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ORIGINAL PAPER

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EFFECTS OF THREE GELLING AGENTS ON THE SHELF LIFE AND THE RHEOLOGICAL, PHYSICOCHEMICAL, NUTRITIONAL, MICROBIOLOGICAL, AND SENSORY CHARACTERISTICS OF AGUAYMANTO COMPOTE (*PHYSALIS PERUVIANA* L.)

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ABSTRACT

Background. Aguaymanto (*Physalis peruviana* L.) is a rich source of nutrients, antioxidants, and bioactive compounds that provides health benefits. As such, it is considered a superfood. It can also be used in other foods, such as juices, liqueurs, jams, desserts, compotes, gastronomic ingredients, supplements, and dried fruit. The objective of this research was to evaluate the effects of three gelling agents: carboxymethylcellulose, pectin, and xanthan gum, on the shelf life and the rheological, physicochemical, nutritional, microbiological, and sensory characteristics of aguaymanto compote during its formulation.
Materials and methods. Three thickening agents (xanthan gum, carboxymethylcellulose, and pectin) were used to prepare the aguaymanto compote, whose values of shear stress and strain rate (γ) were evaluated and adjusted to the Ostwald de Waele model. Likewise, physicochemical characterization and sensory evaluation were carried out in two different environments, involving university students using a 5-point hedonic scale and preschool children, in which the percentage of acceptability was established. The product with the best sensory attributes had its proximal chemical composition, microbiological analysis, and shelf life determined.
Results. The compotes showed non-Newtonian behavior of the pseudoplastic type. Flow curves adjusted to the model showed that as the temperature increases (17°C, 25°C, 35°C, and 45°C) with the same concentration, the consistency index decreases, and the flow behavior index increases. In all the samples, as γ and temperature increase, the apparent viscosity decreases, and the 0.1% gelling agents generate different apparent viscosities ($p < 0.05$). Likewise, the panelists gave high scores to the compote formulated with carboxymethylcellulose, presenting a lower pH (3.96) and high moisture (77.49%) with an absence of total coliforms, molds and yeasts. In addition, the shelf life was approximately 367 days, without the addition of preservatives.
Conclusion. The results show that the aguaymanto compote presents a non-Newtonian behavior with pseudoplastic fluid characteristics, guarantees hygiene and sanitation concerning national and international technical

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standards, and presents a shelf life of 367.03 days, making it an excellent alternative for large-scale application in the food industry. In addition, values closely related to the expected values were found; therefore, the models were well developed.

Keywords: rheological parameters, cape gooseberry, carboxymethylcellulose, pectin, xanthan gum

INTRODUCTION

Physalis peruviana L. is a plant belonging to the genus Physalis of the Solanaceae family that is native to South America in the Peruvian Andes and found mainly in the regions of Ancash, Cajamarca, Cusco, Huánuco, and Junín (MIDAGRI, 2020). It is generally grown in tropical and subtropical countries (Mazova et al., 2020). Goldenberry has become an economic export crop in many countries and is known as aguaymanto, Inca berry, poha berry, cape gooseberry, groundcherry, and husk berry (Fischer and Melgarejo, 2020).

The fruit of aguaymanto is yellow to orange, wrapped in a cap, and a rich source of nutrients (Castro et al., 2008) such as carbohydrates (10.52%), proteins (1.09%), lipids (0.51%), and fiber (0.34%), as well as minerals (Repo and Encina, 2008) such as potassium (292.65 mg/100 g of pulp), phosphorus (37.90 mg/100 g of pulp), calcium (10.55 mg/100 g of pulp), iron (1.24 mg/100 g of pulp), and zinc (0.40 mg/100 g of pulp). High levels of vitamins (Osorio and Roldan, 2003) such as A (1730 I.U.), B1 (0.10 mg/100 g of pulp), B2 (0.17 mg/100 g of pulp), B3 (0.80 mg/100 g of pulp), and C (20.00 mg/100 g of pulp), as well as (Málaga et al., 2013) antioxidants (4.12 ±0.18 umol Trolox eq./g), total phenolic compounds (58.60 ±1.96 mg AGE/100 g), and total carotenoids (2.94 ±0.43 mg β-carotene eq./100 g) give the fruit medicinal properties that make it usable as an anti-inflammatory, antioxidant, antidiabetic, antitumor, immunosuppressive, and antiseptic (Nocetti et al., 2020; Oztruk et al., 2017; Shenstone et al., 2020). Due to its pleasant flavor, this fruit can be used in juices, liqueurs, jams, salads, desserts, compotes, gourmet kitchen ingredients and dried fruits (Mokhtar et al., 2018).

