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Original Article

Formulation and Evaluation of a Tropical Fruit Compote Enriched with Gelatinised Quinoa Flour

Formulación y evaluación de una compota de frutas tropicales enriquecida con harina gelatinizada de quinoa

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ABSTRACT

Compote is a widely consumed food among children and a favorable target for developing new formulations to tackle food insecurity and child malnutrition. The objective of this study was to evaluate alternatives for the formulation and preparation of compotes made with tropical fruits and gelatinized quinoa flour (Chenopodium quinoa). The fruits used were guava, mango and passion fruit. A completely randomized block experimental design was developed with three treatments and 80 repetitions. The treatments used differ only in the composition of the compote, with a common production procedure including pasteurization by heat treatment to ensure safety. The product was sensory evaluated using a hedonic facial scale, along with physicochemical and microbiological tests, and an analysis of the nutritional value of the most accepted compote. ANOVA was applied with a statistical value of p:<0.05 using the STATGRAPHICS statistical software. The concentrations of guava and quinoa differentiated the formulations: F1 (guava 55.77 %, quinoa flour 23.91 %), F2 (guava 63.74 %; quinoa flour 15.94 %) and F3 (guava 71 .71 %; quinoa flour 7.97 %); maintaining for the three formulations, in similar proportions the rest of the constituents composed of mango, passion fruit, sugar, citric acid and vitamin C. F3 demonstrated the highest acceptability while meeting the physicochemical, nutritional, and microbiological requirements established by the reference standards, ensuring the compote's quality and safety.

Keywords: Compote, guava, gelatinized quinoa flour, sensory evaluation

RESUMEN

La revisión sistemática se realizó utilizando la metodología PRISMA y se centró en la La compota es un alimento muy consumido entre la población infantil y un blanco propicio para encontrar nuevas formulaciones que combatan la inseguridad alimentaria y desnutrición infantil. El objetivo de este estudio fue evaluar alternativas de formulación y preparación de compotas a base de frutas tropicales y harina gelatinizada de quinua. Las frutas empleadas fueron guayaba, mango y maracuyá. Se desarrolló un diseño experimental de bloque completamente al azar con tres tratamientos y 80 repeticiones. Los tratamientos empleados difieren únicamente de la composición de la compota, con un procedimiento de elaboración común que incluyó una operación de pasteurización por tratamiento térmico que garantizó la inocuidad. Se evaluó sensorialmente el producto empleando una escala hedónica facial; se realizaron ensayos fisicoquímicos, microbiológicos, así como un análisis del valor nutricional que presenta la compota de mayor aceptación. Se aplicó ANOVA con un valor estadístico p:<0,05 mediante el paquete estadístico STATGRAPHICS. Las formulaciones fueron diferenciadas por las concentraciones de guayaba y quinua: F1 (guayaba 55,77 %, harina de quinua 23,91 %), F2 (guayaba 63,74 %; harina de quinua 15,94 %) y F3 (guayaba 71,71 %; harina de quinua 7,97 %); manteniendo para las tres formulaciones, en proporciones similares el resto de los constituyentes compuestos por mango, maracuyá, azúcar, ácido cítrico y vitamina C. La F3 fue la de mayor aceptabilidad, al mismo tiempo que cumplió con los requisitos fisicoquímicos, nutricionales y microbiológicos establecidos en las normas usadas como referencia, de manera que se garantiza la calidad e inocuidad de la compota.

Palabras clave: Compota, guayaba, harina gelatinizada de quinua, evaluación sensorial.

INTRODUCTION

Food insecurity has been identified as one of the major global challenges. By the end of 2019, more than 135 million people across 55 countries and territories were facing severe food insecurity, and approximately 183 million people were in stressed food security conditions, at high risk of falling into acute food insecurity (FAO, 2020b). This difficult situation has been exacerbated by COVID-19 and the global food crisis, with undernourishment affecting nearly 800 million people worldwide even before the pandemic (WFP, 2017).

