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ORIGINAL ARTICLE

Approaching the sensory profile of Paipa cheese, the Colombian ripened cheese with protected designation of origin

Estudo do perfil sensorial do queijo Paipa, o queijo curado da Colômbia com denominação de origem protegida

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Abstract

Paipa cheese is the unique Colombian ripened cheese produced from raw milk that has a protected designation of origin (PDO); nonetheless, to date, the dairy product lacks a defined sensory profile, since no study has been previously performed. The aim of this study was to approach the definition of the sensory attributes of the Paipa cheeses that are produced within the PDO region in order to establish the organoleptic aspects of the PDO regulation. A trained panel of five members used the multidimensional approach as a descriptive sensory analysis to establish the sensory profile of Paipa cheese; such analysis was complemented with the method used for PDO cheeses were three cheese producers, two government delegates, one gastronomy expert and two Paipa cheese researchers participated in the descriptive sensory analysis. A microbiological assessment (mesophilic aerobic bacteria, lactic acid bacteria, total and fecal coliforms, coagulase-positive Staphylococci, *Salmonella* spp. and *Listeria monocytogenes*) of cheese samples was carried out prior to sensory analysis to guarantee the safety of the samples. The descriptive sensory analysis was performed with 17 cheese samples that represented 77% of Paipa cheese produced in the PDO region. 82 sensory descriptors were identified and 47 were finally established (seven descriptors for appearance, 15 for odor, 15 for taste and 10 for texture) for describing the sensory profile of Paipa cheese. Due to the presence of pathogenic bacteria, the texture and taste profiles of Paipa cheese were based only on three samples. Sensory profiles of cheese samples were highly heterogeneous and it may be a consequence of the variations among raw milk used and/or manufacturing practices of cheese producers. Therefore, in order to find the sensory identity of Paipa cheese and guarantee quality and safety, cheese production and raw milk characteristics must be defined and regulated among milk and Paipa cheese producers.

Keywords: Artisanal cheese; Raw milk cheese; Sensory profile by a multidimensional approach; Descriptive sensory analysis; Microbiological characterization; Principal component analysis.

Resumo

O queijo Paipa é o único queijo curado colombiano com denominação de origem protegida (DOP) e é feito com leite cru; No entanto, até o momento, o produto não apresenta um perfil sensorial definido, já que nenhum estudo foi feito até o momento. O objetivo deste estudo foi abordar a definição dos atributos sensoriais dos queijos Paipa produzidos na região do DOP, a fim de estabelecer os aspectos organolépticos da regulação DOP. Um painel treinado de cinco membros utilizou o teste de análise sensorial descritiva por abordagem multidimensional para estabelecer o perfil sensorial do queijo Paipa; esta análise foi complementada com o método utilizado para queijos DOP, no qual participaram também três produtores de queijo, dois delegados do governo, um especialista em gastronomia e dois pesquisadores do queijo Paipa. A avaliação microbiológica (bactérias aeróbicas mesofílicas, bactérias do ácido láctico, coliformes totais e fecais, estafilococos coagulase positiva, *Salmonella* spp. *Listeria monocytogenes*) das amostras de queijo foi feita antes da análise sensorial a fim de garantir a segurança das amostras a serem testadas. A análise sensorial descritiva foi feita com 17 amostras de queijos que representaram 77% dos queijos Paipa produzidos na região DOP. 82 descritores sensoriais foram identificados e finalmente 47 foram estabelecidos (sete descritores para aparência, 15 para odor, 15 para sabor e 10 para textura) para descrever o perfil sensorial do queijo Paipa. Devido à presença de bactérias patogênicas, os perfis de textura e sabor do queijo Paipa estiveram baseados em apenas três amostras. Os perfis sensoriais das amostras de queijo foram altamente heterogêneos e isso pode ser uma consequência da grande variação nas características do leite cru e/ou nas práticas de elaboração dos produtores de queijo. Portanto, para encontrar a identidade sensorial do queijo Paipa e garantir sua qualidade e segurança sanitária, a produção de queijo e as características do leite cru devem ser definidas e regulamentadas entre os produtores de leite e queijo Paipa.

Palavras-chave: Queijo artesanal; Queijo feito de leite cru; Perfil sensorial usando uma abordagem multidimensional; Análise sensorial descritiva; Caracterização microbiológica; Análise do componente principal.

Highlights

- The sensory profile of Paipa cheese was defined using a multidimensional approach
- The sensory profile of Paipa cheese was highly heterogeneous among samples
- 82 sensory descriptors were identified and 47 were finally established

1 Introduction

Paipa cheese is the unique Colombian ripened cheese and since 2011 has protected designation of origin – PDO (Colombia, 2011). The cheese is produced from raw milk in the cities of Paipa and Sotaquirá, located in the state of Boyacá, Colombia at 5º40' and 5º55' north latitudes and 73º03' and 73º16' west longitudes, respectively. Paipa and Sotaquirá have mountainous geography, an altitude around 2581 meters above sea level (Instituto Geográfico Agustín Codazzi, 1996) and exhibit cold climate with average temperature of 14 °C and 76% relative humidity (Instituto de Hidrología Meteorología y Estudios Ambientales, 2015).

Paipa cheese presents a maturation of 21 days and is elaborated from raw milk that is obtained mainly by hand milking. More than 95% of the milk is produced by small producers with less than 50 animals (Colombia, 2016). Cheese production is based on the tradition, knowledge and know-how of some families that are located in the northwestern region of Boyacá state (Instituto de Ciencia y Tecnología de Alimentos, 1986).

