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Sensory and Instrumental Consistency of Processed Cheeses

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Abstract

The objective of this study was to evaluate the instrumental and sensory texture of seven cheeses, as well as correlate sensory measurements of texture with mechanical properties. The cheeses were composed of different types of basic mass (casein and whey proteins) and emulsifying salts. Instrumental analysis of texture was performed using the universal mechanical testing machine (Instron) for determining the properties of firmness, elasticity, adhesiveness, gumminess, chewiness and cohesiveness. Data was analyzed using the principal component analysis and clustering analysis. Sensory texture was evaluated by a group of semi-trained assessors according to the ranking-difference test for texture of the products. The results were analyzed by the Friedman test; while sensory and instrumental texture measurements were correlated by the Spearman correlation coefficient. With regard to sensory and instrumental texture of the cheeses, the formation of three groups was observed: a first group consisting of cheeses with intermediate texture, another consisting of softer products and a third group formed of more consistent cheeses. Texture differences of the cheeses were determined by their protein and emulsifying agent composition. Sensory consistency presented a significant correlation ($|r_s| > 0.90$ and $p < 0.01$) with the properties of mechanical: firmness, adhesiveness, chewiness and elasticity. On the other hand, the sensory texture measurement is not correlated with the instrumental measurements of gumminess and cohesiveness, indicating that they do not reflect the human perception of cheese texture.

Keywords: cheese texture, ranking test, texture profile analysis, correlation

1. Introduction

Processed cheeses are considered of great economic importance due to their versatility as a food or ingredient in fast food products. This type of cheese is produced by fusing natural cheeses and with different degrees of maturity, supplemented with various ingredients and emulsifying agents, followed by heating the mixture until obtaining a homogeneous mass. Other optional dairy (fat, skimmed milk powder, whey proteins, caseins, caseinates, etc.) and non-dairyingredients (water, vegetable fat, colorants, flavorants, salts, hydrocolloids, preservatives and others) may be added to the mixture (Guinee, Cari, & Kaláb, 2004; Lee, Anema, & Klostermeyer, 2004).

The processed cheese matrix is formed of a continuous protein network, in which the fat and aqueous phases are dispersed (Udyarajan, Horne, & Lucey, 2007). Texture of the processed cheese, an important attribute in terms of sensory quality, is defined according to (i) composition, (ii) structural arrangements of components present (e.g., microstructure), (iii) physical-chemical state of the constituents, and (iv) macrostructure, which reflects the potential heterogeneity of the cheese texture, such as consistency, creaminess, spreadability and others (O'Callaghan & Guinee, 2004).

However, the texture of processed cheeses may be affected by many factors, including shelf life of the natural cheese (e.g., degree of proteolysis), the pH of the mass to be melted, processing and storage conditions (processing temperature, stirring speed, time and temperature of fusion, cooling rate, storage temperature), composition of the natural cheese (dry matter content, fat content and other), presence and concentration of ions (especially calcium, sodium and potassium), type and concentration of sugars and emulsifiers, among other factors (Bowland & Foegeding, 2001; Buñka et al., 2007; Dimitreli & Thomareis, 2007; Guinee, Cari, & Kaláb, 2004; Lee, Anema, & Klostermeyer, 2004; Lu, Shirashoji, & Lucey, 2007; Marchesseau et al., 1997; Piska & Stetina, 2004; Shirashoji, Jaeggi, & Lucey, 2006). The incorporation of hydrocolloid can also cause changes to the product structure and its texture (Bennett et al., 2006; Gustaw & Mleko, 2007; Lu Shirashoji, & Lucey, 2007).

These hydrocolloids, also referred to as stabilizers, emulsifiers or thickeners, can improve the texture and consistency of food by immobilizing water, thus forming a structure composed of a protein network or polysaccharides which permits gelation or increasedviscosity of the product. Commercially important hydrocolloids that may be used in the dairy industry are, for example, carrageenan, locust bean gum, xanthan gum, guar gum, polydextrose, modified starch or pectin (Bennett et al., 2006; Gustaw & Mleko, 2007; Williams & Phillips, 2000).

