Research article

Development of new eggplant spread product: A rheological and chemical characterization

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ABSTRACT

Eggplant (*Solanum melongena*) is an important vegetable of the *Nightshade* family with high demand due to its nutritional value and medicinal properties. The principal objective of this work was to develop and standardize a spread eggplant paste (SEP) with the addition of guar gum and evaluate its physicochemical, bromatological, sensory, and rheological characteristics. A two-factor factorial design with three levels was used for the formulation, evaluating the percentage of guar gum and oil. Flow curves in steady-state and small-amplitude oscillatory shear tests were performed to evaluate the rheological properties of the pastes. Sensorial analysis was performed using descriptive analysis. The standardized eggplant showed no signs of phase separation being stable during storage. Samples presented a non-Newtonian shear-thinning behavior described by Ostwald de-Waele model ($R^2 > 0.969$). The products exhibit more elastic than viscous behavior, with a higher storage modulus than loss modulus in the evaluated frequency range, where the modules could be well described by a power function of the oscillatory frequency. The sensory evaluation revealed that the product color, odor, taste, and spreadability were acceptable, being an alternative for the transformation and agro-industrial use of eggplant for production chain development.

1. Introduction

Eggplant (*Solanum melongena*) is a vegetable belonging to the *Nightshade* family [1], and it is the third most relevant crop behind potatoes and tomatoes [2]. The demand for eggplant has increased due to its high nutritional value, mainly due to its high fiber value [3, 4] and its important content of phenols with antioxidant activity [5]. Yao et al. [6] mention that frequent consumption of phenolic compounds through food is related to health benefits due to anti-inflammatory, antiviral and antimutagenic properties. These interesting bioactive properties of eggplant make it a crop of growing interest for the development of products.

In recent years, more research has been carried out to study this vegetable, including genetic studies related to cultivation to improve its performance and post-harvest quality [7, 8]; the optimization of the extraction process of anthocyanins from the shell and microencapsulation [9, 10] and even value-added products enriched with bioactive microencapsulated compounds from eggplant [11]. Despite all these advances, the development of a formulation of food products from eggplant is lacking; therefore, the standardization of eggplant paste

becomes a viable option for the development of new foods with added value, as it is helpful to reduce post-harvest losses and to obtain a product to take advantage of its bioactive properties.

For the development of new food products, the nutritional and sensory qualities are considered relevant [12]; parameters such as taste, flavor, color, appearance, and texture influence consumer behavior when choosing, buying, and consuming products. The results of the sensory evaluation are indicators of food safety, raw material quality, and processing conditions, which help to increase the perceived value of food [13]. The rheological properties challenge the correct development of the product, mainly in products with hydrocolloids as stabilizers [14, 15, 16]. In this case, the final product is expected a moderately viscous paste with high stability and suitable spreadability. From the food industry's perspective, the analysis and comprehension of the rheological properties of food can help optimize processes, product quality control, and storage stability [17]. Rao and Steffe [18] mention that viscoelastic properties perform an important role in food processing and quality; these parameters depend on multiple factors such as the time and temperature of processing, the solids content, and the ingredients used in the formulation. Since the choice of food for consumption is based on sensory

factors and the functional and nutritional value of the product, the best spread formulation should make the product have an acceptable appearance and texture [19]. Therefore, the current study aimed to develop and evaluate the physicochemical, bromatological, sensory and rheological characteristics of a spread paste obtained from eggplant (*Solanum melongena*) with guar gum.

2. Materials and methods

2.1. Materials

The eggplant harvested in the municipality of Santa Catalina (Bolivar, Colombia) was employed in a commercial maturity state. Guar gum (E-412) and ascorbic acid were purchased from Tecnas S.A. (Medellin, Colombia).