Globally, the consumption of edible parts of plants or their natural products has seen a significant increase, driven by the recognition of their nutritional benefits, as highlighted in reports by the Food and Agriculture Organization of the United Nations (FAO, 2020a). Consequently, the food industry has devoted considerable attention to the development of bioactive products using fruit pulp and by-products (Rodrigues *et al.*, 2021).

Guava (*Psidium guajava* L.) is one of the most nutritionally valuable fruits and has been widely used in children's diets. This fruit demonstrates remarkable adaptability to various environmental conditions and contains high levels of vitamins and minerals. It is especially rich in vitamin C, which meets the nutritional requirements of children under 8 years old (IICA, 2015). Guava is also credited with medicinal properties due to the presence of various secondary metabolites, including benzophenones, flavonoids, tannins, triterpenoids, and meroterpenoids (Zou and Liu, 2023).

Similarly, mango (*Mangifera indica* L.), a tropical fruit consumed worldwide, boasts a rich composition of phytochemicals, β-carotene, fiber, magnesium, potassium, and vitamins A and C. It also contains anthocyanins and polyphenols, such as flavonoids and mangiferin. These components give the fruit antioxidant, antidiabetic, anticancer, and immunomodulatory properties, as evidenced by recent studies (Castro *et al*., 2023; Sabuz *et al*., 2023; Stamper *et al*., 2023). In addition to its nutritional benefits, mango is highly regarded for its sensory properties, and its processed derivatives encompass a wide range of products, including juices, nectars, pulps, purees, compotes, fruit leathers, jams, pickles, chutneys, dried slices, and canned pieces (Marçal and Pintado, 2021).

Passion fruit (*Passiflora edulis*) is another widely consumed fruit, known for its high nutritional value. Its composition includes a significant proportion of water, particularly in the peel (87%). Carbohydrates are a major component of the peel, pulp, and seeds. The seeds contain proteins (13.2% of dry weight) and lipids (14.9% of dry weight), including linoleic, linolenic, oleic, palmitic, and stearic acids. The peel stands out for its high fiber content (61.7% of dry weight). Additionally, the pulp and juice are rich in vitamin C, while the seeds and peel provide significant amounts of potassium, copper, magnesium, zinc, iron, phenols, and cyanidin-3-glucoside, as well as carotenoids.

Passion fruit is used in various preparations, including salad dressings, ice creams, desserts, juices, liqueurs, tropical punches, yogurts, jams, and confectionery. The peel has applications in wine or tea production, as a source of pectin, medicinal ingredients, and animal feed. Cold-pressed seeds produce a pale yellow oil with a mild, pleasant flavor, used both in cooking and as a raw material in the paint and varnish industry (Fonseca *et al*., 2022).

Among the most nutritionally valuable components used to supplement compotes, quinoa stands out. This pseudocereal has been highlighted by the FAO for its immense potential due to its high carbohydrate content, its provision of all essential amino acids, trace elements, and vitamins required for human nutrition, and its lack of gluten-forming proteins (Dueñas, 2014; Fundación PROINPA, 2011).

In their study, Mu *et al*. (2023) concluded that replacing wheat flour with quinoa flour can be a valuable alternative as an ingredient in the production of functional food products. This is supported by quinoa's remarkable functional and rheological qualities, its sensory and nutritional characteristics, as well as its physicochemical attributes.

To lay the groundwork for designing a product aimed at the children's market, it is essential to explore the acceptability of such a product within this population segment by evaluating different formulations. It is also necessary to define, with an eye toward establishing the technology for its industrial production, the pasteurization, storage, and preservation conditions that ensure durability, stability, and the retention of its nutritional properties. In this context, the objective of this study was to evaluate formulation and preparation alternatives for compotes made with tropical fruits and gelatinized quinoa flour that ensure acceptability and appropriate nutritional properties for the pediatric population.

MATERIALS AND METHODS

To achieve the research objective, three formulations were designed with varying proportions of fruits and quinoa flour. The treatment process for all formulations was identical, consisting of preparing the pulps and compotes, including pasteurization and packaging. Table 1 shows the three formulations evaluated in this study.