Compote is a complementary food that is gradually offered to children from six months of age and is commonly prepared using a variety of fruit pulps (Aldana and Rivas, 2019; Marrugo et al., 2017). This is a product based on whole fruit, fruit pieces, fruit pulp, or fruit puree with or without fruit juice or fruit juice concentrate (Codex Stan 79-1981). In addition, it may be formulated with or without water and sweeteners may be added. It is hermetically heat treated before and after sealing (NTP 203.106:1985).

As aguaymanto fruit has benefits for human health, and because it is cultivated easily in large areas of the Peruvian Andes, its pulp can be used to develop a compote that provides children with a range of quality nutrients.

Gelling agents are widely used in many food formulations to improve their quality attributes and shelf life and to achieve an optimal texture (Saha and Bhattacharya, 2010). The foremost reason to apply gelling agents to foods is their capacity to modify the rheology (viscosity and texture properties) of the food system, which helps to modify their sensory properties when used as important food additives. Likewise, several food formulations and food products use gelling agents as additives to attain the desired viscosity and mouth feel.

Among the main gelling agents used in food additives are carboxymethyl cellulose (CMC), methylcellulose (MC), xanthan gum, and pectin. In the scientific literature, various gelling agents have been used to enhance compotes of pineapple (Pereira et al., 2015), quinoa (Zambrano et al., 2019), soy milk, mango (Koosamart et al., 2016), peach (Marrugo et al., 2017; Pérez et al., 2016) loquat (Quintero et al., 2021), and pumpkin (Camayo-Lapa et al., 2020).

However, there is still no research on aguaymanto compote in the scientific literature. Thus, this work aimed to evaluate the effects of three gelling agents, carboxymethylcellulose, pectin, and xanthan gum, on the formulation of aguaymanto compote and its rheological, physicochemical, nutritional, microbiological, sensory, and shelf life characteristics.

MATERIALS AND METHODS

Samples

Mature aguaymanto (*Physalis peruviana* L.) fruits were acquired from the farm "Cultivos orgánicos Doña Romilda" (11°19'28" S, 75°41'28" W), located in the town center of Picoy, Acobamba district, Tarma Province, Junín-Peru Region. All analyses were carried out in the laboratories of the professional school of Agroindustrial Engineering of the Faculty of Applied Sciences of the National University of the Center of Peru.

Compote preparation

The calyx of the aguaymanto was removed to obtain the fruits. These fruits were carefully washed and then disinfected by immersion in water with 50 mg·L^{-1} of sodium hypochlorite for 5 min. Then, using refining equipment (VULCANO, DFV 19, Peru), the fruits were broken down into a fine pulp. This was heated at 75°C for 5 min to inactivate the enzyme that causes browning and eliminate the air retained in the pulp. Three compote formulations were prepared using pulp and water in a 1:3 ratio (pulp:water), starch, white sugar, and boiled water with a cinnamon stick. To this, different gelling agents – carboxymethylcellulose (E-466, purity >99.5%), xanthan gum (E-415, purity >91%) and pectin (E-440, low methoxylation amidated pectin) – were added at 0.1% by weight (Table 1) according to the Codex standard for packaged foods for infants and children, Codex Stan 73-1981 (maximum permitted limit of 0.2 g of gelling agent per 100 g of product). This mixture was cooked at a temperature of 75ºC for 10 minutes. It was then packed in 4-ounce glass containers, which were finally subjected to a heat treatment of 115ºC for 26 minutes using an autoclave (BIOGEN, AUT-40, China) to eliminate pathogenic microorganisms. The product was stored for 450 days at room temperature (approximately 18ºC).

Rheological analysis

Rheological measurements of aguaymanto compote were performed with a rotational viscometer (Brookfield, DV III Plus, USA) operated with 500 ml of sample and spindle N°5 under the conditions of rotational speed (N) 0.5, 1, 2, 4, 5, 10, 50 and 100 rpm and working temperatures of 17, 25, 35 and 45°C obtaining the reading of % torque [α].

