International Food Research Journal 27(6): 1132 - 1140 (December 2020)

Journal homepage: *http://www.ifrj.upm.edu.my*

Characterisation and consumer liking of white cheeses from different milk fermentation: correlation between sensorial and instrumental analyses

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Article history

Received: 18 May 2020
Received in revised form:
21 July 2020
Accepted:
24 August 2020

Keywords

white cheese,
sheep milk,
goat milk,
cow milk,
sensory,
texture,
consumer liking

Abstract

In the present work, the consumer liking and physicochemical, textural, and sensorial characteristics of white cheeses made from different milk origins (sheep, goat, and cow); and the correlation of instrumental and sensorial-textural attributes were studied. Results were examined using principal component analysis (PCA) and multidimensional scaling (MDS) texture maps which showed that the change of textural properties of sheep, goat, and cow cheeses was significantly different. These deviations between cheeses could be attributed to different milk compositions with various gel networks and ripening phenomena of cheeses. Instrumental hardness and adhesiveness were significantly correlated with sensory data. Sensory chewiness was positively correlated with gumminess and chewiness. Sensorial fracture and instrumental hardness had the highest positive correlation and also significantly positively correlated with instrumental fracturability. It was found that dry matter values were also highly positively correlated with fracturability and hardness. Cooked, whey, creamy, and fermented terms were determined as characteristic sensory descriptors by using quantitative descriptive analysis (QDA).

Introduction

Textural properties of dairy foods can be determined using descriptive sensory (subjective) or instrumental (objective) analyses. Both sensory and texture evaluations directly affect food acceptance and preference of consumers, and the design of new products (Paula and Conti-Silva, 2014; Singham *et al.,* 2015). The viscous and textural properties of foods are primarily measured by sensory analysis techniques defined by trained judges to evaluate specific sensory properties (Foegeding, 2007). In general, sensory perceptions about food, taste, and texture are mostly shaped by chewing, swallowing, saliva secretion, temperature changes, and tongue movements (Dijksterhuis and Piggott, 2001).

The texture profile analysis (TPA) is exemplified by the double-axial compression of the sample without breaking. The specified evaluations are used effectively to define the hardness, adhesiveness, cohesiveness, springiness, gumminess, chewiness, and resilience values of dairy foods by imitating the mechanical behaviour of chewing with TPA (Bourne, 2002). Meanwhile, texture mapping techniques are some of the tools that are used to visually assess the texture of foods based on the selected instrumental and sensorial methods. Since quality control and optimisation of the development of new products are made by instrumental measurements without anticipating consumer acceptance, using texture maps to correlate instrumental and sensorial measurements is very important in order to reach the aforementioned goal (Paula and Conti-Silva, 2014).

Cheese is a dairy product with a complex microstructure which mainly consists of casein, fat, and water, and has a variety of characteristics. The rheological, textural, and sensorial properties of cheeses are changed independently of the dairy matrix and the acid aggregation of casein micelles. Furthermore, milk composition (dry matter and protein content) is the main factor for cheese properties. For example, goat milk has therapeutic properties in human nutrition due to its high digestibility, buffering capacity, and lipid content (Gunasekaran and Ak, 2003). Sheep milk contains dry matter, protein, and fat higher than goat and cow milk, as well as higher specific gravity, viscosity, refractive index, and titratable acidity (Haenlein and Wendorff, 2006). Bovine milk contains high levels of αs_1-casein which affects cheese proteolysis, texture, and microprofile matrix (Park *et al.,* 2007; Ceballos *et al.,* 2009).

Today, determining the relationship between subjective and objective measurements through research has revealed the combined use of instrumental

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techniques and sensorial evaluations in industrial processes (Szczesniak, 2002). With the determination of the correlation between sensorial and instrumental measurements; (i) instruments to measure quality control of food processing are defined, (ii) the consumer response is estimated by determining the degree of appreciation and the general acceptance point of a new product, (iii) understanding the sensory skills of the texture is realised by perceiving in the mouth, and (iv) instrumental methods are improved or optimised to complement the sensorial evaluation (Szczesniak, 1987).