Texture is the most important characteristic of processed cheese when facing the purchasing decisions of consumers (Konstance & Holsinger, 1992; Park, Rosenau, & Peleg, 1984), which addresses a multi-parametric concept defined as an integration of sensory attributes for a product perceptible by mechanical, tactile and eventually visual and auditory receptors (ISO, 1992).

Moreover, although texture is by definition (IS0, 1981) a sensory property, there are many published studies on the use of instrumental techniques to evaluate texture since these methods are generally cheaper and easier to control, representing an interesting alternative to sensory evaluation and thus providing instrumental data that can be correlated with sensory perception (Lassoued et al., 2008). In this sense, many instrumental methods have been developed to determine the textural properties of food (Bourne, 2002), with emphasis on the method which imitates human perception, the Texture Profile Analysis (TPA). This technique has been effectively applied to a wide range of foods, especially in cheeses, as observed in studies performed by Lemay, Paquin & Lacroix (1994), Guinee, Auty and Fenelon (2000), Messens et al. (2000), Gonzalez et al. (2001), Irigoyen et al. (2002) and Van Hekken et al. (2007).

Tamime et al. (1999) evaluated the sensory and instrumental texture measurements of processed cheeses containing fat substitutes and reported that the sensory attribute of cheese spreadability was positively correlated ($p < 0.05$) with the instrumental measurement of elasticity and negativelycorrelated with cohesiveness. Significant correlation ($|r| > 0.50$ and $p < 0.10$) between sensory and mechanical evaluations were also observed in the analysis of firmness of Manchego cheese by Gonzalez-Vinas et al. (2001).

Therefore, the objective of the present study was to evaluate the textural properties of processed cheeses, containing different masses (natural cheese) and types of emulsifying salts, by means of subjective (sensory) and imitative methods (TPA), as well ascorrelation with sensory texture measurements with the mechanical properties.

2. Material and Methods

2.1 Samples

Seven types of processed cheeses of the same brand were analyzed. These products presented different compositions of the mass (protein) and different types of emulsifying agents for each formulation (Table 1), and therefore presented different characteristics of taste and texture. The samples were provided by the manufacturer, where all products had the same fabrication date. They were maintained at 7 ± 1 ºC before being analyzed and all measurements were performed within the predetermined shelf-life of each sample.

Table 1. Composition of the processed cheeses in relation to the protein mass and the emulsifier agents

SAMPLE	PRODUCT	PROTEIN MASS (BASIC)	EMULSIFIER/STABILIZER AGENTS
F1	Ricotta cream	Whey protein	Guar gum and xanthan gum
F2	Light ricotta cream	Whey protein	Guar gum, xanthan gum and WPC
F3	*Requeijão*	Caseinprotein	Powdered milk, WPC, sodium tetrapyrophosphate and trisodium phosphate
F4	Light *requeijão*	Caseinprotein	Powdered milk, WPC, sodium tetrapyrophosphate and polydextrose
F5	Light *requeijão* with fibers	Caseinprotein	Powdered milk, WPC, sodium tetrapyrophosphate, polydextrose and trisodiumphophate
F6	*Requeijão* type pizza	Caseinprotein	Sodium tetrapyrophosphate and trisodiumphophate
F7	Cream cheese	Caseinprotein	Guar gum, xanthan gum and carrageenan

WPC: whey protein concentrate.

Requeijãocremoso is a typical Brazilian industrialized product marketed as ready for consumption, similar to cream cheese, but less consistent.

2.2 Instrumental Analysis: Texture Profile Analysis (TPA)

The texture properties of processed cheeses were determined by the Texture Profile Analysis (Bourne, 2002), which was conducted in a universal machine for mechanical testing (Instron - Series 3367, USA, 2005). The analyses were performed at 25 ± 1 ºC, representing the oral temperature during consumption (Engelen et al., 2003; Tárrega et al., 2005).