The results were adjusted to Mitschka's methodology, finding the shear stress τ (Pa) which is obtained from the readings of α multiplied by the constant K_a (1.05, value of spindle no. 5, eq. 1); and the strain rate γ (1/s) which is obtained by multiplying the rotation speed (N) by the constant K_n (value calculated based on the number of spindle and the slope generated between Log of N and Log of T, eq. 2). Being the value of T the product of α by 71.87 (constant assigned to the equipment).

$$\tau = K_a \cdot \alpha \qquad (1)$$

$$\gamma = K_n \cdot N \qquad (2)$$

With this, the Waelle's Ostwald model is applied to obtain the rheological parameters: consistency index K (Pa·s^n), flow behavior index n, and apparent viscosity (cP) (Shapovalov, 2017).

Sensory analysis

The sensory evaluation was carried out in two different environments, the first being an evaluation with the

Table 1. The standard formulation of aguaymanto compote, %

Component	Xanthan gum	Carboxymethylcellulose	Pectin
Pulp: water (1:3)	80.81	80.81	80.81
Starch	5.64	5.64	5.64
White sugar	12.93	12.93	12.93
Canela en rama, hervida en agua*	0.52	0.52	0.52
Gelling agent	0.10	0.10	0.10

*Cinnamon stick boiled in water for 10 min.

participation of 30 students with average ages between 18 and 25 years, all of whom work professionally in Agroindustrial Engineering for the UNCP – Tarma subsidiary. They received an evaluation sheet structured with hedonic scales of "I like it a lot" (5 points) "I dislike it a lot" (1 point), to assess color attributes, smell, taste, texture, and overall appearance. To do this, adequate spaces were used according to procedures established by ISO 8589 (2007). Thus, with the compote of greater acceptability, the second evaluation was carried out, with the participation of 30 children of pre-school age (from 3 to 5 years old) of the I.E.I. "San Ramón" and I.E. "Amelia Macassi" #202, from the province of Tarma, Junín region, Peru. Before starting, permission was received from both management and parents. Then each infant received a bottle of 4-ounce compote (approximately 113 g) and a teaspoon, with each being checked to find the percentage of consumption to establish the percentage of acceptance and percentage of rejection of the compote (Pedrero and Pangborn, 1989).

Physicochemical, proximate chemical and microbiological analysis

Titratable acidity was determined by AOAC method 942.15 by titrating the samples with 0.1 M NaOH and expressed as percent citric acid (AOAC, 1996). The pH was determined by potentiometric method AOAC 981.12, using a pH meter (Schott, PH11, Germany) at 20°C. Soluble solids (°Brix) was measured with an Abbe digital Abbe digital refractometer (Schmidt--Haensch, DHR-60, Germany) with a scale from 0 to 60% Brix at 20°C. Ash was calculated in a muffle furnace (MF200, China) at 550°C to a white color. Protein was determined by the Kjeldahl method and calculated using a factor of 6.25 for conversion. Total oil was determined using a Soxhlet extractor.

The dietary fiber content was calculated following the method 991.43 of AOAC (2000). The moisture content of the compote was determined using an oven (ED115 Binder, Germany) set at 110 ±5ºC until it reached constant weight.

The carbohydrate content was calculated by the difference between 100 and the sum of ash, oil percentage, moisture, and proteins (Rodrigues et al., 2009).

Microbiological parameters in the compote were evaluated using Petrifilm plates for rapid counts of total coliforms, molds, and yeasts (Bird et al., 2015).

Shelf life analysis

The shelf life of the compote was evaluated using accelerated testing, with the modeling of data: Y – clarity values (L^*), X – days of storage, a – constant, and b – pending of the linear regression (equation 3). The sample analyzed throughout the investigation was stored at a temperature of 18°C and a relative humidity of 85%. This was homogenized at room temperature, taking 4 ml of sample with three repetitions to be deposited in glass cells, in which clarity values (L^*), a^*, and b^* were determined. This was recorded between 0 and 450 days using a colorimeter (Lovibond, RT100, Germany) with D65 illuminant and a standard 10º observer.

$$Y = a + bx \tag{3}$$

Statistical analysis

The results obtained were expressed as mean ±standard deviation (SD) using three replicates. Differences among the treatments with different gelling agents (carboxymethylcellulose, xanthan gum, and pectin) were determined through analysis of variance (ANOVA) and subsequent POS-HOC Tukey test. A $p < 0.05$ value was significant. Sensory analysis was evaluated using the non-parametric Friedman test. Correlation analyses were performed using the Pearson correlation. All data were treated with the Software SPSS v 24, and the free software R Project.