Brined cheeses are among the oldest types of cheeses originating from the Middle East and the Mediterranean. Soft or semi-hard brined white cheese, which is originated from Turkey and other Mediterranean countries, is manufactured from the milk of sheep, goat, or cow, or a mixture of them (Eren-Vapur and Ozcan, 2012). The aims of the present work were (i) to assess the texture of white cheeses by objective methods (instrumental analysis) and subjective methods (sensorial evaluation), and to perform a correlation between them by using quantitative descriptive analysis of sensory (QDA) and texture profile analysis (TPA), (ii) to investigate the influence of chemical composition and milk type on the sensorial and textural properties of cheese, and (iii) to investigate the results using multidimensional scaling (MDS) texture maps and principal component analysis (PCA), which shows that the visual and instrumental evaluation of cheese properties differ.

Materials and methods

Materials

A total of 30 cheese samples of different milk origins (sample code: cow, 1 - 10; goat, 11 - 20; and sheep, 21 - 30) were produced according to the traditional white cheese production in different dairy plants. Samples were immediately stored at 0 - 4°C until further analysis.

Descriptive analysis of sensory properties and sensory textures

Thirteen panellists (five males and eight females) between the ages of 22 - 45 among students and staff were involved. Quantitative descriptive analysis (QDA) of sensory properties was modified and performed in accordance with Leiva and Figueroa (2010). Primarily, the samples were presented to the panellists in order to generate the texture description parameters. All panellists were trained with reference samples on cheese profiling of many different types of cheese made from cow, goat, and sheep milk.

The standardised definitions of sensory and texture language were presented as: appearance (general appearance of cheese), body and texture (firmness of the sample evaluated in the mouth), hardness (amount of force required to completely bite the cheese), fracturability/brittleness (amount of fracturability in the cheese after biting), springiness/elasticity (total amount of recovery after press), cohesiveness (rating to which the chewed mass sticks together), adhesiveness (rating to which the chewed mass sticks to mouth surface), chewiness (the number of chews required to masticate a solid food to a state pending for swallowing), gumminess (a denseness that persists throughout mastication, the energy required to disintegrate a cheese to a state ready for swallowing), resilience (elasticity, ability of the cheese to recover to its fundamental form), saltiness (taste, basic taste typical of sodium chloride), taste (the fundamental taste sensation associated with a fermented and ripe cheeses), flavour (aroma associated with cheese taste and odour characteristics), and colour (visual estimation of intensity, the intensity of cheese colour ranging from white to cream).

In the second session, the sensory and texture properties were scored. The panellists analysed all cheeses in triplicate tasting of six samples in each session.

Instrumental analyses of texture

Textural properties (hardness (g), adhesiveness (gs^{-1}), cohesiveness, chewiness (gmm^{-1}), fracturability (g), gumminess (gs^{-1}), springiness (mm), and resilience) were measured using a TA-XT Plus (Stable Micro Systems) textural device, using two bite compressions in a 36 mm diameter cylindrical sample as described by Gutiérrez-Méndez *et al.* (2013).

Physicochemical analysis

Physical and chemical analyses were performed using the methods recommended by AOAC (2000): Dry matter content (DM), titratable acidity (TA, as grams of lactic acid/100 mL), and NaCl (Mohr method) were determined in the samples according to the method 926.08, 920.124, and 935.43, respectively. The methods of AOAC (2000) were also used to determine moisture and ash contents (method 948.12) and also fat content (Gerber method; method 933.05).

Statistical analysis

The means of the analysis results were compared using variance analysis followed by the

Tukey's test ($p < 0.05$ and 0.01), using the PASW Statistics 18 software (SPSS Inc., USA). The results were also standardised and subjected to multidimensional scaling analysis (MDS) and principal component analysis (PCA), using the Statistica 7.0 software (StatSoft, Inc., USA) (Ghosh and Chattopadhyay, 2012).

Results and discussion

Descriptive analysis on sensory properties

Generally, physical and instrumental measurements cannot determine the adjustment response due to the difficulty of mimicking psychological or sensory responses. Hence, sensory methods achieve the most precise results by test parameters that provide information about how products are perceived by the senses (Singham *et al.,* 2015). Quantitative descriptive analysis (QDA) is one of the most commonly used methods for sensory evaluation in the foods and sensory descriptions which allows for more immediate measurement of human perception as compared to the instrumental methods (Ross, 2009).

The evaluation of sensory analysis results of white cheeses made from sheep, goat, and cow milk by multidimensional scaling analysis (MDS) is given in Figure 1a. Multidimensional scaling analysis reveals the similarities and differences between the cheeses. It is one of the techniques of interdependence, and involves mathematical, geometric, and statistical operations in which spatial model can be obtained which manifests itself as visually appealing to people. Similar objects represented by points are closer to each other on this map, while objects with different distances are farther away (Valentin *et al.,* 2016).