Table 1.
Experimental Formulations of the Compotes

Raw materials	Formulations (% by weight)		
	F1	F2	F3
Guava	55.77	63.74	71.71
Mango	5.00	5.00	5.00
Passion fruit	5.00	5.00	5.00
Quinoa flour	23.91	15.94	7.97
Sugar	5.00	5.00	5.00
Water	5.00	5.00	5.00
Citric acid	0.07	0.07	0.07
Vitamic C	0.25	0.25	0.25

Each of the three formulations was subjected to sensory evaluation to determine the formulation with the highest acceptance. This selected formulation underwent physicochemical and microbiological analyses to assess its suitability for consumption and its properties as a compote aimed at meeting the nutritional requirements of the pediatric population.

The physicochemical tests were performed to evaluate a set of requirements outlined in the Ecuadorian technical standard NTE INEN 2009:95, "Strained and chopped foods, packaged for infants and young children. Requirements," sourced from the Ecuadorian Standardization Service (INEN, 1995), which was used as a reference. Additional standards were used for specific determinations: AOAC 981.12 (pH), INEN 14 (total solids), AOAC 942.15 (titratable acidity), INEN 14 (vitamin C). All tests were performed in triplicate at the Laboratorio de la Sociedad de Aseguramiento Técnico (SAT) in Lima, Peru. Microbiological tests were conducted to determine compliance with the requirements set by the Peruvian sanitary standard for food quality and safety (MINSA, 2008). These analyses were carried out immediately after the production process and included aerobic mesophilic bacteria, molds and yeasts, E. coli, total coliforms and Salmonella spp. All microbiological tests were performed at the Microbiology Laboratory of the National Fisheries Health Organization (SANIPES), located in Lima, Peru.

Aerobic mesophilic bacteria were determined using the method described in the manual of the U.S. Food and Drug Administration (FDA), specifically the Bacteriological Analytical Manual within the official methods of the AOAC (FDA, 2001a). Molds and yeasts were analyzed following the compendium of methods for microbiological examinations of food (FDA, 2001b).

The determination of E. coli and total coliforms was conducted following the international standard ISO 16649-3:2015, "Microbiology of the food chain - Horizontal method for the enumeration of beta-glucuronidase-positive Escherichia coli - Part 3: Detection and most probable number technique using 5-bromo-4-chloro-3-indolyl-β-D-glucuronide" (ISO, 2015). For the determination of Salmonella, the Peruvian standard NTP-ISO 6579-1:2019, "Microbiology of the food chain. Horizontal method for the detection, enumeration, and serotyping of Salmonella. Part 1: Detection of Salmonella spp.” (INACAL, 2019), adopted from the ISO standard with the same purpose, was used.

The sensory evaluation was based on a Randomized Complete Block Design (RCBD) with three treatments and 80 repetitions, corresponding to the total number of panelists. This sensory evaluation aimed to determine the variability in acceptance among the different formulations.

For this purpose, a hedonic facial scale with five options was used: Hated it (1), I didn’t like it (2), Indifferent (3), I liked it (4), and I loved it (5). The organoleptic characteristics evaluated were color, aroma, and flavor. The 80 panelists were children aged 6 to 8 years, who tasted a 25 g sample of fruit compote separately using a plastic spoon. The experimental data obtained were tabulated and processed using the STATGRAPHICS statistical software. An ANOVA test was performed to verify if there were significant differences among the formulations in relation to the evaluated organoleptic characteristics. Formulation, titratable acidity determination, and vitamin C analysis were conducted at the laboratory of the National Federico Villarreal University in Lima. The physicochemical analyses were performed at the Technical Assurance Society (SAT) laboratory in Lima.

The microbiological analysis was conducted at the Microbiology Laboratory of the National Fisheries Health Agency – SANIPES, Lima, Peru, and the sensory test was carried out at a private school in Lima. The preparation of the fruit pulps followed the procedure described by Martínez and Vásquez (2021). This included the following steps: (1) Reception and selection; (2) Washing; (3) Cutting; (4) Blanching; (5) Blending; and (6) Sieving.