RESULTS AND DISCUSSION

Rheological profile

The rheological profile of the aguaymanto compote was formulated with 3 gelling agents, xanthan gum, carboxymethylcellulose, and pectin, evaluated at four different temperatures of 17°C, 25°C, 35°C, and 45°C. Adjusted to the Mitschka's methodology and Ostwald's model or Power Law, denoted to be a non-Newtonian fluid (exponential variation) for all temperatures and gelling agents studied of the pseudoplastic type by the non-linear trend and concave curve (Fig. 1).

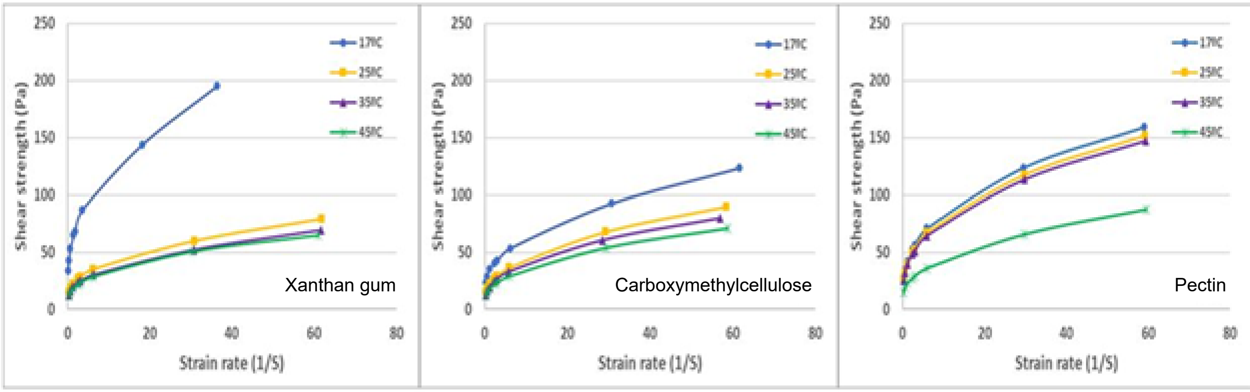

Fig. 1. Rheological curves of the aguaymanto compote with three gelling agents, xanthan gum, carboxymethylcellulose, and pectin, at four different temperatures (17°C, 25°C, 35°C, and 45°C)

Rheological behavior depends on factors such as concentration, soluble solids content, particle size, and temperature (Balestra et al., 2011; Ramírez-Sucre and Baigts-Allende, 2016).

Table 2 shows the dependence of the parameters of the Ostwald de Waele model (n = flow behavior index and K = flow consistency index in Pa·s^n) for aguaymanto compote at four different temperatures (17°C, 25°C, 35°C, and 45°C) and with three gelling agents (carboxymethylcellulose, xanthan gum, and pectin). As can be observed, the Ostwald de Waele model fits well the measured values which are shown through the values of coefficient of determination R^2 (0.992–0.996). With the three gelling agents, when the temperature is increased, the flow consistency index K decreased and the flow behavior index n had a slight

Table 2. Parameters n and K of the Ostwald de Waele model for the aguaymanto compote and at four different temperatures (17°C, 25°C, 35°C, and 45°C) and with three gelling agents (xanthan gum, carboxymethylcellulose and pectin)

Gelling agents	T °C	Flow consistency index K Pa·s^n	Flow behavior index (n)	R^2	r
Xanthan gum	17	57.88	0.32	0.994	0.998
	25	20.96	0.31	0.993	0.998
	35	18.40	0.31	0.994	0.999
	45	16.97	0.32	0.992	0.997
Carboxymethylcellulose	17	21.52	0.34	0.993	0.996
	25	32.06	0.31	0.992	0.997
	35	18.85	0.35	0.994	0.996
	45	17.24	0.33	0.995	0.997
Pectin	17	40.13	0.33	0.996	0.998
	25	38.18	0.33	0.993	0.999
	35	37.14	0.33	0.992	0.996
	45	21.59	0.33	0.995	0.997

increase. The same trends were found by Pilamala et al. (2018) in the compote of apple, sweet potato, and gooseberry, by Camayo-Lapa et al. (2020) in pumpkin compote, by De Hombre et al. (2017) in mango pulp, by Figueroa-Flórez et al. (2017) in sweetened mango pulp, and by Mechato and Siche (2020) in passion fruit juice. The flow behavior index (n) showed values less than the unit, confirming the pseudo-plasticity of the aguaymanto compote formulation. This suggests the presence of substances of high molecular weight, such as polysaccharides, solids dispersed in the liquid phase, protein contents, and soluble salts (low concentration).