2.2. Standardization and physicochemical properties of eggplant paste - EP

Different samples of SEP were formulated employing a two-factor factorial design with three levels evaluating sunflower oil (2.5, 5.0, and 7.5 %w/w) and guar gum (0.5, 1.0, and 1.5 %w/w) concentration on the physicochemical, rheological, and sensorial properties of pastes. Then, blends of oregano, pepper, garlic and thyme (1.5 % w/w), sugar (4 % w/w), salt (1 % w/w), ascorbic acid (0.5 % w/w), sodium benzoate (0.5 % w/w) and vinegar (0.5 % w/w) were added. Nine formulations and a control sample (a commercial sample of eggplant paste with lentils, with 5 % sunflower oil and 0 % guar gum) were obtained, as shown in Table 1.

Initially, eggplant was washed and disinfected by immersion in a water solution with 100 ppm of sodium hypochlorite. Subsequently, the pulp was scalded to inactivate microorganisms and enzymes by immersion in water at 90 °C for 10 min. The pulp was mechanically ground and sieved, separating the seed and skin. The eggplant pulp and the ingredients were mixed using a classic stand mixer (Kitchen Aid, Benton Harbor, United States) and homogenized at 10,000 rpm for 10 min using an Ultra Turrax T-25 (IKA, Deutschland, Germany). After that, the samples were sterilized at 121 °C for 5 min to extend the product's shelf life and storage at 4 °C for further analysis.

2.3. Rheological characterization

Steady and dynamic properties of SEP were evaluated following the procedures described by Quintana et al. [20], employing a Modular Advanced Rheometer Haake Mars 60 (Thermo-Scientific, Germany) with serrated parallel plates (35 mm diameter, 1 mm gap, and relative roughness 0.4) to prevent slip effects.

2.3.1. Steady-shear viscosity measurements

Viscous flow curves were conducted with a shear rate range from 10^{-3} to 10^3 s^{-1} for 300 s at 25 °C.

2.3.2. Dynamic rheological measurements

Dynamic rheological measurements of the SEP tests were performed inside the linear viscoelastic region in a frequency range of $10^{-2} - 10^2$ rad/s. Stress sweep tests at 1 Hz at frequencies from 0.01 Pa to 1000 Pa were performed previously on each sample to determine the linear viscoelasticity regime.

2.4. Sensory analysis

Sensory descriptive analysis of SEP was done to provide their sensory characteristic. Panelist ($n = 60$, 30 female, 30 male, aged 18–30 years) were recruited among staff and students at the University of Cartagena. Informed consent was obtained from all panelists for the sensory experiments. Participants were instructed to evaluate each sample individually to identify and control the factors that can produce biases [21]. In each session, nine formulations with different percentages of gum and oil and a control sample were obtained commercially and served at the same time. 10 g of each SEP was conditioned at 25 °C before testing. The sample evaluation was verified by repeating each session after resting for at least two hours. Tap water was offered ad libitum to cleanse the palate to avoid carryover effects and neutralize sensory adaptation. The hedonic scale was used to assess the intensity and acceptability of flavor, color, texture, and taste. The intensity was determined using a 7-point scale (1 being the lowest and 7 the highest). Panelists were also inquired on acceptance using qualitative punctuation of "I dislike it very much", "I dislike moderately", "I dislike slightly", "Indifferent", "I like slightly", "I like moderately," and "I like very much", as described in the technical guide GTC 165 [21]. Results were expressed as a percentage of acceptability.

2.5. Physicochemical and bromatological properties

The physicochemical and bromatological properties were evaluated in the sample with better sensorial properties. The moisture, ash, fat, protein, raw fiber, and carbohydrate contents were determined on eggplant paste employing the methods described by AOAC [22]. Titratable acidity (expressed as percent citric acid) was analyzed by titration with NaOH; the pH was measured using a digital pH meter (Model HI 9124, Hanna Instruments, Woonsocket, RI, USA).

2.6. Statistical analysis

All measurements were done per triplicate. One-way analysis of variance (ANOVA) was used to determine significant differences ($p <$

Table 1. Physicochemical and rheological parameters for eggplant paste.