The last operation was performed using a sieve with perforations of approximately 1 mm to separate the pulp from the seeds. Blanching was conducted for 10 minutes at a temperature of 75 °C.

From the prepared fruit pulps, the enriched fruit compote with gelatinized quinoa flour was made following the flowchart presented in Figure 1.

To establish the pasteurization regime, it was considered that the product to be processed (compote) is of high acidity, with a pH between 4.0 and 4.5. Consequently, the reference microorganism used was the fungus Byssochlamys fulva (Casusol, 2016; Encina-Zelada *et al.*, 2013; Bernal-Sánchez and Rojas-Hurtado, 2013; Guevara and Cancio, 2008; Pesantes and Tejada, 2021), due to its high thermal resistance at low pH values. A decimal reduction time of one minute was determined at 93.3 °C, with a thermal resistance constant (Z) of 8.9 °C (Stumbo, 1973).

Based on the premise of reducing the microbial load by five decimal logarithmic units $(\log \frac{N_0}{N} = 5)$, the lethal effect of pasteurization (F_0) was determined using the following equation:

$$F_0 = \log \frac{N_0}{N} D_{93,3}^{8,9}$$

Where:

$D_{93,3}^{8,9} = 1$ – Decimal reduction time (min)

To determine the pasteurization time at a temperature of 95ºC (T1), the equation was used:

$$t = F_0 10^{(T_0 - T_1)/Z}$$

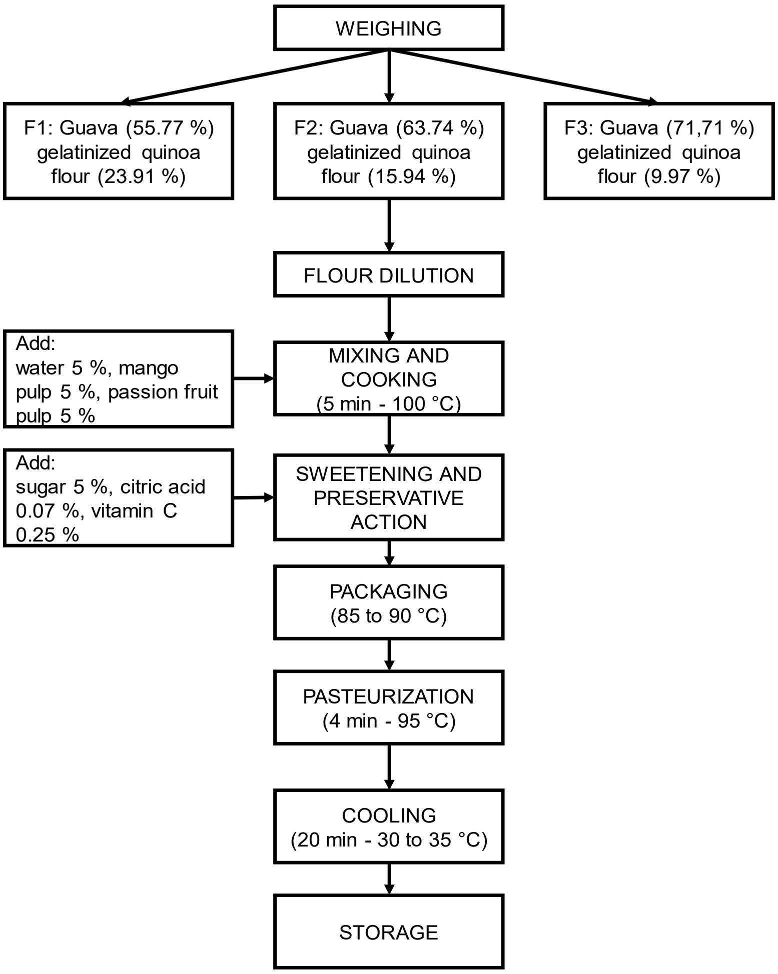

Figure 1. Flowchart for the preparation of the compote

In this case, T0 is the reference temperature at which the decimal reduction time (D) was determined. The nutritional content of the most acceptable compote was determined on the basis of 100 g of compote and from food composition tables for energy (kcal), protein (g), fat (g), total carbohydrates (g), dietary fiber (g), calcium (mg), iron (mg) and vitamin C (mg).