A probe measuring 15 mm in diameter was moved perpendicular to the processed cheese sample contained within a cylinder measuring 50 mm in diameter and 40 mm high (Pons & Fiszman, 1996). The test conditions were: load cell of 1 KN, compression distance of 20% the height of the product, speed of 1.0 mm/s and contact time of 5 seconds, with two penetration cycles, as described by Gallina et al. (2008). The force exerted on the product was automatically registered and the texture properties of firmness (N), gumminess (N), cohesiveness (dimensionless), chewiness (J) and elasticity (mm) were automatically calculated by the Blue Hill 2.0 software (Instron, United States, 2005) from the curves of force (N) x time (s) generated during the test. Five analyses were performed for each sample.

The results were statistically analyzed according to the Principal Component Analysis (PCA), which is a technique that provides a graphical representation (two-dimensional) of the texture properties, allowing for simple interpretation and at the same time provides a robust analysis of changes in the products. Grouping of similar products was also performed in relation to the instrumental texture characteristics so as to characterize the similarities among texture of the cheeses. For this purpose a cluster analysis was performed, using the *k-means clustering* procedure. The groups suggested by the cluster analysis were confirmed by the Analysis of Variance with one factor (groups), followed by comparison of the means using the Tukey test ($\alpha = 0.10$).

2.3 Sensorial Analysis

The ranking test (ISO, 1988) was applied twice under different conditions: *(1)ranking-difference*– the samples were ranked in relation to the consistency of the processed cheesesby 40 semi-trained assessors, scoring the least consistent product with “1” and the most consistent cheese with “7”, *(2)ranking-preference*– 65 habitual consumers of processed cheese ranked the samples according to the individual preference of each consumer, assigning the score of “1” to the least preferred product and the score “7” to the most preferred. The tests were performed in individual booths with white light and mineral water. Results were analyzed using the Friedman test at 0.01 probability, as recommended by Meilgaard, Civille and Carr (2006) and Minim (2010).

2.4 Correlation between Instrumental and Sensorial Measurements

The correlation between measurements of instrumental (TPA) and sensory texture (consistency) was determined using the Spearman correlation coefficient, as was performed by Tárrega and Costell (2007).

3. Results and Discussion

3.1 Instrumental Texture (TPA)

The cheeses samples showed significant differences based on the F-test ($p < 0.10$) for texture properties of firmness, elasticity and chewiness. The averages obtained for each sample in relation to each of the instrumental measurements are shown in Table 2.

Table 2. Averages of texture instrumental properties of processed cheeses

Sample	Firmness (N)	Adhesivity (J)	Chewiness (J)	Cohesiviness (Dimensionless)	Gumminess (N)	Elasticity (Mm)
F1	0.14888	-0.00073	1.54735	0.99282	2.33671	3.87603
F2	0.19638	-0.00092	1.94201	0.95494	0.14023	5.94029
F3	0.25640	-0.00159	3.16443	2.96976	0.23020	8.55184
F4	0.38848	-0.00208	3.65969	0.96966	0.26210	9.78889
F5	0.40716	-0.00205	4.10905	0.96584	0.29385	10.1049
F6	1.54476	-0.00719	16.34162	0.98276	1.16884	11.34816
F7	1.76878	-0.01048	15.23168	0.97868	1.09129	11.63480

In the Principal Components Analysis (Figure 1), the first component explained 91.20% of data variation and the second component 7.36%, therefore totaling 98.56% of the total variation of the cheese texture. The instrumental measurements of texture, firmness, elasticity, chewiness and adhesiveness showed significant correlation ($p < 0.10$) with the first principal component, which explains the maximum variation of the data (Table 3). However, the property ofgumminess correlated only with the second main component, associated with low explanation of the data, and cohesiveness presented no correlation ($p > 0.10$) with either component. Thus, the textural properties of gumminess and cohesiveness showed little importance in differentiatingthe instrumental texture of the cheesesbecause the second principal component only accounted for 7.36% of the variation in the texture instrumental data.