Therefore, pseudoplastic behavior could be a consequence of both the presence of starch and proteins (low concentration), but mainly of the gelling agents. Similar findings were observed by Pilamala et al. (2018), with n values ranging from 0.451 to 0.502 (compote apple), while De Hombre et al. (2017) reported a value of 0.31 for n (mango pulp), and Figueroa-Flórez et al. (2017) reported a n value of 0.32. All gelling agents showed properties of pseudo-plasticity, with xanthan gum showing high pseudo-plasticity compared to the other two agents.

Research has shown the effects of a gelling agent in various products, such as instant fishmeal creams, where the control sample had a viscosity of 0.711 cP and the addition of xanthan gum at 0.1% amounted to 0.742 cP (Barragán et al., 2016), and in the kumis type milk drink, where the control presented lower viscosity compared to the addition of a mixture of guar gum and xanthan gum at 0.08%, which increased viscosity (Gaviria et al., 2010). Other research found that, a fermented beverage with the addition of passion fruit pulp and CMC and enriched with vitamins A and D, the control sample presented 23 cP, and the addition of different trademarks of CMC at 0.1% increased the viscosity from 97.73 to 499.33 cP (Sepúlveda et al., 2002). Others have also presented variations from low concentrations and pseudoplastic behavior. Therefore, there is variation in the creep limit, rheological parameters, and apparent viscosity, which are attributed to the presence of polymeric substances of high molecular weight such as xanthan gum, CMC, guar gum, and pectin (Saha and Bhattacharya, 2010).

Figure 2 shows the graphical dependence of the apparent viscosity corrected on the shear stress recorded for three gelling agents (carboxymethylcellulose (A), pectin (B), and xanthan gum (C)) and at four different temperatures (17°C, 25°C, 35°C, and 45°C). It was found that the corrected apparent viscosity decreased with increasing temperature and deformation rate (Fig. 2). Similar behaviors have been reported in pumpkin compote (Camayo-Lapa et al., 2020), strawberry puree (Bukurov et al., 2012), and fruits and vegetables (Diamante and Umemoto, 2015). The viscosity also decreased over time for the three gelling agents and four temperatures. Similar trends were reported in acai berry pulp and strawberry compote (Costa et al., 2018; Obradovic et al., 2020).

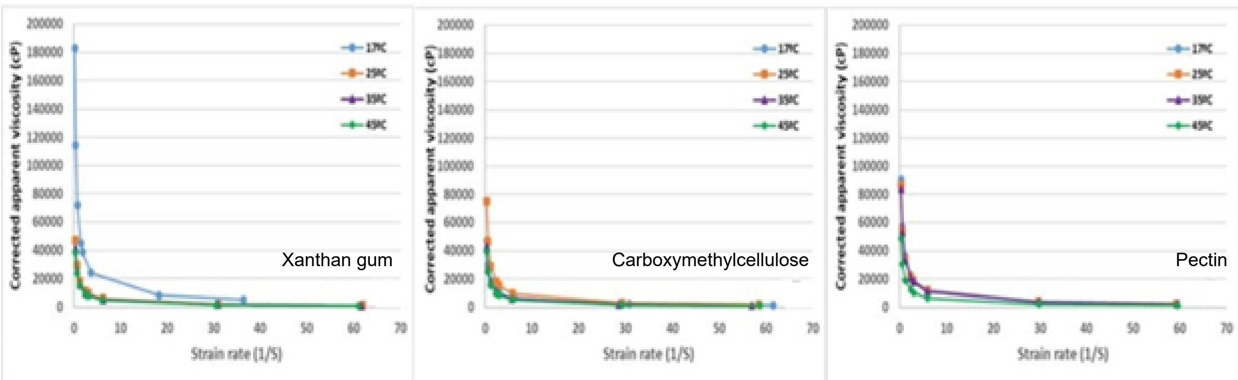

Fig. 2. Apparent viscosity corrected with the Ostwald de Waele model in the aguaymanto compote with three different gelling agents, xanthan gum, carboxymethylcellulose, and pectin and evaluated at four different temperatures (17°C, 25°C, 35°C, and 45°C) using the Ostwald Waele model

The apparent viscosities corrected showed a very small difference for the four temperatures studied and similar behavior among the gelling agents used for aguaymanto compote formulation. This behavior was corroborated by Alvarado and Aguilera (2001), who established that, if the temperature increases, the intermolecular spaces also increase. In contrast, intermolecular forces, viscosity (apparent or true), and resistance to flow decrease (Steffe, 1996).