RESULTS AND DISCUSSIONS

Table 2 presents the results of the sensory evaluation, which assessed the acceptability of the organoleptic characteristics (color, flavor, and aroma) of the three formulations using a hedonic facial scale. These results express, as percentages, the ratings assigned to each attribute and formulation.

It can be observed that most panelists reacted negatively (“Hated it” and “Didn’t like it”) for all three evaluated attributes in formulation F1. Meanwhile, the categories “Didn’t like it” and “Indifferent” were the most prevalent for F2. For these two formulations, no panelists rated them with the categories “I liked it” or “I loved it.”

For formulation F3, most responses fell into the “Loved it” category for color and aroma, and into the “Liked it” category for flavor. Significant differences were observed between flavor and color as well as aroma and color ($p < 0.05$) for F3 when compared to the other formulations. Multiple Range Tests conducted using the STATGRAPHICS statistical package confirmed that each formulation belonged to different homogeneous groups.

Based on the results of the statistical analysis, it was demonstrated that there were significant differences among the formulations for each of the three characteristics: color, flavor, and aroma. The F3 formulation, containing 71.71% guava and 7.97% gelatinized quinoa flour, achieved the highest acceptance among the panelists.

Table 2.

Acceptability of organoleptic characteristics (color, flavor and aroma) of the different formulations according to the hedonic facial scale

Hedonic		F1			F2			F3	
facial scale	color	flavor	aroma	color	flavor	aroma	color	flavor	aroma
Hated it	52.50	51.25	53.75	-	-	1.25	-	-	-
Didn't like it	45.00	48.75	43.75	60.00	51.25	40.00	-	-	-
Indifferent	2.50	-	2.50	40.00	48.75	58.75	-	-	-
Liked it	-	-	-	-	-	-	16.25	55.00	46.25
Loved it	-	-	-	-	-	-	83.75	45.00	53.75

The sensory evaluation conducted and the higher acceptance of formulation F3 reveal the preference of children for compotes with a high proportion of guava. This formulation achieved 100% ratings within the categories “Liked it” and “Loved it,” surpassing the results reported by Berdugo *et al*. (2021). Their study developed a food product for children made with mango (*Mangifera indica* L.) and moringa (*Moringa oleifera* Lam), achieving acceptance rates between 68% and 88% for the evaluated attributes, including color, flavor, aroma, and texture.

Table 3 reports the physicochemical indicators for the most accepted formulation (F3). The test results show minimal variability across the three replicates and the three indicators.

The pH and acidity values indicate that the accepted formulation (F3) has a slightly acidic character. Based on these results and comparisons with those reported by other authors, it was noted that the pH and °Brix (soluble solids) values were lower than those observed by Cardona and López (2020), who developed three compotes: pumpkin (pH = 6.8; 31.8 °Brix), carrot (pH = 7.4; 30.5 °Brix), and fig (pH = 6.2; 18.0 °Brix). Although differences in pH and soluble solids were observed, the accepted formulation complies with the Ecuadorian standard NTE INEN 2009:95, which requires a pH below 4.5 and a total soluble solids content above 15% by weight.

Table 3.