Table 3. Explanation of principal components in the evaluation of the instrumental texture data

Principal Components	1º	2º	3º	4º	5º	6º
Percentage of explanation	91.20	7.36	1.01	0.41	0.02	0.00

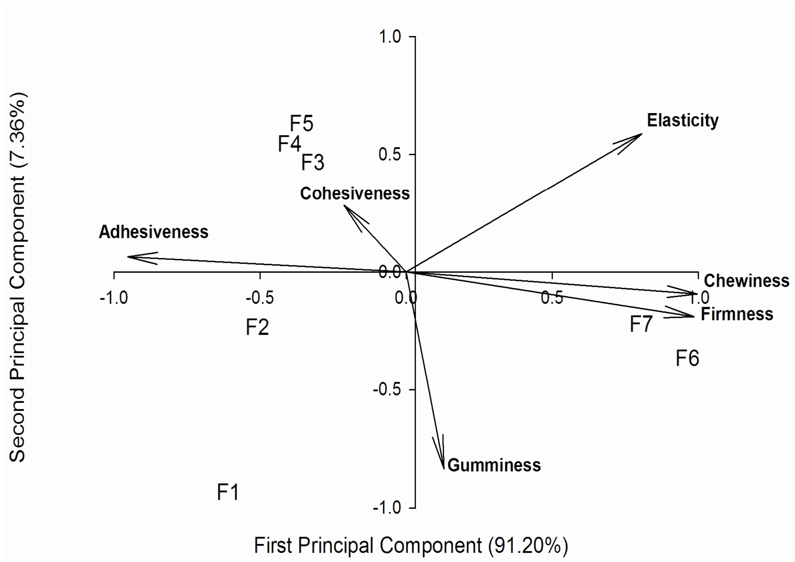

Figure 1. Principal components analysis of the instrumental texture properties for the processed cheeses

By means of the cluster analysis using the *k-means clustering* method, there is the formation of three groups of cheeses with respect to texture properties, where one group is formed of *requeijão* cheeses (traditional, light and with fibers), another consisting of ricotta cream (traditional and light) and a third group formed by the cream cheese and pizza *requeijão* cheese. The groups generated in the cluster analysis were confirmed by Analysis of Variance with one factor (groups), followed by comparison of averages by the Tukey test ($\alpha = 0.10$). Formation of the groups showed to be significant ($p < 0.10$) for the texture properties, with the exception of gumminess and cohesiveness. It should also be noted that these properties were of little importance to the characterization of cheese texture.

The texture properties of chewiness, elasticity and firmness showed positive correlation ($p < 0.10$) with the first principal component, and therefore characterized the cream cheese and pizza *requeijão* products. The adhesiveness attribute, negatively correlated with the first principal component, showed greatest intensity in the *requeijão* cheeses and light ricotta creams.

It was found that ricotta creams were characterized by showing lower intensity of firmness, chewiness and elasticity. These products present whey proteins as the basic protein matrix, which partially denatured under the action of heat, and opposite from the action of gums (guar and xanthan), form a three-dimensional structure, where fat and water are dispersed (Simeone, Alfani, & Guido, 2004; Thaiudom & Goff, 2003). Thus, products with low consistency and smooth texture were obtained due to the weak bonds established between the whey proteins in the formation of the protein matrix. Moreover, it was found that the whey protein concentrate (WPC), present in light ricotta cream, efficiently substituted fat since these products had the same instrumental characterization, observing a similarity in intensity of texture properties. Interestingly, a higher intensity was observed for adhesiveness of the light product compared to the traditional production, which is probably due to the action of whey proteins under the action of heat and constant stirring (Mounsey et al., 2007).