Sensory analysis

The scores for the acceptability attributes as well as the Friedman test for the first stage of evaluation with the adult panelists are shown in Table 3. In general, the scores ranged from 3.53 to 4.63 on the scale "I like" to "I like it very much" concerning the attributes of color and texture when the compote was formulated with xanthan gum, carboxymethylcellulose, and pectin. No significant differences ($p > 0.05$) were found between color and texture attributes for the three formulations. In contrast, the smell, taste, and general acceptability showed a significant difference ($p < 0.05$), with the best attributes being presented by the compote formulated with 0.10% of carboxymethyl cellulose (Fig. 3).

Sotomayor et al. (2018) suggest that sensory properties play an important role at the time of purchase because most purchasers are looking for an attractive color, smell, taste, aroma, and texture, which are valued through the personal appreciation of the panelist. Thus, the first evaluation carried out allowed the aguaymanto compote formulated with 0.10% of carboxymethylcellulose to be preselected.

This product was tested again by the target population "children of pre-school age", where 86% of acceptance versus 13.30% of rejection of the compote consumed was reported. Quintero et al. (2021) and Marrugo et al. (2017) achieved an acceptability of 70% when formulated loquat compote was gelled with

Table 3. Friedman test for the sensory attributes of aguaymanto compote formulated with xanthan gum, carboxymethylcellulose, and pectin

Attributes	Formulation	n	Sum (ranks)	Mean (ranks)	Mean	T^2	p
Color	xanthan gum	30	55.00	1.83	4.13[ns]	1.28	0.28
	carboxymethylcellulose	30	64.00	2.13	4.37[ns]		
	pectin	30	61.00	2.03	4.30[ns]		
Smell	xanthan gum	30	65.50	2.18	4.20[a]	5.76	0.005
	carboxymethylcellulose	30	65.50	2.18	4.20[a]		
	pectin	30	49.00	1.63	3.73[b]		
Taste	xanthan gum	30	65.00	2.17	4.13[a]	5.04	0.0096
	carboxymethylcellulose	30	66.00	2.2	4.27[a]		
	pectin	30	49.00	1.63	3.53[b]		
Texture	xanthan gum	30	56.50	1.88	4.13[ns]	0.53	0.5939
	carboxymethylcellulose	30	62.50	2.08	4.30[ns]		
	pectin	30	61.00	2.03	4.17[ns]		
General acceptability	xanthan gum	30	59.50	1.98	4.17[b]	9.23	0.003
	carboxymethylcellulose	30	71.50	2.38	4.63[a]		
	pectin	30	49.00	1.63	3.90[c]		

[ns] in column is not significant. [a, b, c] states the statistical difference between compote formulations.

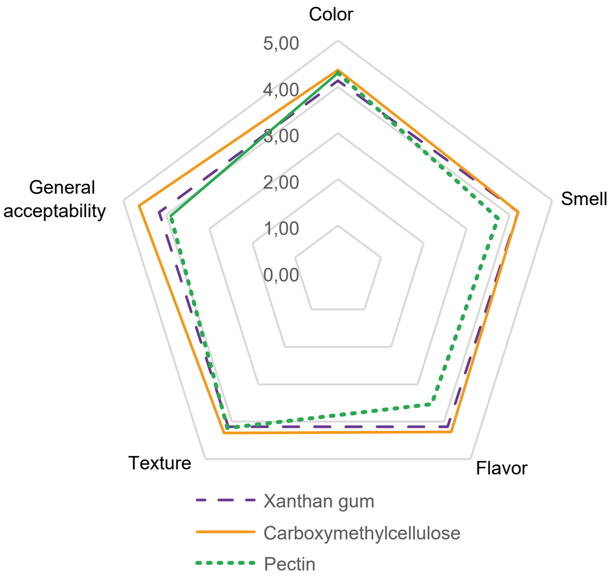

Fig. 3. Sensory analysis of the aguaymanto compote using three different gelling agents (xanthan gum, carboxymethylcellulose, and pectin) to establish the optimal product

Gracilaria debiliss agar and mango compote with *Zaragoza* bean starch thickener. Camayo et al. (2020) reported an acceptability of 96.67% for pumpkin compote formulated with 0.15% xanthan gum. This elevated acceptance could be due to the homogeneous cooking of the fruit, as reported by Gomes da Silva et al. (2019), who evaluated the effects of bioactive compounds and the acceptability of pumpkin compote. Pedrero and Pangborn (1989) reported 85% of acceptability as a minimum to accept compotes. Thus, this result indicates that this product may be positioned within the market if working at an industrial level.