According to PDO regulation (Res. No. 070802), raw milk for producing Paipa cheese must comply with compositional, physicochemical and microbiological characteristics as follows: 3% lipid, 3% protein, 11.4% total solids, 0.16% lactic acid (titratable acidity), pH 6.5, $<7\times10^5$ CFU/mL total mesophilic aerobic bacteria, somatic cell count (SCC) below 3×10^5 SCC/mL (Colombia, 2011).

Microbiological characteristics of Paipa cheese are typified by the presence of indigenous lactic acid bacteria (LAB) as well as pathogens (coliforms, *E. coli, Listeria monocytogenes, Salmonella* spp and

coagulase-positive Staphylococci). Recently, Castellanos et al. (2020) reported a dominant presence of LAB such as *Lactococcus, Enterococcus, Leuconostoc* and *Streptococcus* in Paipa cheese as well as potentially human-pathogenic bacteria of Enterobacteriaceae family.

PDO regulation also indicates that Paipa cheese proximate composition shall be 47.43% moisture, 52.57% total solids, 21.81% lipid, 24.3% protein, 2.1% salt, 1.1% lactic acid (titratable acidity) and pH 5.21. Cheese appearance shall be of cylindrical shape with pale yellow slightly bright color, smooth wrinkled rind of 5-mm thickness and a core with small and irregular eyes. The texture shall be semi-hard, dry, slightly friable and not sandy. The taste shall be mild acid followed by moderate bitter, and the odor is characterized as rancid (Colombia, 2011). According to Montel et al. (2014), artisanal cheeses that are made with raw milk exhibit a wide range of sensory descriptors due to the diversity of biochemical reactions produced during ripening process, nevertheless, Paipa cheese PDO regulation indicated few sensory descriptors. Based on that, the aim of this study was to characterize the sensory attributes of Paipa cheese to precisely define the identity of the artisanal Colombian cheese to develop the full potential of the PDO region and its different actors.

2 Materials and methods

According to the information provided by the local and state governments as well as the Association of Paipa cheese producers (*Asoquesopaipa*), 22 producers are registered in both cities, 16 are located in Paipa and six (6) in Sotaquirá.

Before the experiment, cheese producers were gathered to explain the scope of the study and to ask whether they wanted to participate. After the meeting, 17 of the 22 Paipa cheese producers identified in the territory (77%) agreed to supply samples of cheese to accomplish the study.

2.1 Materials

Each cheese producer provided three samples of Paipa cheese (0.5 kg each). Cheeses were vacuum packaged once they completed 30 days of ripening. Cheese maturation was performed at 15 °C and 75% relative humidity approximately. Cheese samples were transported under refrigeration (2.5 ± 1 °C) to the University of Antioquia, Medellin, Antioquia, Colombia for sensory and microbiological analyses.

2.2 Cheese microbiological analyses

Prior to sensory analysis, cheese samples were subjected to standard microbiological assessment in the Laboratory of Public Health of the University of Antioquia, Medellín, Antioquia, Colombia. The evaluation comprised the quantification of mesophilic aerobic bacteria by the pour plate technique (International Organization for Standardization, 2013), lactic acid bacteria by the colony-count method at 30 °C (International Organization for Standardization, 1998), total and thermotolerant coliform with the Most Probable Number (MPN) method (Feng et al., 2020), coagulase-positive Staphylococci by the colony-count technique (Instituto Colombiano de Normas Técnicas y Certificación, 2007) and the presence of *Salmonella* spp. (International Organization for Standardization, 2017a) and *Listeria monocytogenes* (International Organization for Standardization, 2017b) by selective enrichment media and isolation on selective agar.

2.3 Cheese color assessment

The color of core and rind of Paipa cheese was assessed by comparing the 17 cheese samples with the Pantone color system (Spinelli et al., 2014) in the Laboratory of Food Sensory Analysis of the University of Antioquia, Medellin, Antioquia, Colombia.

2.4 Sensory analysis

A descriptive sensory analysis of Paipa cheese was performed in the Laboratory of Food Sensory Analysis of the University of Antioquia, Medellin, Antioquia, Colombia. The test was based on the technique of sensory profile by a multidimensional approach (Instituto Colombiano de Normas Técnicas y Certificación, 1996) which was complemented with the sensory method used for cheeses with designation of origin (Bérodier et al., 1997).

2.4.1 Panel and committee training and identification of sensory descriptors

Panel of five (5) judges with more than five years of experience in sensory analysis were selected to perform the descriptive analysis. The judges were trained in four training sessions of two hours each using four (4) commercial brands of Paipa cheese as training samples. Cheese samples of 1.5 cm×1.5 cm×5 cm containing core and rind were placed in plastic plates with 3-digit random codes, and presented to panelists at 14 ± 2 °C in a sequential order (Montero et al., 2005). Thereafter, a preliminary list of sensory descriptors that characterize the attributes of appearance, odor, taste and texture of Paipa cheese was developed by the trained sensory panel.

In addition, a committee composed by three (3) traditional Paipa cheese producers, two (2) researchers, two (2) government delegates from Paipa and Boyacá, and one (1) member from the gastronomic sector was constituted (Ojeda et al., 2015) to precisely define the list of descriptors. The committee participated in four training sessions (three hours each) on sensory analysis to establish the complete list of descriptors for the attributes of appearance, odor, taste and texture of Paipa cheese. A consent format was signed by each committee member, and their personal information was confidential and protected.