Physicochemical Indicators for the Selected Formulation

Replicates	pH	°Brix	Acidity % (mg/100 mL)
1	4.01	20	0.195
2	4.00	22	0.195
3	4.00	21	0.195
Average	**4.00**	**21**	**0.195**

The F3 formulation also aligns with reference standards and shows very similar physicochemical indicators to the compotes developed by Tiaga *et al.* (2021). They used purple and white sweet potatoes combined with pineapple (*Ananas comosus*) and banana (*Musa x paradisiaca*). In their study, the pH values were 4.38 and 4.28 for the purple and white sweet potato compotes, respectively. Regarding soluble solids, the purple sweet potato compote had an average of 22.43 °Brix, while the white sweet potato compote had an average of 8.56 °Brix. This difference was attributed to the higher sugar content in the purple sweet potato. It is important to highlight that, according to the Codex Alimentarius (FAO, 2022), sweetened compotes must contain a minimum of 16.5% total soluble solids (16.5 °Brix), a value closely aligned with the Ecuadorian standard and also met by the F3 formulation.

The results of the microbiological tests for the selected formulation are shown in Table 4. This table demonstrates compliance with the NTS No. 071-MINSA/DIGESA standard for all tested microbial agents.

Table 4.
Results of Microbiological Analysis for the Selected Formulation

Microbial Agent Analysis	Result after processing	Max. limit (cfu/mL) *
Mesophilic aerobes	< 250 cfu/g	10^4
Molds and yeasts	<10 cfu/g	10^2
E. *coli* and total coliforms	0 NMP/g	10
Salmonella spp	Not detected /25 g	Absence/25

* Standard: NTS No. 071-MINSA/DIGESA

The results shown in Table 4, which determine the microbiological quality of the compote, are strongly influenced by the pasteurization method employed and described in the methodology. By referencing an organism with high thermal resistance at low pH values (*Byssochlamys fulva*), as well as its decimal reduction time (D) and thermal resistance constant (Z), the calculated pasteurization time was 3.22 minutes, rounded to 4 minutes for practical purposes, as shown in the compote production process flowchart (Figure 1).

The pasteurization method used, with a low exposure time to the heating agent, not only ensured a safe final product but also minimized the negative impact on the sensory quality of the compote. This is supported by the positive acceptance of the sensory evaluation panel. Similarly, this approach is likely to preserve the nutritional quality of the ingredients, thereby positively influencing the nutritional value of the compote. The nutritional value is reported in Table 5.

Table 5.
Nutritional Value of the Most Accepted Formulation

Nutrients	Nutritional value
Energy (Kcal)	86.38
Total carbohydrates (g)	14.79
Proteins (g)	1.64
Fat (g)	0.95
Dietary fiber (g)	4.71
Calcium (mg)	23.73
Iron (mg)	1.03
Vitamin C (mg)	131.84

Note: per 100g of weight

Regarding the nutritional content, the selected compote (F3) was found to be particularly rich in vitamin C, with 131.84 mg/100 g, which is partly attributed to the significant presence of guava in its composition, a fruit that is four times richer in this vitamin than orange (Zou and Liu, 2023). This concentration of vitamin C is well above the nutritional requirements for children aged six to 24 months, which is 50 mg/day (WHO, 2003). The studied formulation is also rich in calcium, carbohydrates, and proteins due to the significant contribution of quinoa. The latter ensures the presence of all essential amino acids for human nutrition in the formulation, as well as a protein concentration in the compote of 1.64 g/100 g. The caloric content, exceeding 85 kcal/100 g, is also considered adequate as it surpasses other reference compotes (Aldana *et al.*, 2018).

CONCLUSIONS

The three evaluated compote formulations, which were made from guava pulp and quinoa flour, show statistically significant differences in terms of taste, color, and smell with a confidence level of 95.0%. The most accepted formulation is coded as F3, which contains 71.71% guava and 7.97% gelatinized quinoa flour. The most accepted formulation according to the sensory evaluation results (F3) meets the physicochemical parameters established in the Ecuadorian technical standard NTE INEN 2 009:95, used as a reference to establish the requirements for products aimed at infants and young children. This formulation has a composition that meets the nutritional requirements for children aged six to 24 months, making it an alternative to ensure adequate child nutrition. The technological process used for the preparation of the fruit pulps and the compote guarantees the microbiological requirements established by the Peruvian health standard for food quality and safety (MINSA, 2008).

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