-12 (Table 2). As shown in Figure 1, there was greater distance between sheep and cow cheeses in PC1 and PC2. Thus, sheep cheeses had lower PC1 values than cow cheeses, which is based on the lower concentrations of C14:1 *cis*-7, C15:0, C15:1 *cis*-9, C16:1 *cis*-11, C17:0, C17:1 *cis*-7, C18:0, and C18:3 *cis*-9,*cis*-12,*cis*-15 and higher concentrations of C8:0, C10:0, C12:0, and C16:0. As mentioned above, FA with fewer than 14 carbons are mainly derived from de novo synthesis and are at higher proportions in cheeses from small ruminants than in cheeses manufactured with cow milk (Partidário et al., 2008; Aguilar et al., 2014). Similarly, C14:1 *cis*-11 and C16:1 *cis*-11 are usually found in lower levels in cheeses manufactured with sheep milk than in cheeses manufactured with cow milk (O'Donnell et al., 2010; Vargas-Bello-Pérez et al., 2018).

Sensory Characteristics of Manchego Type Cheeses

Due to its high economical value in the Mexican retail sector, only Manchego type cheeses were analyzed to

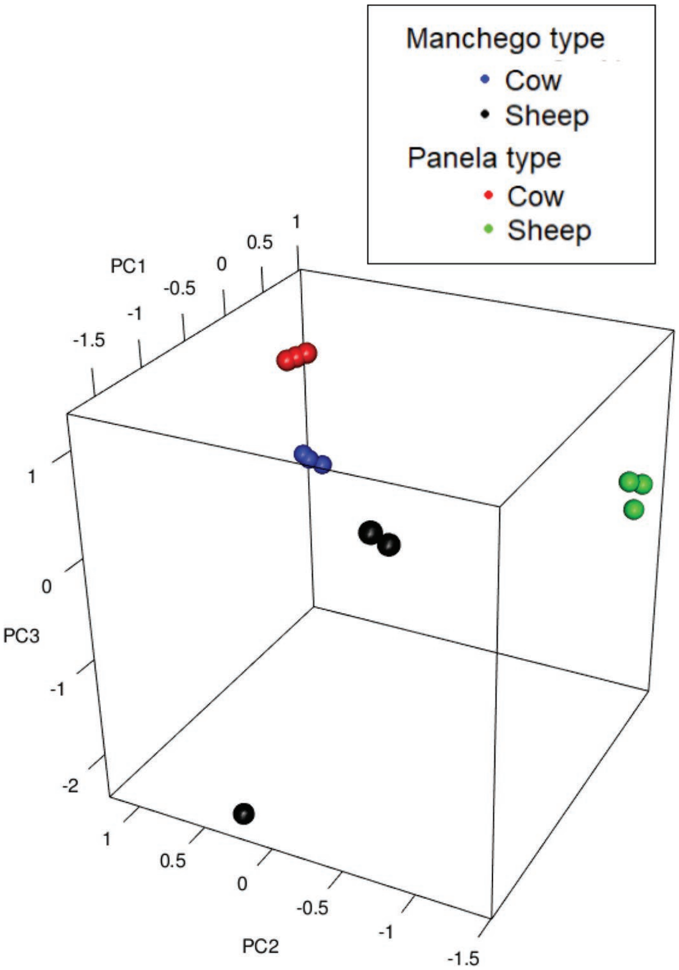

Figure 1. Positioning of Manchego type and Panela cheeses manufactured with either hair sheep milk or cow milk according to fatty acid profiles obtained for principal components (PC) 1, 2, and 3.

determine the sensory characteristics. Scores for odor, texture, flavor, and overall acceptance were higher in Manchego type cheeses manufactured with hair sheep milk than in those manufactured with cow milk (Table 4). Manchego cheese from sheep milk commonly has a hard, compact, dense, and fatty texture with sheep aromas and strong aftertaste flavors (González-Viñas et al., 2001). Although this was not determined in the present study, 4-methyloctanoic and 4-ethyloctanoic acid along with *p*-cresol, *m*-cresol, and 3,4-dimethyl phenol are responsible for the sheepy notes in sheep cheeses. These components are commonly identified as a strong flavor in untrained panelists (Ryffel et al., 2008). This fact was reflected in the scores obtained for that attribute in Manchego type cheeses.