2.4.2 Paipa cheese sensory profile definition

After verifying the microbiological safety of the 17 Paipa cheese samples, the trained sensory panel performed the descriptive sensory analysis based on the sensory profile by a multidimensional approach that was carried out in the Laboratory of Sensory Analysis of the University of Antioquia, Medellin, Antioquia, Colombia.

The cheese samples that did not comply with microbiological safety (Colombia, 1989) were tested only for odor and appearance attributes. Cheese samples (1.5 cm × 1.5 cm × 5 cm) containing core and rind were placed in plastic plates with 3-digit random codes and were presented to panelists in sequential order at 14 ± 2 °C (Montero et al., 2005). The panelists evaluated the samples against the complete list of Paipa cheese descriptors and established the intensities of each descriptor in a scale from 0 to 5 (where 0 = Not perceived 5 = Strong) In accordance with the Colombian Technical Standard NTC 3932 (Instituto Colombiano de Normas Técnicas y Certificación, 1996). Thereafter, some descriptors such as hedonistic, quantitative, defects, synonyms, antonyms, irrelevant descriptors as well as terms that described the product with their own names, were removed from the list. Further reduction of sensory descriptors was accomplished based on the frequency (F) and intensity (I) of the terms, establishing a matrix of geometric means [$M = \sqrt{(F \times I)}$] (Instituto Colombiano de Normas Técnicas y Certificación, 1996).

2.5 Statistical analyses

The intensities of the sensory descriptors were statistically analyzed using the non-parametric Kruskal-Wallis test with a significance value of 0.05. Moreover, a Principal Component Analysis (PCA) was accomplished to identify correlations among sensory descriptors. Statistical analyses were performed using R Project *v 3.5.2*, free software for statistical computing.

3 Results and discussion

3.1 Cheese microbiological analyses

Microbial characterization of Paipa cheese samples is presented in Table 1. According to the results, it could be noted that only three samples, No. 2, 7 and 8, complied with fecal coliforms limit (< 3 MPN/g) that is established by Colombian cheese regulation (Colombia, 1989). Furthermore, Lactic Acid Bacteria (LAB) were the most abundant microorganisms which is important due to their key role on the development of sensory characteristic of cheese (Londoño-Zapata et al., 2017), whereas the pathogenic *Salmonella* sp. was absent in cheese samples.

Table 1. Microbiological characterization of Paipa cheese samples.

Cheese sample	Total coliforms (MPN[a]/g)	Fecal coliforms (MPN[a]/g)	Coagulase-positive Staphylococci (CFU/g)	Aerobic mesophiles (1×10^3 CFU/g)	LAB[b] (CFU/g)	*Salmonella* sp.	*Listeria monocytogenes*
1	>1,100	>1,100	<100	>300	>300	Negative	Negative
2	>1,100	<3	<100	>300	>300	Negative	Negative
3	>1,100	1,100	100	>300	>300	Negative	Negative
4	29	11	1.2	>300	>300	Negative	Negative
5	>1,100	>1,100	2.7	>300	>300	Negative	Negative
6	>1,100	240	>200	>300	>300	Negative	Positive
7	23	<3	<100	>300	>300	Negative	Negative
8	43	<3	<100	>300	>300	Negative	Negative
9	>1,100	9.1	>200	>300	>300	Negative	Negative
10	<1,100	460	>200	>300	>300	Negative	Negative
11	>1,100	240	3.3	>300	>300	Negative	Negative
12	>1,100	23	<100	>300	>300	Negative	Negative
13	>1,100	>1,100	>200	>300	>300	Negative	Negative
14	240	11	<100	>300	>300	Negative	Negative
15	240	93	37	>300	>300	Negative	Negative
16	>1,100	23	<100	>300	>300	Negative	Positive
17	>1,100	240	3.9	>300	>300	Negative	Positive
R. 1804[c]	N/A[d]	<3	<100	N/A[d]	N/A[d]	Negative	N/A[d]

[a]Most Probable Number. [b]Lactic Acid Bacteria. [c]Resolution 1804 of 1989 of the Ministry of Health of Colombia (1989). [d]Does not apply.

Three samples (No. 6, 16 and 17) exhibited the presence of *L. monocytogenes* (Table 1), a potentially pathogenic microorganism. *L. monocytogenes* may arise from several sources such as contaminated or poorly cleaned and sanitized areas or equipment from the dairy plant. Nevertheless, when it is detected in dairy products, it has been linked to herd contamination e.g., raw milk, forage silage or unhygienic milking practices (D'Amico & Donnelly, 2017). Chatelard-Chauvin et al. (2015) indicated that cheeses elaborated from raw milk (non-thermally processed) and maturated for less than 45 days, as is the case of Paipa cheese, are generally contaminated with *L. monocytogenes*. On the contrary, recent studies have positively associated the microbial diversity of artisan raw milk cheeses with a lower prevalence of *L. monocytogenes* (Gérard et al., 2021). 47% of Paipa cheese exceeded the maximum limit of coagulase-positive Staphylococci (<100 CFU/g), and these microorganisms has been associated with bad hygienic practices during cheese processing as well as the use of raw milk contaminated with mastitis (Hait, 2012). Fecal coliform estimation, specifically *E. coli*, is an indicator of hygienic quality of the cheese. This microorganism is not always a pathogen since it is a regular microorganism found inside human and animal intestine; nonetheless, some serogroups, such as *E. coli* O157:H7 can be pathogenic due to the production of the shiga toxins (STEC). According to D'Amico & Donnelly (2017), *E. coli* O157:H7 can easily contaminate raw milk in the farm.