Textural sensory evaluation and linearly distinctive results of cheese varieties showed that sheep milk cheese varieties have unique sensory properties which are very different from other cheeses. Textural sensory evaluation and linear discriminant analysis results showed that cheeses produced from sheep milk had more distinct sensory properties than other cheeses (Figure 1a). Hardness, which is defined as the force applied by the molar teeth to compress the cheese, was higher in goat cheese than that of cow and sheep. The colour of the sheep cheeses in general was more liked, while the aroma of cow cheeses was more accepted. The differences in the structure of cheeses with types of milk depend on different casein concentrations and structures (Ceballos *et al.,* 2009).

Instrumental texture

The texture of the cheese is described in Figure 1b. In general, goat milk cheeses presented higher degrees of adhesiveness, fracturability, and hardness values, while sheep cheeses had high gumminess, chewiness, and springiness values than other cheeses.

It has been stated that protein gelation and texture changed with the increase in acidity of cheeses, which resulted in soft cheeses that were easily fragmented (Madadlou *et al.,* 2006). In addition, the proteolysis and lipolysis also influenced the texture of cheeses, especially the hardness and stickiness (Wendin *et al.,* 2000; Gunasekaran and Ak, 2003). These variations in the milk composition caused changes in the cheese macro- and microstructure; consequently, goat milk cheeses were harder while cow cheeses were more resilient (Figure 1b).

Storage and production differences affect cheese texture. In addition, in rennet gels, the techno-functional properties of cheese are affected by the coagulation of milk which is critically influenced by type of rennet and concentration, temperature, coagulation time, and milk composition (Madadlou *et al.,* 2005). The decreasing moisture content in cheese matrix also increases the hardness. In addition, maturation also reduces hardness in cheeses (Awad, 2011).

Examining Figure 1b, it can be seen that as the distances between the cheeses increased, the differences also increased. Due to their fragile microstructure, low texture goat products are less compact and have weak acid gels which is caused by lower mean diameter, degree of hydration, and casein content (especially αs_1-casein in goat milk) (Delgado *et al.,* 2017).

Physicochemical properties

Figure 1c shows the similarities and differences of the white cheeses obtained from different animal milk (sheep, goat, and cow). Domagała (2009) explained the distinct differences in cheese properties with various raw milk compositions and physicochemical characteristics. From Figure 1c, it can be seen that the distances between the cheeses increased, while the similarities increased as the distances decreased. Cheeses from similar milk type were grouped together. The physicochemical properties of the white cheeses were affected by milk constituents in different milk and ripening period of cheeses (Figure 1c).

Proteolysis and casein degradation influence biochemistry, texture, and flavour of cheeses during ripening of cheese varieties from different origins.

Korish and Abd Elhamid (2012) explained that the low hardness, springiness, and chewiness values of Kareish cheese were related to the level of the cheese moisture content. Earlier, Olson and Johnson (1990) indicated that the amounts of moisture, protein, and fat were significant effect for cheese texture. Fat and moisture form the filler in the casein matrix of cheese texture, and give lubrication and softness to the product (Madadlou *et al.,* 2005).

Mallatou *et al.* (1994) noted that white-brined cheeses made from goat milk were harder than cheeses made from sheep milk due to the different casein structure properties. Cheese with low pH value showed high gumminess, while high pH value cheese had more plastic structure (Bhaskaracharya and Shah, 2001). High moisture content makes the cheese network even softer, and weakens the protein network thus resulting in the soft texture