The *requeijão* cheeses (traditional, *light* and with fibers) made up a group of cheeses in which texture is characterized by the mechanical properties of adhesiveness and elasticity. These products present a rigid protein matrix due to the strong interactions established between casein fractions present in the basic mass of these products. Processed cheeses still rely on the action of the emulsifying agents trisodium tetrapyrophosphate and trisodium phosphate for the strengthening of its structure. These are emulsifying salts whose purpose is to complex the calcium present in casein, thereby maintaining the fat globules dispersed in the protein matrix, increasing the creaming potential of the cheese (Dimitreli et al., 2005). Products with reduced fat showed that polydextrose can be used as a substitute, which is a water soluble polymer and has a mechanism similar to soluble fibers, as in the case ofpectins and β-glucans, decreasing the level of cholesterol and blood glucose (Govers et al., 1999; Chandalia et al., 2000). In addition to its physiological effect, it acts to improve texture in foods, functioning as a stabilizer and thickener in addition to wetting; therefore it is widely used in reduced fat products. The addition of this polymer to foods has been approved by the U.S. Food and Drug Administration in over 50 countries (Jecfa, 1995), and according to Brazilian law, when adding 3 g of fiber per 100 g of product, the food can be considered a "source of fiber" (Brasil, 1998), which is the case of light *requeijão* cheese with fibers. Interestingly, both light *requeijão* cheeses are supplemented with polydextrose, but only one reaches the minimum needed to be considered a "source of fiber".

The pizza *requeijão* cheese and cream cheese showed high intensity for the texture properties of firmness, chewiness and adhesiveness. In *requeijão* this behavior is probably due to the presence of the trisodium phosphate emulsifying agent concomitant with casein, which is an emulsifying salt that allows for higher levels of cheese creaming and is recommended for production of more consistent processed cheeses (Dimitreli et al., 2005). In relation to the cream cheese, this characterization is subject to the action of the thickening agents guar gum, xanthan gum and carrageenan, which form highly viscous solutions due to their high water retention capacity (Thaiudom & Goff, 2003; Cerníková et al., 2008).

3.2 Ranking Tests: Difference and Preference

In the difference ranking test, the formation of three groups of processed cheeses was verified according to intensity of sensory consistency (Figure 2). The ricotta creams (traditional and light) showed a lower intensity of the consistency attribute, and the cream cheese and pizza *requeijão* cheese the greatest intensity. The *requeijão* cheeses (traditional, light and with fiber) formed a group with intermediate consistency, which did not differ at the probability level of 0.01. It is noted that the sensory test for difference ranking generated a result very similar to the instrumental analysis of the texture of the cheeses, where formation of the same groups was observed.

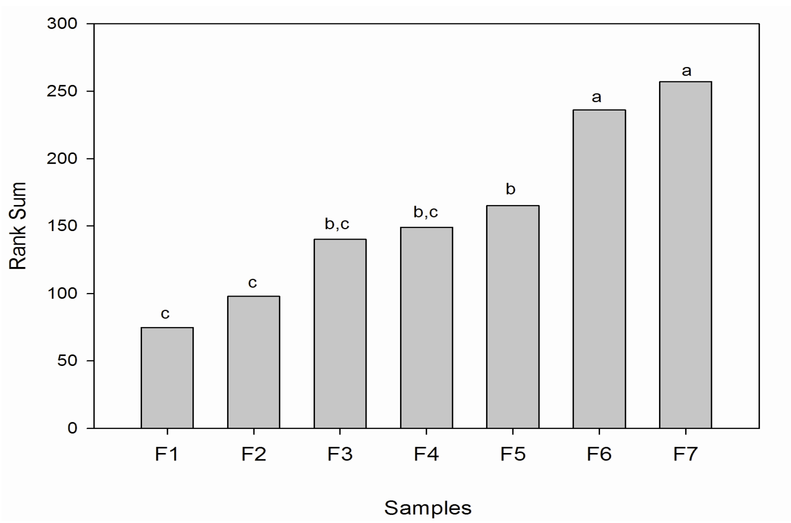

Figure 2. Rank sum of the difference ranking test for each processed cheese in relation to sensorial consistency. Rank sum followed by the same letters do not differ by the Friedman test at the significance level of 0.01