Furthermore, Yoon et al. (2016) reported that *E. coli* and Coliforms are frequently identified in cheeses that were produced from raw milk.

Controlling the presence of pathogens in Paipa cheese is challenging due to the use of non-thermally treated milk and the short-term ripening period (Baars, 2019). The former is required in order to preserve the natural microbiota and enzymes of raw milk which are the key for the sensory characteristics and identity of Paipa cheese (O'Sullivan & Cotter, 2017), and on the other hand, the short maturation time is deficient for reducing the pathogens present in raw milk (Chatelard-Chauvin et al., 2015). Therefore, improving milking practices as well as good manufacturing practices throughout the Paipa cheese chain is crucial to guarantee the dairy product safety and sensory quality.

3.2 Cheese color assessment

According to the Pantone color system, the color of Paipa cheese rind and core was homogeneous among samples. Core color was defined as pastel yellow, 11-0616 TPX (Figure 1A and 1B) while the rind was described as corn silk, 13-0932 TPX (Figure 1C and 1D). Moreover, the cheese rind exhibited a 5-mm thickness (Figure 1A and 1B).

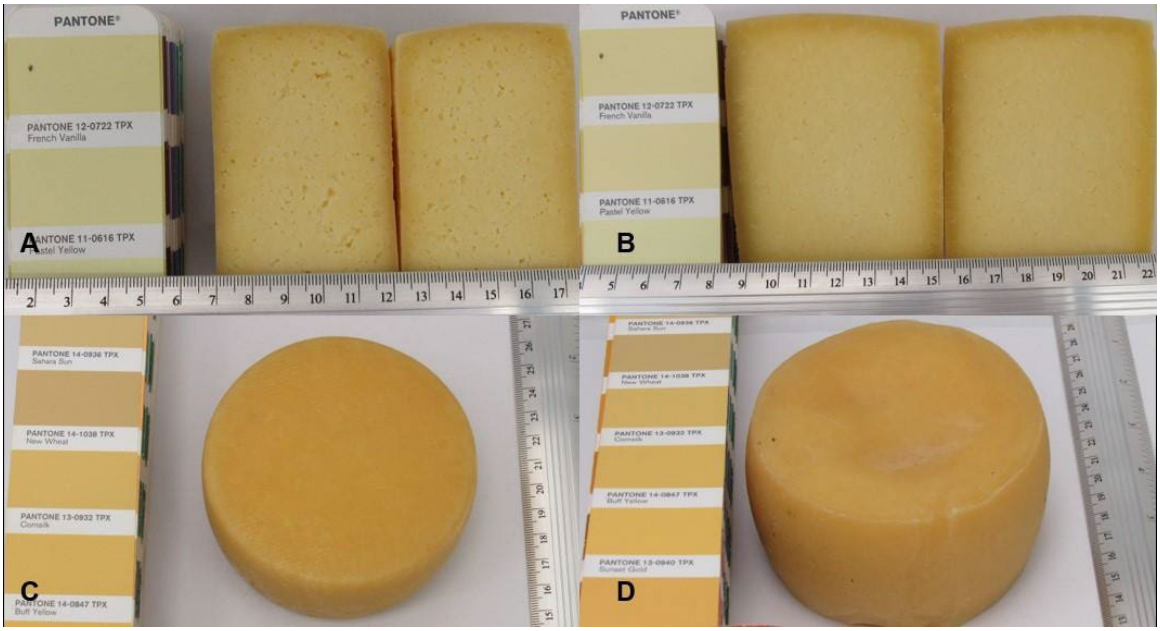

Figure 1. Appearance and color of Paipa cheese core (A and B) and rind (C and D).

Paipa cheese exhibited homogeneous color among samples. According to some authors, cheese color may be a consequence of i) the carotenoid pigments contained in the raw milk of grazing cows (Kalac, 2011), ii) the lipid oxidation that occur mainly on the cheese surface (Hong et al., 1995) and iii) moisture loss (Álvarez et al., 2007) during the ripening process. Arteaga et al. (2009) and Villegas et al. (2015) reported similar rind and core color for Chanco (Chile) and Chapingo (Mexico) cheeses, two Latin-American cheeses with short maturation.

3.3 Identification of Paipa cheese sensory descriptors

The list of descriptors for the sensory attributes of Paipa cheese was composed by 82 sensory descriptors. Nine for appearance, 28 for odor, 30 for taste and 15 for texture (Table 2). The high number of sensory descriptors that were established for Paipa cheese have proved that the dairy product has a higher variety of tastes, odors and textures than those indicated by the PDO regulation. Such abundance is expected in cheeses that are elaborated with traditional practices as well as raw milk (O'Sullivan & Cotter, 2017) as is the case of Paipa cheese.

Table 2. Complete list of sensory descriptors of Paipa cheese.