Physicochemical composition

Physicochemical parameters of aguaymanto compote with greater acceptability (formulated with 0.1% of carboxymethylcellulose) are presented in Table 4. The pH showed a value of 3.96 ±0.08, indicating that the compote is an acidic food. This acidity may be related to the raw material that was used. This result is similar to that found by Pereira et al. (2015) in pineapple compote with a pH of 3.36, and Pilamala et al. (2018), who reported a pH between 3.23 to 3.54 in the apple-based compote variety Emilia. In contrast, Marrugo et al. (2017) and Quintero et al. (2021) found a pH of 4.28 and 4.32 in mango compote and loquat compote, respectively, when using the gelling agent of bean starch Zaragoza.

The percentage of acidity in the compote showed a value of 0.51 ±0.04%. Marrugo et al. (2017) reported lower values of percentage acidity (0.03–0.04) in mango compote. In contrast, Pilamala et al. (2018) found a higher acidity content of 0.64% and 1.05% in apple sauce. The difference in acidity content may be related to the raw material used for compote formulation.

The soluble solid showed a value of 18.00 ±0.46%. This value is within the established standard NTP 203.106 (2012) and NTE INEN 2009:95 (1995) INEN 1995-10 (2009), with a minimum of 16.5% and 15.0%, respectively. A similar finding (14%) was reported by Marrugo et al. (2017) in their mango compote. In contrast, Pereira et al. (2015) obtained 32% of soluble solids in the compote of pineapple, which may be related to the fact that the investigations are from different countries whose regulations also have different parameters.

Table 4. Physicochemical composition of aguaymanto compote formulated with carboxymethylcellulose (0.1%)

Analysis	Results
pH	3.96 ±0.08
Acidity (expressed in citric acid), %	0.55 ±0.11
Soluble solids, %	18.00 ±0.46

n = 3 replicates.

Proximal composition

Table 5 shows the proximate composition of aguaymanto compote formulated with carboxymethylcellulose (0.1%). The moisture content presented a value of 77.49% ±0.02; similar finding was reported by Pilamala et al. (2018) in apple, sweet potato and currant compote with 79.64%. Likewise this value was higher in loquat compote (62.2% ±2.6 to 66.1% ±2.2) (Quintero et al., 2021) and lower than pumpkin compote (82.45% ±0.02) (Camayo-Lapa et al., 2020). In case of ash content it was 0.32% ±0.03; lower value than reported by Quintero et al. (2021) with 0.81 ±0.11% to 0.85 ±0.08% and Camayo-Lapa et al. (2020) with 1.34 ±0.02%, but similar to Pilamala et al. (2018) with

Table 5. Proximal composition of aguaymanto compote in 100 g of compote formulated with carboxymethylcellulose

Parameter	Wet base, %
Moisture	77.49 ±0.02
Ash	0.32 ±0.03
Protein	0.19 ±0.02
Fat	0.02 ±0.01
Fiber	0.43 ±0.11
Carbohydrates	21.55 ±0.18

Data are expressed as mean ±standard deviation (SD), *n* = 3.

0.32%. For proteins, 0.19% ±0.02 was obtained in the investigation; lower result than Pilamala et al. (2018) with 0.73%, Quintero et al. (2021) with 0.39% ±0.02 to 0.42% ±0.01 and Camayo-Lapa et al. (2020) with 1.68% ±0.02. Fat was 0.02% ±0.01; lower value than that presented by Quintero et al. (2021) with 0.45% ±0.04 to 0.50% ±0.01 and Camayo-Lapa et al. (2020) 1.01% ±0.01. In fiber it was 0.43% ±0.11; lower result than reported in apple, sweet potato and currant compote with 2.29% (Pilamala et al., 2018) and pumpkin compote with 2.35% ±0.04 (Camayo-Lapa et al., 2020). Finally, in carbohydrates, 21.55% ±0.18 was obtained; the result was higher than that of Pilamala et al. (2018) with 14.60% and Camayo-Lapa et al. (2020) with 11.17% ±0.04. The variability of the results could be due to the nature and composition of the raw materials used.

Microbiological analysis

The count of molds and yeasts showed values <100 ufc/ml, while total coliforms were <10 ufc/ml. These results indicate that the aguaymanto compote is suitable for human consumption since it does not present any microbiological risk. In addition, this compote complies with the standards established in the NTP 203.106 (2012; product free of microorganisms under normal storage conditions), NTS 071-Minsa/Digesa for products with a pH of 4.6 (semi-preserved), which indicates a low probability of developing microorganisms, and the Codex Stan 79-1981 standard. With this, it is possible to affirm that the product is safe for consumption.