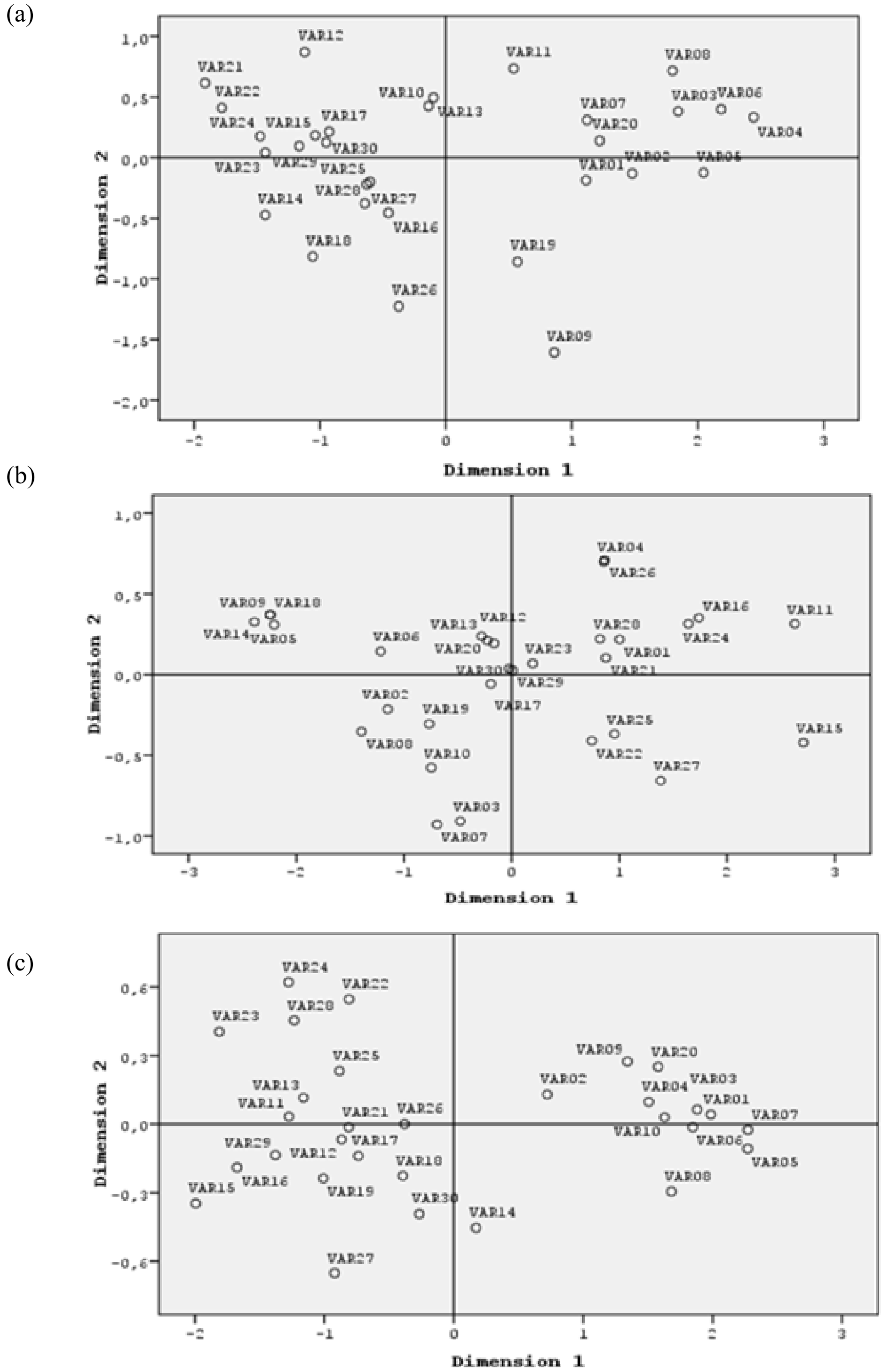

Figure 1. Multidimensional scaling (MDS) spatial mapping of white cheeses (cow milk: 1 - 10; goat milk: 11 - 20; and sheep milk: 21 - 30) for (a) sensory evaluation, (b) textural properties, and (c) physicochemical properties.

(Buriti *et al.,* 2005).