Appearance	Odor	Taste	Texture
5-mm thickness (R[a])	Lactic	Lactic	Brittle
Opacity (R[a])	Fresh	Fresh	Greasy
Color uniformity (R[a])	Lactic ferment	Fatty	Lumpy
Stain (R[a], C[b])	Fatty	Salty	Hard
White mold (R[a])	Acid	Acid	Chewable
Cracks (R[a], C[b])	Aromatic	Lactic ferment	Fatty mouthfeel
Eyes (C[b])	Buttery	Umami	Moist
Uniformity of eyes (C[b])	Sweet	Buttery	Adhesive
White dots (C[b])	Fruity	Sweet	Mealy
	Pungent	Astringent	Meltable
	Salty	Barny	Springy
	Cooked	Bitter	Cohesive
	Bitter	Cooked	Grinding
	Moldy	Fruity	Grainy
	Peculiar	Woody	Rubbery
	Barny	Valeric acid	
	Leather	Leather	
	Rancid-butyric	Pungent	
	Valeric acid	Peculiar	
	Ammoniated	Rancid-butyric	
	Caramel	Nutty	
	Nuts	Moldy	
	Yeasty	Ammoniated	
	Wood	Alcohol	
	Alcohol	Waxy	
	Glue like	Rubber like	
	Rubber like	Toasty	
	Waxy	Smoky	
		Caramel	
		Glue like	

[a]Rind. [b]Core. Definitions of sensory descriptors[1].

[1] **Appearance**: 5-mm thickness: millimeters thick of the cheese rind. Opacity: the extent to which the surface of the cheese is matte or dull. Color uniformity: uniformly colored cheese is free of speckles, marbling, blemishes and other. Stain: sign, mark or color different from the inside or outside of the cheese. White mold: visible white mold growth on cheese rind. Cracks: narrow and elongated opening on the inside or outside of the cheese. Eyes: rounded holes inside the cheese. Uniformity of eyes: similarity in shape and distribution of the eyes inside the cheese. White dots: white spots or dots inside the cheese.
Odor: Lactic: aromatics associated with milk and dairy. Fresh: aromatics associated with fresh dairy products. Lactic ferment: aromatics associated with fermented dairy products such as yogurt. Fatty: aromatics associated with milk fat. Acid: aromatics associated with acids (citric, lactic, and others). Aromatic: overall intensity of the aromatic sensations perceived. Buttery: aromatics associated with fresh butter. Sweet: sweets aromatics associated with fresh dairy products. Fruity: sweets aromatics associated with fresh fruits. Pungent: trigeminal sensation in the nose associated with burning sensation. Salty: aromatics associated with salts. Cooked: aromatics associated with cooked milk. Bitter: aromatics associated with the bitter primary taste. Moldy: aromatics associated with molds or freshly turned soil. Peculiar: characteristic aromatics not associated with other odors. Barny: phenolic aromatics associated with barns and livestock trailers. Leather: aromatics associated with cowhide. Rancid-butyric: aromatics associated with sour milk and oxidized milk fats. Valeric acid: aromatics associated with valerianic acid. Ammoniated: aromatics associated with ammonia. Caramel: aromatics associated with burnt or melted sugar. Nutty: aromatics associated with various nuts such as peanuts, hazelnuts and walnuts. Yeasty: aromatics associated with yeast fermentation. Wood: aromatics associated with wood. Alcohol: aromatics associated with distilled spirits. Glue like: aromatics associated with glue. Rubber like: aromatics associated with rubber. Waxy: sweet aromatics that are associated with wax paper or wax candles
Taste: Lactic: tastes associated with milk and dairy. Fresh: tastes associated with fresh dairy products. Fatty: tastes associated with milk fat. Salty: primary taste or taste sensation caused by salts. Acid: primary taste or taste sensation caused by acids (citric, lactic, and others). Lactic ferment: tastes associated with fermented dairy products such as yogurt. Umami: primary taste or taste sensation caused by certain peptides and nucleotides associated with the taste of monosodium glutamate. Buttery: tastes associated with fresh butter. Sweet: primary taste caused by sugars. Astringent: complex of trigeminal sensations of dryness, wrinkling and shrinkage in the oral cavity. Barny: tastes associated with fresh butter with barns and livestock trailers. Bitter: primary flavor associated with caffeine and other alkaloids. Cooked: tastes associated with cooked milk. Fruity: sweets tastes associated with fresh fruits. Woody: tastes associated with wood. Valeric acid: tastes associated with valerianic acid. Leather: tastes associated with cowhide. Pungent: trigeminal sensation in the mouth associated with burning sensation. Peculiar: characteristic tastes not associated with other odors. Rancid-butyric: tastes associated oxidized milk fats. Nutty: tastes associated with various nuts such as peanuts, hazelnuts and walnuts. Moldy: tastes associated with molds. Ammoniated: tastes associated with ammonia. Alcohol: tastes associated with distilled spirits. Waxy: tastes associated with waxes or paraffins. Rubber like: tastes associated with rubber. Toasty: combination of roasted tastes. Smoky: taste perception of burning wood smoke. Caramel: tastes associated with burnt or melted sugar. Glue like: tastes associated with glue.
Texture: Brittle: degree of fracture of the sample after the first bite. Greasy: composition texture attribute where fat content is perceived. Lumpy: degree to which granular structures are formed in the mouth during chewing. Hard: force required to break the cheese when the first bite is taken. Chewable: degree of chewing necessary for the cheese to be ready to be swallowed. Fatty mouthfeel: fatty mouthfeel after eating the cheese. Moist: composition texture attribute where moisture content is perceived. Adhesive: degree to which the chewed mass adheres to the surface of the mouth. Mealy: sensation in the mouth when the sample breaks into small pieces and is difficult to pick up for swallowing. Meltable: sensation of melting felt between the palate and the tongue. Springy: resilience after exerting a deforming force. Cohesive: degree to which the chewed cheese mass is held together. Gritty: gritty sensation in the mouth during chewing. Grainy: grainy sensation in the mouth during chewing. Rubbery: effort required to break down the cheese and make it ready to swallow.