Shelf life determination

In the aguaymanto compote formulated with carboxymethylcellulose (0.1%), the color analysis was performed through a colorimeter (Lovibond, RT100, Germany) with illuminant D 65, and a standard observer of 10º through the reflection spectra of the samples were used to determine the coordinates of the CIE $L^*a^*b^*$, where clarity (L) varies between 0 and 100. Component a (yellow-blue axis) and component b (magenta-green axis) can be between +127 and –128 to determine the color change as detailed in Table 6.

From the data obtained, we sought the best correlation and relationship between the days of storage versus the colorimetric parameters L^*, a^*, and b^*, as shown in Table 7.

Table 6. Clarity values at different time intervals of the aguaymanto compote formulated with carboxymethylcellulose (0.1%)

Time days	L^*	a^*	b^*
0	33.07 ±0.01	3.54 ±0.07	20.11 ±0.01
30	32.51 ±0.02	3.51 ±0.03	20.09 ±0.06
60	32.15 ±0.05	3.48 ±0.04	18.85 ±0.03
90	31.84 ±0.06	3.46 ±0.05	18.84 ±0.03
120	31.46 ±0.06	3.41 ±0.03	18.75 ±0.04
150	31.09 ±0.07	3.39 ±0.03	18.69 ±0.06
180	30.77 ±0.04	3.35 ±0.04	18.15 ±0.01
210	30.38 ±0.05	3.32 ±0.02	18.14 ±0.05
240	29.94 ±0.04	3.28 ±0.04	17.99 ±0.04
270	29.52 ±0.03	3.24 ±0.05	17.95 ±0.03
300	29.18 ±0.04	3.18 ±0.01	17.92 ±0.04
330	28.72 ±0.03	3.12 ±0.06	15.82 ±0.03
360	28.53 ±0.02	3.09 ±0.08	15.82 ±0.01
390	28.24 ±0.01	3.04 ±0.04	15.14 ±0.02
420	27.89 ±0.04	2.17 ± 0.02	13.7 ±0.05
450	27.56 ±0.06	2.13 ± 0.07	10.01 ±0.05

Table 7. Pearson correlation test and linear regression for colorimetric parameters and storage days

Independent variable	R	R^2	p
L^*	0.999	0.998	0.000
a^*	0.825	0.681	0.000
b^*	0.878	0.772	0.000

Independent variable storage days.

From Table 7, it is established that the color parameter L^* presents the highest correlation coefficient, which is positive and highly significant ($p < 0.05$), so the inference of useful life was made using mathematical modeling between the value of clarity (L^*) and the storage days with equation 4.

$$y = -0.0122x + 32.918 \quad (4)$$

where:
y – clarity (L^*),
x – storage days.

Equation 4 represents the predictive model that allows establishing the shelf life of aguaymanto compote with a value of $R^2 = 0.999$ ($p < 0.05$). This allows establishing the loss of quality in terms of color, with a clarity $L = 28.44$ (this value is obtained by reducing the clarity by 14% of the initial value of $L = 33.07$), which was established as an acceptable control parameter.

In lower values than that clarity, it would degrade the color related to the physical attribute measured in the compote. Thus, a shelf life of 367 days (12 months approximately) was obtained, which far surpasses compotes made without the use of preservatives, such as apple with sweet potato and gooseberry, which had a shelf life of 24 days at 18°C (Pilamala et al., 2018), and pumpkin compote (Camayo-Lapa et al., 2020).

CONCLUSIONS

The aguaymanto compote had a non-Newtonian behavior with pseudoplastic fluid characteristics. Preparing compotes based on aguaymanto pulp and determining their rheological behavior offers an excellent source of knowledge for these types of fluids and their large-scale application in the food industry. In addition, the product has a high moisture content, contains fiber and carbohydrates, is free of microorganisms such as molds, yeasts, and its total coliforms are harmless. It also complies with national and international technical standards. The shelf life obtained was 367 days under environmental conditions. One of the strengths of this research work is that aguaymanto is harvested all year round in several provinces of Peru. However, one limitation is that the Peruvian population does not have the habit of consuming compotes with different nutrient-rich raw materials. Compote has a significant amount of sugar and its consumption is aimed at different age groups since it is a nutritious and functional food available to the consumer.

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