Sample code	Sunflower Oil (% w/w)	Guar gum (% w/w)	Physicochemical parameters		Rheological Parameters		
			pH	% acidity	k (Pa·s^n)	n	R^2
F1	7.5	0.5	4.92 ± 0.03[b]	0.28 ± 0.06[b]	192.32 ± 3.52[a]	0.21 ± 0.01[ab]	0.977
F2	5	1.0	5.07 ± 0.04[a]	0.27 ± 0.04[ab]	218.90 ± 3.51[d]	0.21 ± 0.01[ab]	0.979
F3	5	0.5	5.06 ± 0.04[ac]	0.26 ± 0.06[ab]	140.31 ± 2.52[e]	0.22 ± 0.02[b]	0.992
F4	7.5	1.0	5.00 ± 0.02[c]	0.27 ± 0.02[b]	180.34 ± 2.83[b]	0.20 ± 0.01[ab]	0.973
F5	5	1.5	5.11 ± 0.04[a]	0.26 ± 0.04[ab]	240.50 ± 3.51[c]	0.20 ± 0.01[ab]	0.977
F6	2.5	0.5	5.12 ± 0.03[ad]	0.26 ± 0.01[ab]	189.34 ± 2.74[a]	0.13 ± 0.02[c]	0.980
F7	7.5	1.5	5.02 ± 0.03[c]	0.27 ± 0.01[ab]	249.50 ± 3.64[c]	0.20 ± 0.01[ab]	0.969
F8	2.5	1.5	5.17 ± 0.01[d]	0.27 ± 0.02[ab]	180.21 ± 2.06[b]	0.19 ± 0.03[a]	0.987
F9	2.5	1.0	5.22 ± 0.02[d]	0.26 ± 0.01[ab]	176.90 ± 1.53[b]	0.19 ± 0.02[a]	0.970
Control	5.0	0	5.42 ± 0.03[e]	0.20 ± 0.03[a]	91.70 ± 1.00[f]	0.13 ± 0.01[c]	0.988

Different letters show significant differences ($p < 0.05$).

0.05) in treatment with subsequent comparison of means using the Tukey test using Statgraphics software (version centurión XVI).

3. Results and discussion

Nine different stable samples of SEP were obtained with similar physicochemical properties (Table 1), revealing a slightly acid product. The pH of samples was found between 4.92 to 5.22 and acidity between 0.26 and 0.28 %, and the F1 presented the lowest pH value (4.92 ± 0.03) and the highest acidity (0.28 ± 0.06 %) while F9 showed the highest pH value (5.22 ± 0.02) and lower acidity (0.26 ± 0.01 %). The percentage of guar gum and oil did not show significant differences ($p > 0.05$) except for samples with 0.5 % guar gum (F1, F3 and F6), concluding that the proportion of oil is directly related to the acidity of the paste. It is related to the low pH of sunflower oil (pH 4) [23], a higher proportion of oil in the formulation, which decreases the pH of the samples. Additionally, it can be observed that there are significant differences ($p < 0.05$) between the samples in terms of pH and acidity, attributed to the physicochemical properties such as acidity and pH of food products directly influenced by the raw material used for their preparation and the added acids and bases [24, 25]. These physicochemical properties allow us to determine the stability of the different product formulations against microbial growth during preservation [26]. Regarding the incidence of the addition of hydrocolloids on the physicochemical parameters, studies have shown that gums did not affect variables such as pH in the food matrix [27, 28].

3.1. Steady-state shear properties

The variations in the apparent viscosity (η) in the shear rate ($\dot{\gamma}$) function at 25 °C for different SEP were studied, as shown in Figure 1. Viscosity is the key parameter to describe the ability of the SEP sample to spread and flow [29]. All samples present a non-Newtonian behavior, showing the shear-thinning region, characterized by the potential decrease in their viscosity caused by the increase in the shear rate [30] due to large particles and high molecular weight compounds of SEP.