3.4 Paipa cheese sensory profile definition

As mentioned before, the sensory characterization of Paipa cheese was limited due to the detection of pathogens in several samples. Thus, texture (Figure 2A) and taste (Figure 2B) profiles were based on three cheese samples that exhibited no pathogenic bacteria (samples No. 2, 7 and 8), while appearance (Figure 3A) and odor (Figure 3B) profiles were established with all the 17 Paipa cheese samples.

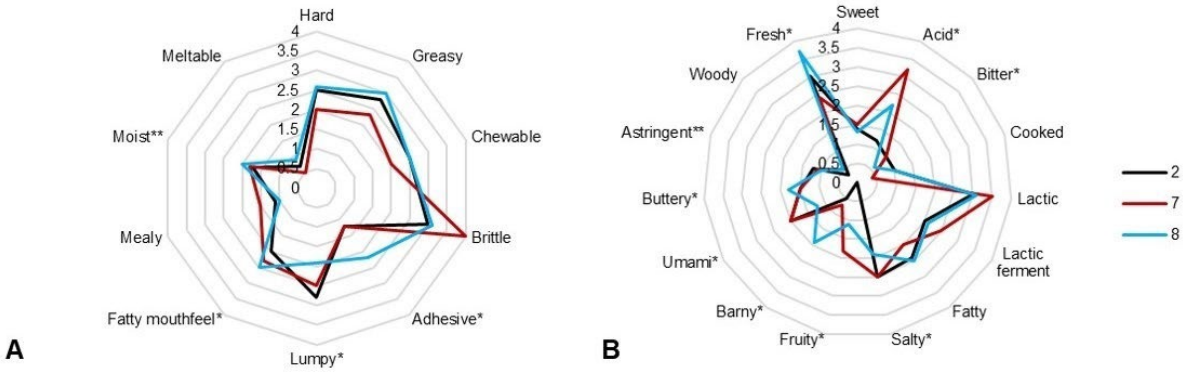

Figure 2. Texture (A) and taste (B) profile of Paipa cheese. Descriptors with (*) indicate significant statistical difference among samples ($p < 0.05$). Descriptors with (**) indicate significant statistical difference among judges ($p < 0.05$).

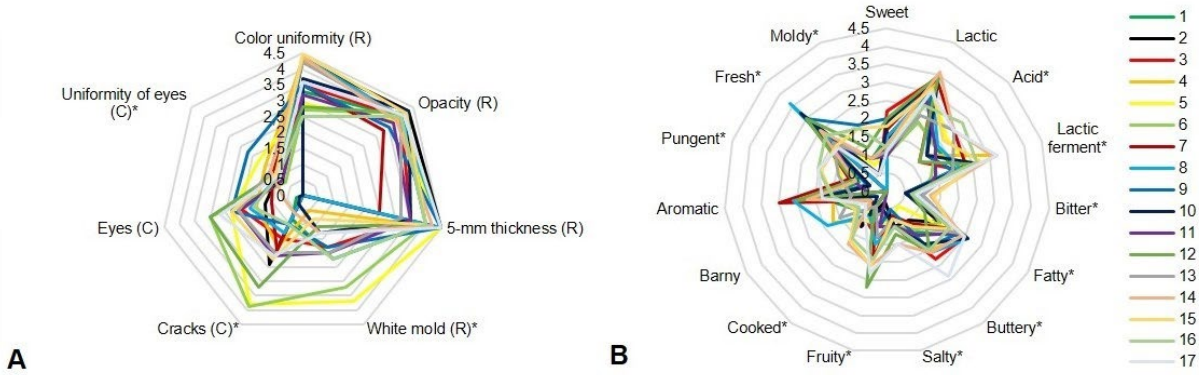

Figure 3. Appearance (A) and odor (B) profile of Paipa cheese. Descriptors with (*) indicate significant statistical difference among samples ($p < 0.05$). R = Rind; C = Core.

The trained sensory panel used the complete list of 82 sensory descriptors that was previously defined by the committee (Table 2) to evaluate cheese samples. At the end, the sensory panel reduced the list to 47 (Table 3). The reduced or definitive list of descriptors was sufficient to preserve the overall sensory profile of Paipa cheese that is produced in the PDO region.

Table 3. Definitive list of sensory descriptors of Paipa cheese.

Appearance	Odor	Taste	Texture
5-mm thickness (R[a])	Lactic	Lactic	Brittle
Opacity (R[a])	Fresh	Fresh	Greasy
Color uniformity (R[a])	Lactic ferment	Fatty	Lumpy
White mold (R[a])	Fatty	Salty	Hard
Cracks (C[b])	Acid	Acid	Chewable
Eyes (C[b])	Aromatic	Lactic ferment	Fatty mouthfeel
Uniformity of eyes (C[b])	Buttery	Umami	Moist

Table 3. Continued....

Appearance	Odor	Taste	Texture
	Sweet	Buttery	Adhesive
	Fruity	Sweet	Mealy
	Pungent	Astringent	Meltable
	Salty	Barny	
	Cooked	Bitter	
	Bitter	Cooked	
	Moldy	Fruity	
	Barny	Woody	

[a]Rind. [b]Core.