Correlation between sensory and instrumental texture

Quality control of foods and consumer appreciation in the development of new products and their relationship with instrumental measurements are the main points considered by Paula and Conti-Silva (2014). The instrumental properties correlated with the sensory specifications of texture (Table 1) and PCA (Figure 2b) on the correlation matrix ($p < 0.05$, 0.01). The positive correlation between sensory and the instrumental data found was between instrumental hardness and sensory body and texture ($r = 0.613$, $p < 0.01$), saltiness ($r = 0.482$, $p < 0.01$), fracturability ($r = 0.632$, $p < 0.01$), hardness ($r = 0.446$, $p < 0.05$), gumminess ($r = 0.395$, $p < 0.05$), and chewiness ($r = 0.375$, $p < 0.05$). Upreti *et al.* (2006) stated that the composition of cheese, fat, degree of proteolysis and lipolysis, moisture content, and pH are important factors affecting hardness values. Instrumental adhesiveness [saltiness ($r = 0.455$, $p < 0.05$), fracturability ($r = 0.558$, $p < 0.01$), adhesiveness ($r = 0.554$, $p < 0.01$), springiness ($r = 0.407$, $p < 0.05$), cohesiveness ($r = 0.460$, $p < 0.05$), and gumminess ($r = 0.538$, $p < 0.01$)] was highly correlated with sensory data. Sensory chewiness was significantly and positively correlated with gumminess ($r = 0.466$, $p < 0.01$) and chewiness ($r = 0.444$, $p < 0.05$). No significant correlations were found between sensory properties and instrumental results, mainly for springiness and chewiness. Sensory fracturability and instrumental hardness had the highest positive correlation ($r = 0.632$, $p < 0.01$) and was also positively correlated with instrumental fracturability ($r = 0.552$, $p < 0.01$), adhesiveness ($r = 0.558$, $p < 0.01$), and gumminess ($r = 0.601$, $p < 0.01$). According to Foegeding *et al.* (2003), fracture properties proved to be the most highly correlated with sensory texture.

Generally, the final texture perception is based on human sensory evaluation. Because the sensory evaluations point to subjective results, many studies in recent years aimed to establish a correlation between sensory and instrumental tests (Everett and Auty, 2008). When the sensory resilience values of cheese samples were examined, strong positive correlation was found with instrumental adhesiveness ($r = 0.469$, $p < 0.01$), cohesiveness ($r = 0.375$, $p < 0.05$), gumminess ($r = 0.371$, $p < 0.05$), and chewiness ($r = 0.413$, $p < 0.05$).

Correlation between physicochemical properties and instrumental texture

Correlation of physicochemical properties and instrumental TPA analysis was examined by correlation analysis (Table 2) and PCA (Figure 2b). It was found that dry matter values were highly positively correlated with fracturability ($r = 0.572$, $p < 0.01$), hardness ($r = 0.679$, $p < 0.01$), adhesiveness ($r = 0.653$, $p < 0.01$), gumminess ($r = 0.653$, $p < 0.01$), and chewiness ($r = 0.386$, $p < 0.05$); however, as expected, the same values were found to be negatively correlated with moisture content. A strong positive correlation was determined with fat content of cheeses and textural fracturability ($r = 0.456$, $p < 0.05$), hardness ($r = 0.441$, $p < 0.05$), adhesiveness ($r = 0.684$, $p < 0.01$), and gumminess ($r = 0.721$, $p < 0.01$).

It is well known that milk pH and salt affect cheese curd strength and protein matrix. In the present work, however, there was no correlation

Table 1. Correlation between the sensory and instrumental textural parameters of white cheeses.

Sensory properties	Fracturability	Hardness	Adhesiveness	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
Appearance	-0.062	0.268	0.070	-0.065	-0.136	-0.107	-0.170	-0.102
Body and texture	0.186	0.613**	0.278	-0.022	-0.304	0.230	0.115	-0.081
Saltiness	0.380*	0.482**	0.455*	-0.236	0.158	0.531**	0.469**	-0.132
Fracturability	0.552**	0.632**	0.558**	-0.222	-0.041	0.601**	0.424*	0.284
Hardness	0.202	0.446*	0.246	-0.171	-0.213	0.139	0.014	0.155
Adhesiveness	0.304	0.295	0.554**	-0.028	0.144	0.388*	0.368*	-0.025
Springiness	0.105	0.166	0.407*	0.125	0.124	0.264	0.334	-0.014
Cohesiveness	0.026	0.268	0.460*	0.010	0.277	0.215	0.218	-0.256
Gumminess	0.266	0.395*	0.538**	-0.145	0.025	0.352	0.207	-0.100
Chewiness	0.319	0.375*	0.391*	0.174	0.197	0.466**	0.444*	-0.094
Resilience	0.094	0.102	0.469**	0.110	0.375*	0.371*	0.413*	-0.190

* = Correlation is significant at the 0.05 level; ** = Correlation is significant at the 0.01 level.