Then, the spreadable paste considers a food system with complex rheology containing micro and macronutrients by cluster, single, fragmented, or remnant cells as well as colloidal-dispersed polysaccharides dominated by hydrodynamic forces, interparticle forces, and Brownian motion [31], alignment particles give rise to shear thinning in the viscous flow region [32]. The same behavior has been observed in similar foods, such as spread pigeon pea (*Cajanus cajan*) paste with antioxidants [33] and spreads mushroom paste [34].
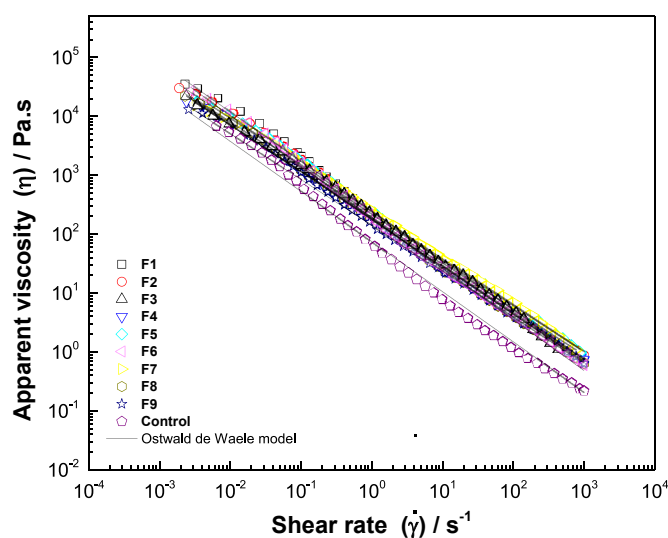
According to Figure 1, the apparent viscosity (η) of SEP can be described using the Ostwald–de- Waele model ($R^2 > 0.969$) (1):

$$\eta = k(\dot{\gamma})^{n-1} \tag{1}$$

where η is the apparent viscosity, n is the flow index and, k is the consistency index. The adjustment parameters are summarized in Table 1; in all cases, $n < 1$, confirming the shear-thinning behavior of the samples [35], where the flux indices show a significant difference ($p < 0.05$) between sunflower oil but not with the percentage of guar gum percentage ($p > 0.05$). Sample F7 (7.5 % of the sunflower oil and 2.5 % guar gum) had the highest k values and the control sample (5.0 % of sunflower oil and 0 % guar gum) was the lowest. This could be attributed to the fact that F7 contained the highest levels of oil and guar gum, and the control sample did not have guar gum. Then, comparing the formulations with 5 % oil, we observed that sample F5 (1.5 % of guar gum) has a higher k value than the others. Then k-values increase with the percentage of gum showing significant differences ($p < 0.05$) concerning the percentage of oil and gum. Therefore, oil and guar gum influence the rheological characteristics of EP; similar results have been found in products such as spread olive paste (*Olea Europea* L.) [36], artichoke sauce (*Cynara scolymus* L.) [37], and milk flavored with cocoa [38] where the influence of guar gum on rheological parameters was observed, also this effect is mainly because guar gum is the most efficient hydrocolloid with thickening property, known to provide solutions classified as pseudoplastic [39].

3.2. Viscoelastic properties

Dynamic viscoelastic properties of SEP are reflective of their three-dimensional molecular structures and interaction therein. The linear viscoelastic region of all samples was identified through sweep experiments performed at 1 Hz in the stress interval from 10^{-3} to 10^3 Pa, confirming that the linear viscoelastic behavior was maintained when the stress was lower than 10 Pa.