The texture of Paipa cheese was the attribute that exhibited the lower variation among samples. Only 30% of the descriptors showed significant statistical difference, and cheese samples No. 2 and 8 displayed high similarity (Figure 2A). On the contrary, taste profile displayed higher heterogeneity where 53% of the descriptors exhibited statistical difference (Figure 2B).

Paipa cheese displayed comparable intensities of texture descriptors when compared to the Mexican Chihuahua cheese on adhesive and fatty mouthfeel, whereas brittleness was higher in the latter (Van Hekken et al., 2006). Descriptors such as core eyes and rind thickness are some of the most frequently sensory descriptors used in descriptive sensory analysis of ripened cheese appearance (Ramírez-Rivera et al., 2018), and these descriptors were determined in the Paipa cheese (Table 3).

The appearance profile showed high variation in some descriptors, e.g., uniformity of eyes, presence of white mold in rind as well as core cracks (Figure 3A). Similarly, the odor profile of Paipa cheese showed high heterogeneity. For instance, more than 70% of odor descriptors displayed significant statistical differences (Figure 3B) which was likely a consequence of differences in the biochemical reactions that took place during cheese ripening. Using raw milk for producing a ripened cheese allows for developing a high spectrum of sensory characteristics due to the diverse biochemical reactions produced by the indigenous microorganisms; nonetheless, some of them may be the cause of food borne illnesses (Yoon et al., 2016). The French Saint-Nectaire, a 30-day ripened cheese, elaborated from raw milk displayed a similar taste profile that included 16 of the Paipa cheese descriptors (Chambers et al., 2009).

The odor and taste profiles of Paipa cheese were mainly characterized by lactic (lactic, fresh, lactic ferment and buttery) and basic (salty, acid, sweet, umami and bitter) tastes, complemented by fruity, fatty, barny, moldy, woody, astringent and pungent notes. Other cheeses of short maturation (approx. 30 days) and produced from raw milk have shown similar sensory profile than Paipa cheese. For instance, (Chambers et al., 2009) described the taste and odor of the French Saint-Nectaire cheese as lactic ferment, fatty, salty, buttery, sweet, fruity, pungent, astringent, cooked, bitter and moldy. The Mexican Chihuahua cheese was characterized as sweet, fatty, cooked, salty, bitter and acid (Van Hekken et al., 2006) while the taste and odor of the Brazilian artisanal Minas cheese was defined as salty, bitter, buttery, sweet and acid (Bemfeito et al., 2016). Nonetheless, the intensity of some taste descriptors such as astringent and buttery were similar to the French Saint-Nectaire cheese while cooked, fatty, sweet, lactic ferment and acid tastes exhibited higher intensities in the Colombian dairy product (Chambers et al., 2009).

Principal Component Analysis (PCA) was carried out with the appearance and odor descriptors due to the higher number of samples. According to the statistical analysis, dimension 1 (35.2%) and dimension 2 (22.6%) explained 57.8% of the variation of Paipa cheese appearance (Figure 4). PCA analysis of Paipa cheese odor profile (Figure 5) displayed 50.6% of variability (27.2% in dimension 1 and 23.4% in dimension 2) among descriptors.

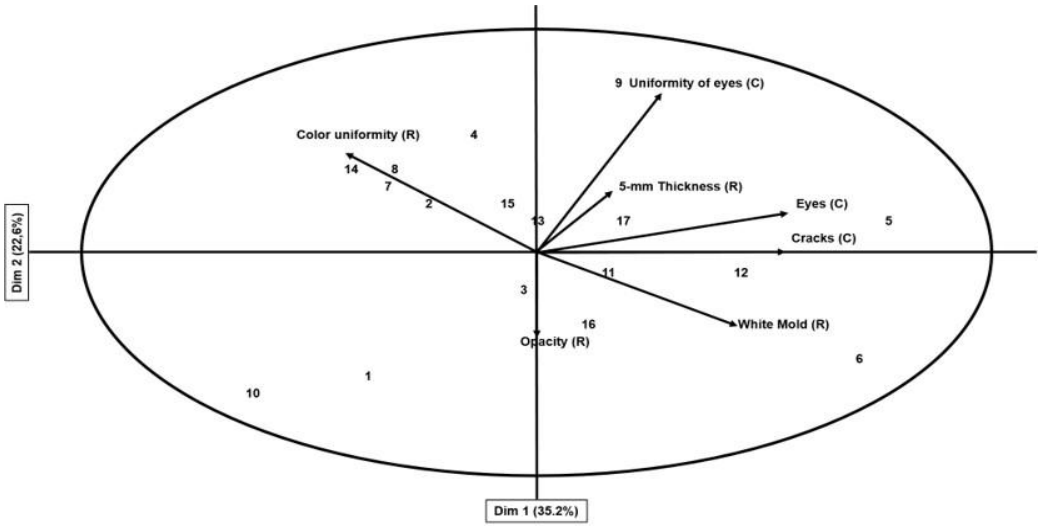

Figure 4. PCA for the appearance of Paipa cheese. R = Rind. C = Core.