(a)

(b)

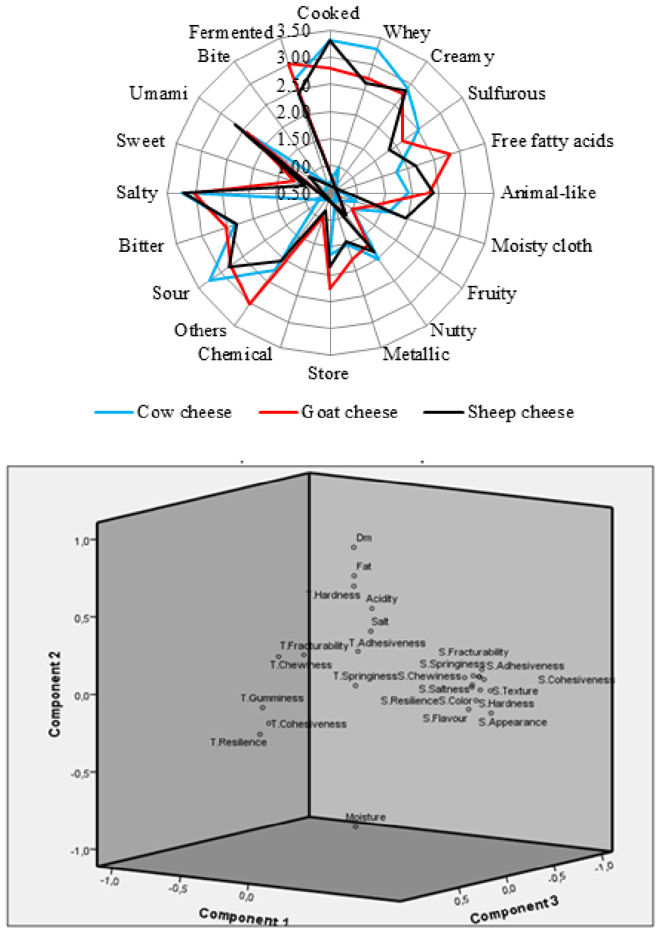

Figure 2. (a) Mean of quantitative descriptive analysis (QDA) of white cheeses from sheep, goat, and cow milk, and (b) principal component analysis of white cheeses for sensory, texture, and physicochemical properties.

between the titratable acidity and salt values of white cheese and the textural parameters ($p > 0.01$) (Table 2). It has been stated by Radulović *et al.* (2011) that the difference between goat and cow white cheeses depends on the pH of the cheese matrix, and gel nets show different hydrophilic properties. Lawlor *et al.* (2001) stated that cohesiveness and firmness are significantly correlated with the pH and chemical composition of cheese. Pereira *et al.* (2006) found that sensorial properties such as firmness and adhesiveness were effectively related to chemical results.

Biochemical properties and casein content of milk obtained from different animal species had a considerable effect on the rheological characteristic of rennet gels (Park *et al.,* 2007). For example, the reduction of total protein (TP) gives deficient bounded and/or relatively hydrolysed proteins into the brine and different gel network stability in cheese made with different milk (Barać *et al.,* 2013).

Correlation between instrumental texture parameters

The correlation of the TPA texture parameters of sheep, goat, and cow milk white

Table 2. Correlation between the physicochemical and instrumental textural parameters of white cheeses.

Physicochemical properties	Fracturability	Hardness	Adhesiveness	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
Titratable acidity (LA)	0.156	0.285	0.101	-0.109	-0.351	0.082	-0.027	-0.214
Salt (%)	-0.179	0.045	0.168	0.194	0.011	-0.087	-0.035	-0.241
Moisture (%)	-0.572**	-0.679**	-0.653**	0.166	0.047	-0.653**	-0.386*	0.063
Dry matter (%)	0.572**	0.679**	0.653**	-0.166	-0.047	0.653**	0.386*	-0.063
Fat (%)	0.456*	0.441*	0.684**	-0.243	0.039	0.721**	0.313	-0.143

* = Correlation is significant at the 0.05 level; ** = Correlation is significant at the 0.01 level.