Figure 2 shows the profiles of the samples in terms of storage modulus (G') and loss modulus (G'') as a function of the angular frequency (rad·s^{-1}) at 25 °C for different formulations of SEP. Dynamic mechanical spectra, i.e., frequency dependence G' and G''. In all cases, G' was higher than G'', indicating a more elastic than viscous behavior, where both functions increase slightly with a frequency almost parallel. Similar behaviors have been reported in various spread products, such as bread
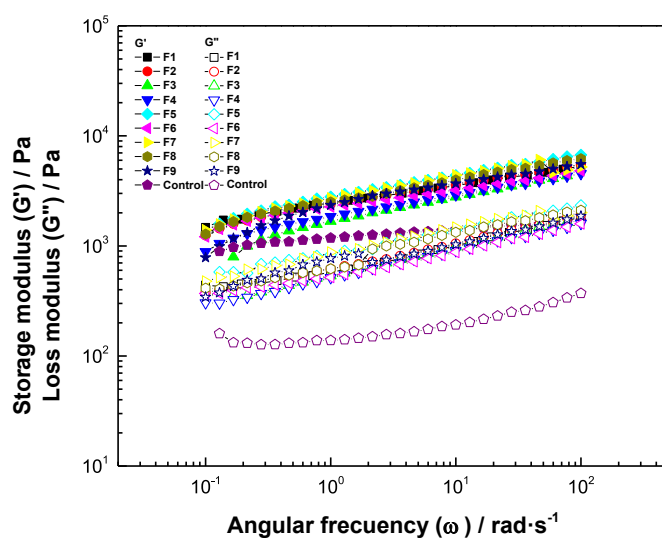

Figure 1. Apparent viscosity versus shear rate for each eggplant paste formulation at 25 °C.

Figure 2. The storage modulus (G') and modulus (G'') as a function of the frequency of eggplant paste at 25 °C.

Table 2. Viscoelastic properties of the formulation of eggplant paste.

Sample code	k' (Pa·s^n)	n'	R^2	k'' (Pa·s^n)	n''	R^2
F1	2393.82 ± 21.65^{ab}	0.16 ± 0.01^a	0.997	592.61 ± 9.74^a	0.23 ± 0.02^{ab}	0.992
F2	2335.91 ± 18.71^b	0.18 ± 0.02^{abc}	0.995	614.22 ± 5.99^a	0.24 ± 0.01^{ab}	0.996
F3	1837.89 ± 17.92^c	0.22 ± 0.02^d	0.996	619.98 ± 9.77^a	0.26 ± 0.01^b	0.993
F4	1807.56 ± 16.51^c	0.20 ± 0.01^{cd}	0.995	512.38 ± 2.86^c	0.24 ± 0.01^{ab}	0.999
F5	2762.88 ± 19.80^e	0.19 ± 0.02^{bc}	0.997	848.02 ± 7.32^d	0.22 ± 0.01^a	0.996
F6	2195.17 ± 17.25^d	0.16 ± 0.01^a	0.994	528.21 ± 7.17^c	0.23 ± 0.02^{ab}	0.993
F7	2403.78 ± 13.41^a	0.21 ± 0.01^d	0.995	751.68 ± 6.36^b	0.23 ± 0.02^{ab}	0.997
F8	2439.30 ± 22.48^a	0.17 ± 0.01^{ab}	0.993	749.20 ± 10.35^b	0.23 ± 0.01^{ab}	0.995
F9	2254.27 ± 47.88^{bd}	0.22 ± 0.02^d	0.983	613.73 ± 6.99^a	0.23 ± 0.02^{ab}	0.993
Control	1162.72 ± 5.62^f	0.08 ± 0.01^e	0.988	140.53 ± 5.42^e	0.18 ± 0.01	0.895

Different letters show significant differences ($p < 0.05$).

spread [40], soy cream cheese [41], and strawberry spread products [42].

The high G' value in the spread paste is indicative of the strong interaction of the particles and a stable network-like structure [43]. Elastic behavior predominates associate with a solid behaved [44] and with the development of a "plateau" zone, which when fully developed is characterized by G' values are almost constant with frequency, a characteristic of quasi-elastic behavior. The structural justification for this behavior is based on the existence of interlacements between the units responsible for the flow material, which in many cases are transitory, as they tend to separate and reform continually [45].

Nevertheless, in the frequency range studied, some differences were observed in the mechanical spectrum of the "plateau", depending on the proportion of guar gum; thus, the formulations of the spread paste (F5, F7, and F8) with 1.5 % guar gum showed higher values of G' and G'' throughout the frequency range, indicating the proximity of the transition region in the mechanical spectrum. On the contrary, the spread paste formulations (F1, F3, and F6) with 0.5 % guar gum showed lower values of G' and G'' with 1.5 % of the stabilizer. This is because the addition of guar gum increases the number of polymers in the system and results in greater elasticity, as mentioned [46] in the development of a rice paste.