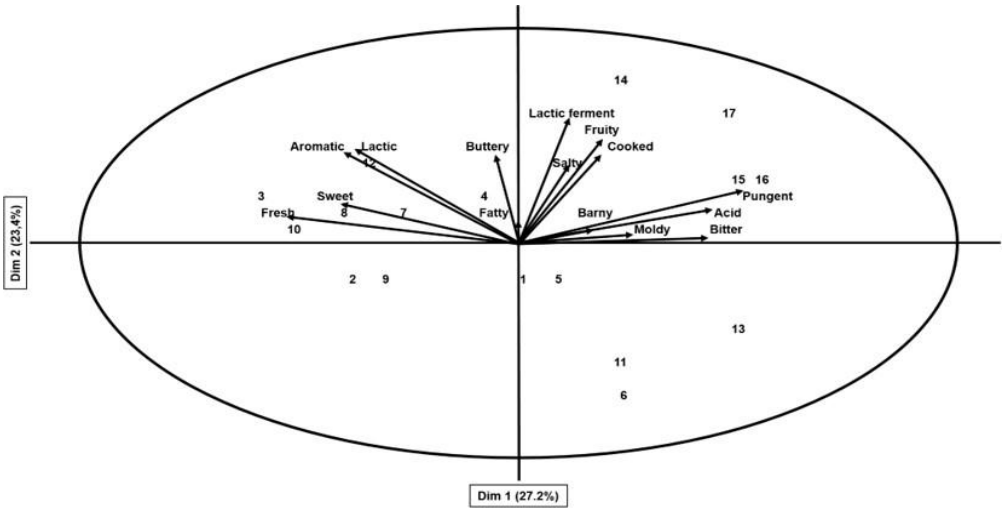

Figure 5. PCA for the odor of Paipa cheese.

PCA of Paipa cheese appearance showed that cheese samples No. 1, 5, 6, 9 and 10 were the cause of major variation (Figure 4); The higher variation among samples were mostly originated by differences in color uniformity of the rind and the presence of eyes and cracks in the core, as was similarly reported by (Braghieri et al., 2015). Core cracks and eyes in Paipa cheese represented 56% of dimension 1 and were correlated as well. Therefore, these two descriptors may be unified as a single descriptor for further Paipa cheese studies. Rind descriptors such as color uniformity, rind thickness and white mold explained 57% of dimension 2. White mold and color uniformity exhibited opposite behaviors; thus, they may be combined in a single descriptor in subsequent studies.

The PCA of the odor attribute indicated that cheese No. 3, 6, 10, 11, 13, 14, 15, 16 and 17 were the samples that caused the highest variation in the attribute (Figure 5), and it was in accordance to (Kraggerud et al., 2012). Odor descriptors such as sweet, fresh, lactic and aromatic were positively correlated. Hence, they may be gathered as a single descriptor denoted as “fresh milk” or “fresh dairy”. Buttery and fatty descriptors were positively correlated and might be gathered into a single one. On the other hand, acid, bitter and pungent were negatively correlated, and were also described by the judges as negative characteristics of Paipa cheese. Nevertheless, such categorization should be based on consumer preferences (Zhang et al., 2011), thus, additional sensory affective tests are highly recommended for future studies.

Figures 4 and 5 showed the high heterogeneity of the attributes regarding the appearance and odor of the Paipa cheese samples that were produced within the PDO region, at the same ripening time (30 days) and elaborated in the same day. (O'Sullivan & Cotter, 2017) indicated that this heterogeneity is commonly found on artisanal cheeses made with raw milk, handicraft production and no controlled processing conditions (Licitra et al., 2019).

The sensory heterogeneity that was found in Paipa cheese indicated that its production may differ among cheese producers and in spite of that, raw milk used for producing cheese may exhibit different gross composition as well as may contain different indigenous microbiota that may cause diverse biochemical reactions during maturation process, thus contributing to differences on sensory attributes (Cotter & Beresford, 2017; Ong et al., 2017). Some of these aspects were proved after visiting some Paipa cheese producers (data not shown). There were detected several variations along Paipa cheese production, e.g., type of coagulant agent, degree of milk skimming, curd size after cutting, the magnitude of the force applied during pre-pressing and pressing, the maturation conditions, among others. For instance, the type of coagulant agent (aspartyl-proteases of microbial origin, chymosin of animal origin or recombinant chymosin) may cause different degrees of proteolysis on paracaseinate complex during ripening of Paipa cheese (Ardö et al., 2017), as well as exhibiting high variation on odor, taste and texture profile of cheese (Usgame-Fagua et al., 2022). The lack of standard conditions and parameters of the operations of Paipa cheese production in the PDO regulation may for instance, have a major impact on cheese moisture loss. A decrease on cheese moisture content may impact the water activity in the product, reducing microbiological and biochemical processes (glycolysis, lipolysis and proteolysis) which are related to the sensory profile of cheese (McSweeney, 2017).

4 Conclusions

A descriptive sensory analysis of Paipa cheese was carried out for the first time. The study was carried out with 77% of Paipa cheese producers identified in the protected territory and a complete sensory profile was determined through a multidimensional approach for the attributes of appearance, texture, odor and taste. Poor microbiological quality, with the presence of some pathogens in Paipa cheese limited the extent of this study. Paipa cheese samples exhibited a high richness of sensory attributes that were not found in the PDO regulation. 82 sensory descriptors were identified, and finally, 47 (seven descriptors for appearance, 15 for odor, 15 for taste and 10 for texture) were established for describing the sensory profile of Paipa cheese. Cheese samples showed high heterogeneity in their sensory attributes, except for the color of the core and rind. Improving milking practices as well as good manufacturing practices throughout Paipa cheese chain is crucial to guarantee the dairy product safety and sensory quality. This study will be considered as the starting point to establish the sensory characteristics of Paipa cheese.

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