The ricotta creams presented lower sum of the scores, thus indicating lower consistency. This is probably due to the presence of whey protein as the basic protein mass, different from the others containing casein (Table 1). Casein favors protein-protein interactions and causes hardening of the protein matrix, thus generating firmer products (Sheehan & Guinee, 2004).

The cream cheese and pizza *requeijão* cheese showed higher sums of scores, therefore greater consistency. Both cheeses contain casein as the basic protein matrix. In the pizza *requeijão* cheese, the elevated intensity of consistency is probably due to the presence of the emulsifying agent trisodium phosphate together with casein. This is an emulsifying salt used to complex the calcium present in casein, thus maintaining the fat globules dispersed in the matrix protein, recommended for production of harder processed cheeses (Dimitreli et al., 2005). The intensity of consistency for the cream cheese is characterized by the presence of thickening agents: guar gum, xanthan gum and carrageenan.

In relation to the *requeijão* cheeses, it was found that these did not differ with regard to sensorial consistency, showing that in the light products the functionality of fat was well substituted by the emulsifying agent polydextrose.

In the preference test (Figure 3), if was found that less consistent products (ricotta creams) were less preferred by consumers. In contrast, cheeses with intermediate consistency (*requeijão* cheeses) were those most preferred. A similar result was found by Silva et al. (2012a), where *requeijão* cheeses with intermediate consistently showed greater preference among consumers.

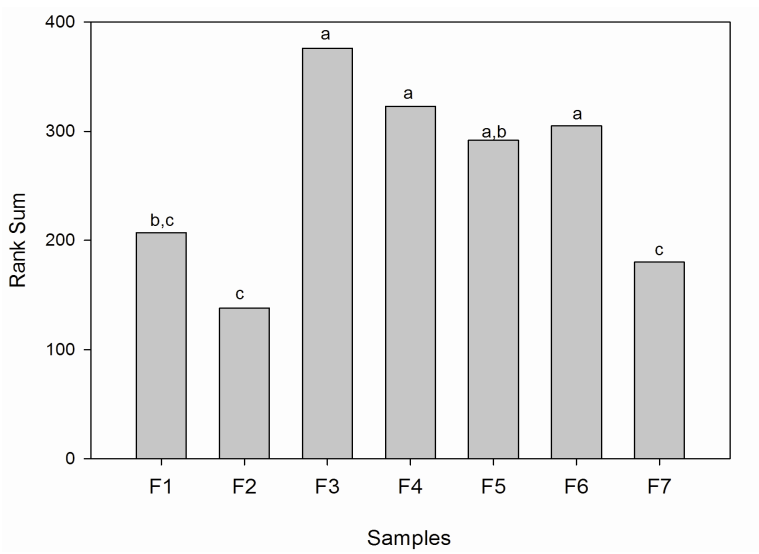

Figure 3. Rank sum of the preference ranking test for each processed cheese. Rank sum followed by the same letters do not differ by the Friedman test at the significance level of 0.01

The pizza *requeijão* cheese showed an increased intensity of the consistency attribute and was one of the most preferred cheeses. However, cream cheese also presented a high consistency but lower preference. This indicates that the texture of these products was not determinant of consumer preference, but did define their choices by means of "familiar" sensorial characteristics of the products, since the products most preferred are the *requeijão* cheeses which are commonly consumed by most Brazilian consumers. This behavior shows that consumer preference is subject to known products, i.e., products with preferred sensory characteristics are part of everyday life.