The storage (G') and loss (G'') modules were fitted to a power-law model (Eqs. (2) and (3)):

$$G' = K' \cdot \omega^{n'} \qquad (2)$$

$$G'' = K'' \cdot \omega^{n''} \qquad (3)$$

Here, exponents n' and n'' represent the slopes of the relationships between modulus and frequency and coefficients $\cdot K'$ and K'' represent the magnitude of G' and G'' respectively, at a given frequency. For instance, an exponent n' near zero means that G' does not change with frequency, representing the characteristic behavior of a fully cured gel [47]. Table 2 shows the power-law equation parameters that describe the modules' dependence on the oscillation frequency. The correlation coefficient R^2 values were always greater than 0.983, except for the control sample, when G'' showed a low correlation with the power-law model ($R^2 = 0.895$), how was expected due to the absence of a stabilizer.

The increase in the percentage of guar gum caused an increase in the values of different modules, which coincides with the significant increase ($p < 0.05$) in the consistency coefficient K' and K''. This behavior is due to the stabilizing and thickening action of guar gum that acts as a bridge between oil and water droplets, causing flocculation of droplets and stronger interaction between components of the paste [48]. Similar results were obtained for various food systems, low-fat spread with the addition of different hydrocolloids [49], spread developed based on pistachio oil [50], and pasta dough supplemented with hydrocolloids and
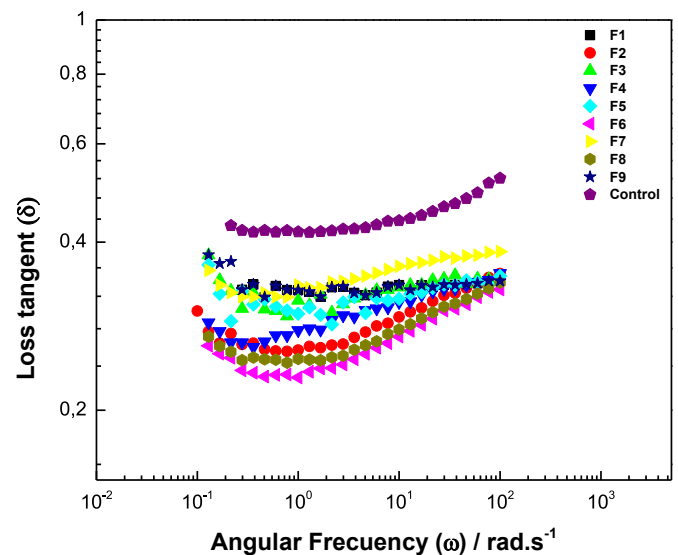

Figure 3. Loss tangent (tan δ) as a function of the frequency of eggplant paste at 25 °C.

fiber [51]. The values of n' and n'' were in the range of 0.16–0.22 to 0.22–0.26, respectively. The values of n'' were slightly higher than n', indicating a higher dependence of G'' frequency and viscous behavior become important at high frequencies while elastic behavior is more independent of frequency [52, 53]. The values of the power-law parameters in pastes agree with those reported for tomato pastes [54, 55].

Loss tangent ($Tan\ \delta = G''/G'$) is one of the parameters representing viscoelasticity characteristics. The loss tangent is zero for an ideal elastic solution, while an ideal viscous solution is infinite. When Tan δ is less than 1, the solution is more elastic than viscous, and the opposite conclusion is correct [49]. Therefore, the gel point can be defined as Tan δ = 1 [56]. Figure 3 showed the behavior of tan δ as a function of frequency, which is less than 1, indicating that the elastic behavior similar to solid is more dominant than the viscous behavior similar to liquid in eggplant paste.

The loss tangent is considered an appropriate measure of colloidal stability in dispersions, and it has been found that when they present values of Tan δ < 0.50, they are less susceptible to phase separation [57]; this behavior is probably due to the stabilizing quality and high-water retention capacity of hydrocolloids in food suspensions, which confers greater elasticity and firmness to the paste and counteracts mechanisms of colloidal instability. Similar results have been reported in instant fishmeal cream formulated with xanthan gum [58] and low-fat mayonnaise with different pectins [59].