cheeses with each other is given in Table 3. Fracturability or breakage is defined as the force required to break a material. Fracturability showed strong correlation with hardness ($r = 0.594$, $p < 0.01$), adhesiveness ($r = 0.457$, $p < 0.05$), gumminess ($r = 0.837$, $p < 0.01$), and chewiness values ($r = 0.672$, $p < 0.01$). Adhesiveness is the work required to overcome gravitational forces between the surface of the food material (tooth, tongue, palate, or prop), and these values also showed high positive correlations with gumminess ($r = 0.605$, $p < 0.01$) and chewiness ($r = 0.541$, $p < 0.01$). The force to be applied in order to achieve a certain deformation in the structure of the foods is defined as hardness. Hardness value showed a negative correlation with cohesiveness ($r = -0.338$, $p < 0.05$), and a positive correlation with gumminess ($r = 0.408$, $p < 0.05$). Gumminess is a semi-solid substance with the energy value required to break up a food item until it becomes ready to swallow. It is a parameter related to foods with a low hardness value. This value was found to correlate with chewiness ($r = 0.846$, $p < 0.01$) and resilience ($r = 0.422$, $p < 0.05$). Springiness is defined as the rate of rotation of the food material over its previous state of deformation, and a positively correlation was found among springiness and chewiness ($r = 0.489$, $p < 0.01$) in white cheese samples. Cohesiveness is the internal bond strength and adherence of the foods, and forming the structure. In white cheese samples, cohesiveness values positively correlated with gumminess ($r = 0.389$, $p < 0.05$), chewiness ($r = 0.401$, $p < 0.05$), and resilience ($r = 0.526$, $p < 0.01$).

In order to define the quality characteristics of cheese, different analyses such as chemical, physical, textural, and sensory analysis are needed. Although the classical methods are used to assess the multivariate data to obtain results, these analyses give important information for each variable that they fail to provide, which is a true information on the existence of a relationship between two or more different characteristics, and do not allow the grouping of homogeneous structures. For this reason, multivariate statistical methods such as Principal Component Analysis (PCA) are needed to make the original variables easier to interpret (Ghosh and Chattopadhyay, 2012).

When assessing the physicochemical, textural, and sensory properties of white cheese samples by PCA, instrumental textural variables were found to be far away from other basic components, and showed stronger correlation within themselves (Figure 2b). The relationships observed from these score plots were also previously explained with correlation analyses (Tables 1, 2, and 3).

A wide range of flavouring compounds have been identified in cheeses, and most of them have been found to be the case of casein degradation (Drake, 2007). The mean quantitative identification test (QDA) of sensory characteristics of white cheeses are shown in Figure 2a. According to these results, in all cheese samples, whey, creamy, salty, and cooked taste were determined as distinct flavours. Free fatty acid, fermented, and animal taste were also felt by panellists in some goat cheeses; this may be caused by the ripening period, and also the content of the cheese was 100% goat milk. In addition to the basic flavours of sheep cheese, sour taste was also detected. These distinct differences in basic flavours and aromas have stemmed from different production technologies and ripening levels of cheeses from different animal milk compositions.

Conclusion

Research and identification of traditional foods contribute to the continuity of cultural heritage and economic development. There are many traditional types of cheeses in the world with

Table 3. Correlation for instrumental textural parameters of white cheeses.

Instrumental textural parameters	Fracturability	Hardness	Adhesiveness	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
Fracturability	1							
Hardness	0.594**	1						
Adhesiveness	0.457*	0.260	1					
Springiness	-0.019	-0.233	0.063	1				
Cohesiveness	-0.088	-0.388*	0.229	0.181	1			
Gumminess	0.837**	0.408*	0.605**	0.061	0.389*	1		
Chewiness	0.672**	0.161	0.541**	0.489**	0.401*	0.846**	1	
Resilience	0.186	-0.015	-0.142	-0.072	0.526**	0.422*	0.248	1

* = Correlation is significant at the 0.05 level; ** = Correlation is significant at the 0.01 level.

different colours, appearances, and tastes, and white cheese is one of these. The present work identified the instrumental and sensory texture characteristics that drive consumer liking on white cheeses. The results obtained show that the variation in cheese quality depends on too many variables, and each variable has a different importance. However, the analysis of the basic components (PCA) shows that the majority of the variance in cheese quality can be explained by textural parameters by grouping the investigated cheese quality characteristics into independent sets. As a result; it can be concluded that basic parameters that vary according to different production technologies such as composition of the cheese, salt content, pH, starter culture, rennet activity in cheese matrix, casein, and serum protein are effective on the physiochemical, textural, and sensory parameters of cow, sheep, and goat milk cheeses. The composition of the casein fractions of the different animal milk, the diameter of the fat globules, and the enzymatic clotting mechanism change the instrumental and sensory texture. Maturation is also a significant factor of variability of cheeses from different milk origins.

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