Table 4. Sensory analysis of Manchego type cheese manufactured with hair sheep milk or cow milk

Attribute[1]	Sheep	Cow	SEM	*P*-value
Color	6.74	7.26	0.14	0.009
Odor	7.05	6.37	0.16	0.004
Texture	6.82	6.12	0.18	0.009
Flavor	7.16	6.17	0.20	0.007
Overall acceptance	7.48	6.83	0.16	0.005

[1]Attributes were scored on a continuous unstructured line intensity scale ranging from 0 (none) to 9 (very high).

The chi-squared test [χ^2 (df = 8, n = 460) = 36.9, $P < 0.01$] indicated dependence between sensory characteristics and the individual preference of the judges. Thus, differences in color and flavor were detected between both Manchego type cheeses ($P < 0.05$; Table 5). Consequently, 55.4% of the judges considered that cow Manchego type cheese had higher color and lower flavor scores than hair sheep Manchego type cheese. None of the other sensory characteristics (i.e., odor, texture, and overall acceptance) were affected by the animal species; however, the individual preference of the judges for hair sheep Manchego type cheese was noticeable. These results were unexpected because Latin American cheese consumers usually prefer cheeses manufactured with cow milk over those manufactured with either sheep or goat milk (Vargas-Bello-Pérez et al., 2014). In the present study, Manchego type cheeses manufactured with hair sheep obtained higher scores for sensory attributes than those manufactured with cow milk. It may be possible that ripening time (i.e., 60 d) was sufficient to improve odor and flavor to a greater extent in hair sheep cheeses (Prados et al., 2007) than in cow cheeses. However, further studies with longer ripening periods should be considered to determine whether Latin American consumers still prefer ripened cheeses

Table 5. Relative preference of Manchego type cheese manufactured with either hair sheep milk or cow milk

Relative preference	Color	Odor	Texture	Flavor	Overall acceptance	*P*-value
Preferred sheep cheese	19.6[a]	50.0	51.1	55.4[a]	54.3	<0.01
Neutral	25.0	19.6	20.7	18.5	20.7	
Preferred cow cheese	55.4[a]	30.4	28.3	26.1	25.0	

[a]Means within a column with a superscript letter were different from expected means. The expected means correspond to 33.3%, which represents panelists who were unable to differentiate cheeses; therefore, there was the same probability (1/3) that the panelist preferred sheep cheese, preferred cow cheese, or remained neutral. *P*-value denotes the overall effect.

manufactured with sheep milk over those manufactured with cow milk.

On the other hand, FA profiles have a strong effect on the quality, nutritional value, and sensory characteristics of dairy products (Vargas-Bello-Pérez et al., 2020). In this regard, the multivariate analysis and chi-squared test from judge preferences of cheeses agreed with and confirmed the results related to FA analysis and sensory characteristics of Manchego type cheeses manufactured with hair sheep milk. Further studies should consider analyzing protein compounds (i.e., bioactive peptides) from both types of cheese as sheep milk contains diverse protein fractions that can be found in caseins and whey proteins (Vargas-Bello-Pérez et al., 2019).

CONCLUSIONS

Both Manchego type cheese and Panela cheese manufactured with hair sheep milk had similar chemical composition and contained higher levels of SCFA, total PUFA, and de novo FA than those manufactured with cow milk. In addition, Manchego type cheeses manufactured with sheep milk obtained higher sensory scores than Manchego type cheeses manufactured with cow milk. Therefore, cheeses from hair sheep could be considered suitable alternatives to cheeses manufactured with cow milk.

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