Table 3. Sensory evaluation for each eggplant paste formulation.

Sample code	Color	Odor	Taste	Spreadability
F1	5.42 ± 0.95^a	4.66 ± 1.37^a	4.33 ± 1.79^a	5.83 ± 1.06^a
F2	5.08 ± 0.95^a	5.00 ± 2.23^a	3.83 ± 1.86^a	5.16 ± 1.34^{ab}
F3	4.84 ± 1.57^a	5.50 ± 1.60^{ab}	4.83 ± 1.57^a	4.83 ± 0.89^{ab}
F4	5.70 ± 1.02^a	4.83 ± 1.46^a	4.83 ± 1.46^a	5.83 ± 0.68^a
F5	4.50 ± 0.95^{ab}	3.66 ± 2.13^{ab}	4.50 ± 1.50^a	5.66 ± 0.74^{ab}
F6	4.00 ± 0.81^{bc}	4.33 ± 0.94^{ab}	4.16 ± 1.57^a	4.83 ± 0.37^{ab}
F7	3.60 ± 1.37^{bc}	3.66 ± 1.37^{ab}	4.00 ± 1.52^a	4.50 ± 0.95^{bc}
F8	4.00 ± 1.52^{bc}	3.50 ± 1.11^{ab}	4.16 ± 1.77^a	4.16 ± 1.06^c
F9	4.50 ± 1.38^{ab}	4.00 ± 1.63^{ab}	4.00 ± 1.73^a	4.83 ± 0.89^{ab}
Control	3.08 ± 1.32^c	2.66 ± 1.24^b	3.16 ± 1.67^a	3.83 ± 1.06^c

Different letters show significant differences ($p < 0.05$).
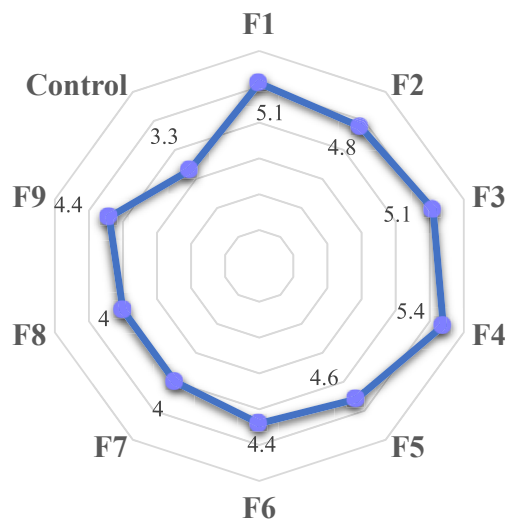
Figure 4. Average ratings for general acceptability of eggplant paste.

3.3. Sensory evaluation

Acceptability ratings of the sensory attribute (color, taste, flavor, and texture) of different formulations and control samples are shown in Table 3. The best-evaluated formulations were F1, F2, F3 and F4, which obtained the best color (5.42, 5.08, 4.84 and 5.7), odor (4.7, 5.0, 5.5 and 4.9), taste (4.4, 3.9, 4.9 and 4.9), and texture values (5.9, 5.2, 4.9 and 5.9), respectively. Samples with the highest percentage of oils (F1 and F4) present the best texture scores; then, the oil content within the paste is directly related to the texture and spreadability character of samples. The formulations F7 and F8 present the lowest acceptability values related to the highest percentage of guar gums because the paste becomes a little gummier, affecting spreadability parameters. The acceptance was then higher in samples with a lower percentage of guar gum.