From this consumer behavior, it is identified that the differentiated products are alternatives to the *requeijão* cheeses, but these are not substituted. In relation to the light *requeijão* cheeses, there was no difference between this and the traditional *requeijão* cheese, indicating a satisfactory behavior of sensory substitution. Thus, there is a need to expand marketing of differentiated products in order to introduce these new products to the consumer market as an alternative version.

3.3 Correlation: Sensorial and Instrumental

As reported above, differences in texture of the processed cheeses containing different base proteins and types of emulsifying agents were detected by the instrumental and sensorial methods. To explore the relationships between methods, the Spearman analysis was used to establish correlations between the consistency perceived by humans and instrumental measurements of texture.

Sensory consistency significantly correlated ($|r_s| > 0.90$ and $p < 0.01$) with the properties of mechanical strength, adhesiveness, chewiness and elasticity, as shown in Table 4. Moreover, this measure of sensory texture showed no correlation with the instrumental measures of cohesiveness and gumminess, indicating that these measures do not reflect the human perception of cheese texture. This result is consistent with the analysis of instrumental analysis for the cheeses, since these properties did not correlate with the first principal component (maximum explanation) and were not important in differentiating product texture.

Sensorial consistency and measurements of firmness, chewiness and elasticity present direct correlations, where the magnitude of these measures varies in the same direction. Therefore, the firmer the cheese, greater will be the intensity of consistency perceived by the assessors. Silva et al. (2012b) also found a direct correlation between sensorial consistency and measures of firmness, chewiness and gumminess in the sensory characterization of processed cheeses with different fat and water contents. The rigid structure of the cheese containing the casein matrix associated to emulsifying agents with elevated creaming action permits the formation of a compact and dense structure, where the force required to disintegrate the food to the consistency of swallowing (chewiness) is high, which is perceived by humans as a veryconsistent product (Simeone, Alfani, & Guido, 2004; Thaiudom & Goff, 2003).

Moreover, sensory consistency presented an inverse correlation with adhesiveness of the cheeses, showing that less consistent products present greater spreadabilityon the palate and therefore adhere more to the surface of the tongue, difficult to remove. It is observed in Figure 1 that the products presenting greatest intensity of instrumental adhesiveness where those with low and intermediary consistency.

Table 4. Spearman correlation between sensory consistency and the instrumental texture properties

Instrumental Texture Properties	Sensory Consistency	
	rs	p-value
Firmness	1.0000	< 0.0001 *
Adhesiveness	-0.96429	0.0005 *
Chewiness	0.96429	0.0005 *
Cohesiveness	-0.10714	0.8192 ns
Gumminess	0.21429	0.6445 ns
Elasticity	1.0000	< 0.0001 *

rs: Spearman correlation coefficient; * significant at 0.01 probability; ns non-significant.

Instrumental evaluation of the texture of foods can provide measurements that correlate with sensory perception, providing practical information to the food industry because from the mechanical properties the sensory consistency of the cheese can be predicted. This is very interesting from a practical context due to the rapid attainment of instrumental measurements. The results obtained in the present study provide information on the practical use of product monitoring and development.

4. Conclusions

The degree of sensory consistency of processed cheeses depends on the protein mass and emulsifying agents present. From the sensory and instrumental analyses, the processed cheeses were classified into three groups: a first low-consistency group formed by the ricotta creams (traditional and light), another intermediate-consistency group consisting of *requeijão*cheeses (traditional, light and with fiber), and finally a group formed by cream cheese and pizza *requeijão* cheese, presenting higher intensity of sensory consistency. The differences in texture of the cheeses were determined by their protein composition and emulsifying agents. In relation to consumer preference, this was defined in terms of “familiar” sensory characteristics of the cheeses, where the “traditional” products (*requeijão* cheeses) were preferred. For the *requeijão* cheeses with low fat content, they showed no difference in preference from the traditional *requeijão* cheeses, indicating a satisfactory behavior of sensory substitution. In contrast, the differentiated products (ricotta and cheese based creams) were less preferred, showing the need to invest in marketing of the new products.

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