In Figure 4, the results of the general acceptability of the different attributes evaluated for the different formulations are presented, compared to a control sample (a commercial sample of eggplant paste with lentils, with 5 % sunflower oil and 0 % guar gum). All paste had an acceptable level of satisfaction compared to the control sample, concluding that the paste with the best sensory characteristics was formulation F4 at the sensory level. These results are comparable with those obtained by Álvarez [60], and Machacon et al. [33], in which significant differences were found at the sensory level between the different formulations of spread pigeon pea paste with antioxidants, spreadable walnut paste from cashew and mushroom spread respectively, this is attributable to the fact that an untrained panel was used,

also, that the amounts of spices used varied between one sample and the other.

The results suggest that guar gum strongly influences the texture of the investigated SEP. The Tan δ parameter is an indicator of the visco-elastic nature of the samples and the organization of the structure in the material: highly structured materials generally give low Tan δ [61]. In general, as the spread paste networks broke down and the firmness and elastic elements decreased, the viscoelastic response became more viscous, and the recovery was lower. Sensorial parameters of spread can also be observed: At higher Tan δ values, the lowest spreadability values were obtained. Then the lowest spreadability values were obtained in the control sample (0 % of guar gum) with the highest Tan δ showing a higher viscous component, so the addition of guar gum increases the viscous parameters improving the sensorial texture, when the sample F7 (7.5 % sunflower oil and 1.5 % of guar gum) with the highest Tan δ values (in comparison with control sample), related to better spreadability properties, thus corroborating the idea that guar gum influence the spread of the investigated eggplant paste; similar results were obtained by Brummel, and Lee [62] who reported that processed cheese spreads with guar gum had decreased firmness, good spreadability, and good mouthfeel. The dynamic rearrangements of interactions among the guar gum and the components of the eggplant matrix were evidenced with a decrease in Tan δ.

3.4. Proximal composition of eggplant spread

The proximal composition of sample F4 was determined considering the rheological properties and the sensory analysis. These samples present 78.00 ± 0.07 of moisture, 10.04 ± 0.06 of total carbohydrate, 2.34 ± 0.02 of total fiber, 1.10 ± 0.02 of protein, 7.82 ± 0.02 of ethereal extract and 1.86 ± 0.07 of ash. F4 presented higher carbohydrate, total fiber, ethereal extract, and ash values than the raw material [63]. The increase in carbohydrates and ethereal extract could be explained by sugar and oil in the paste, respectively. Regarding the amount of ash contained in the spread paste, it is mainly due to the raw material used and the addition to the formulation of spices such as oregano (*Origanum vulgare*) that according to Moreiras et al. [64] contains a percentage of ash of around 7 %, the most relevant nutritional component of the spread paste evaluated was its percentage of total fiber, as it was around 2.34 %, representing an important source of dietary fiber.

Eggplant paste can be considered a food product with a significant nutritional contribution because 100 g of the product provides us with 14 % fat, 12 % fiber, and 5 % carbohydrates of the daily values recommended by the Ministry of Health and Social Protection Colombia [65].

4. Conclusions

The spread product developed from eggplant that employs guar gum as an emulsifying and stabilizing agent has stable characteristics during

storage and analyses. The obtained product could be considered an outstanding contribution, with a good protein and fiber content and good quality attributes. The spread pastes presented a non-Newtonian shear-thinning behavior described by the Ostwald–de Waele model ($R^2 > 0.969$). According to dynamic viscoelastic tests, the product's different formulations have a viscoelastic material behavior, presenting an elastic behavior rather than viscous. Thus, it behaves as a semi-solid food in the studied frequency range, and the modules could be described by a power function of the oscillatory frequency ($R^2 > 0.895$). Sample F4 presented the best evaluation of descriptive sensory revealed in attributes of color, odor, taste, and spreadability. The stabilizers are essential to the food structure and functional design that consumers require in modern society; in this case, guar gum did not have a significant effect on the physico-chemical properties, on the contrary, the addition of guar gum affected the rheological properties and the spreadability of sensory properties significantly. Eggplant paste arises as a potential raw material of importance in the world for the development of new food products with nutritional and sensory characteristics that satisfy the needs of consumers.

Declarations

Author contribution statement

Luis Mieles-Gómez: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Somaris E. Quintana: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Luis A. García-Zapateiro: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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