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Bioactive and Nutritional Potential of an Infant Food based on *Mangifera Indica, Musa Paradisiaca, Chenopodium Quinoa* and *Amaranthus Caudatus* Flour

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Abstract

There are few studies in the scientific literature on Peruvian native cereal-based instant mixes. Food aid programs of the Peruvian government allow food to be distributed to infants in public schools, and in general, these foods contain carbohydrates and a protein fraction, but there is some rejection on the part of consumers due to the sensory aspect of the product that does not has been considered in this population. The objective of this study is to know the bioactive, nutritional potential and the level of sensory acceptance of infant food made from Andean pseudocereals from the Ancash region and tropical fruits from the Piura region, Peru. Three formulations were prepared based on mango, banana, quinoa and kiwicha flours (T1, T2 and T3) and were compared with a commercial product based on kiwicha and oatmeal. The total amounts of phenolic compounds, vitamin C, antioxidant activity, composition, water absorption index, oil, milk was determined; viscosity and sensory evaluations were carried out with the participation of preschool children (4 and 5 years). The content of phenols, ascorbic acid

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(AA) and antioxidant capacity of T1 and T2 were 10 times higher than the control treatment. Physical and chemical composition analysis showed that there were no significant differences among the treatments evaluated. Banana flour contributes to the water and oil absorption capacity and viscosity. Finally, the addition of quinoa and kiwicha flour improves milk absorption capacity. The characteristics of the developed mixtures allow the incorporation of more food and less water to increase viscosity acceptance. The greatest preferences were obtained by T2 and T1, obtaining a level of acceptance above 82%, which shows that today children have a healthy food alternative such as mixtures of Andean pseudocereals and tropical fruits without sacrificing their nutritional qualities.

Introduction

In 2021, 828 million people suffered from hunger in the world, this means a growth of 24% compared to 2019. During the same period, the number of hungry people in South America increased to 11 million. Projections on the prevalence of stunting in boys and girls under five years of age in low- and middle-income countries indicate that between 11.2 and 16.3 million of this population may be affected by child malnutrition.[1] In 2022, in Peru, chronic malnutrition affected 11.7% of girls and boys under five years of age and this figure was 0.2% higher than that recorded in 2021.[2]

Children and adolescents have an optimal growth period when they receive appropriate amounts of nutrients, with a balance of proteins, carbohydrates, fats, vitamins and minerals.[3] When an energy imbalance occurs due to a deficiency or excess of these nutrients, malnutrition can occur,[4,5] affecting child development, which is related to learning capacity, physical activity, language and emotional development, which limit the person's normal performance in adulthood. Even in the university stage, various diseases suffered by students have been evidenced and free food services and nutritional counseling have been implemented.[6] In several rural areas of Peru, the average energy consumption is below the recommended levels.[7] On the other hand, a high consumption of carbohydrates was found in diets low in protein and fat, in addition to a very low intake of micronutrients. An alternative to improve these indicators is the creation of new foods, but these must comply with certain nutritional qualities such as proteins, carbohydrates, fats, fiber, vitamins and minerals.[8] Therefore, food should contain bioactive compounds, such as phenolic compounds, vitamin C, carotenes, flavonoids, tocopherol, among other phytochemical compounds.

The antioxidant capacity of foods is based on the neutralization of free radicals and reactive oxygen species (ROS) by hydrogen atom transfer (HAT), single electron transfer (SET) and chelation of prooxidant metals. In food, this antioxidant action prevents lipid oxidation, prolonging shelf life and maintaining sensory quality. In the human body, it reduces oxidative stress, helping to prevent chronic and degenerative diseases.[9–13]

There are also challenges in the processing of new products from fruits, as they may contain pesticide residues resulting from some agricultural practices. A previous study reported that levels of various pesticides in more than 50% of fruit and vegetable samples from some locations in Pakistan, China and Bangladesh indicated that they were contaminated with organophosphorus, pyrethroid and organochlorine pesticides, in some cases exceeding the FAO/WHO limits for residual levels of these contaminants.[14]

Likewise, synthetic pesticides are necessary to manage diseases such as anthracnose in mango.[15] Peru has a diversity of pseudocereals such as quinoa (Chenopodium quinoa Willdenow) and Kiwicha (Amaranthus caudatus), products with exceptional nutritional characteristics, highlighted for being gluten-free, with high nutritional and bioactive potential, in addition to presenting a complete group of amino acids.[16–18] In 2014, the country stood out as the main producer of quinoa and its production has grown in the last decade at an average annual rate of 9.0%, reaching 113,355 tons of quinoa in 2022, representing 85% of the production of quinoa. Andean grains, grown mainly in Puno, Ayacucho and Apurímac.[19] Also, Peruvian exports of kiwicha, in the first quarter of 2022, reached 701 tons for US$ 1.3 million, this was four times more in volume and three times more in value, compared to the same period of the previous year.[20]

Cereals and pseudocereals have a high content of proteins, vitamins, minerals, as well as a quantity of carbohydrates and fats, which are intended to meet the nutritional needs of preschool children.[21] For this reason, the use of these foods is widely studied along with chocolate, because incorporating up to 4% of maca, sesame, cañigua, kiwicha and chia flour improve the degree of acceptance of chocolate. Associating the consumption of this sweet with beneficial antioxidant properties that reduce oxidative stress and the prevention of cardiovascular diseases, moods and cognitive and sensory responses.[8]

In Piura region, fruits such as mango (Mangifera indica) and banana (Musa cavendish) provide minerals rich in bioactive peptides. However, banana and mango fruit wastage are estimated at 57,450 and 58,893 metric tons (MT), respectively. The production of these fruits represents a share of 10% (banana) and 8% (mango) of the country's total production, both for export and for the national market.[22] Banana packing factories report that 10% of what is received is discarded, which is returned to the producers for marketing through local intermediaries at reduced prices, which represents a significant loss.[23]

The co-products of these fruits, such as bananas, are used to make bakery products, demonstrating adequate behavior from a sensory and nutritional point of view.[24] Mangoes have an important nutritional value that supports human health due to their bioactive components such as total polyphenols in the unripe state. In a previous study it was identified that the concentrations of total polyphenols in fruits of Kent and Tommy Atkins mangoes were 4.81 and 4.42 g/kg respectively, but in the ripe state of the mango they reached concentrations of 5.24 and 4.18 g/kg respectively.[25] Regarding the phytochemical compounds reported, the mango fruit presents flavonoids, phenolic acids and pigments such as carotenoids and chlorophyll found in the edible part of the fruit, as well as the seed and peel, evidencing that mango co-products are beneficial to health26. An accessible alternative for mango co-products is the production of instant mixes, which are characterized by their practicality in transportation, distribution and consumption. A previous study found positive results using instant mixes made from fruits such as amaranth, oat flakes and immature banana peel with foods rich in protein, minerals, glucan, dietary fiber, essential amino acids, phenolic and antioxidant activity.[27] Another study reported that mango peel flour in instant beverage improved its functional qualities due to its bioactive compounds (vitamin C and phenolic content) and crude fiber, with high antioxidant activity.[28] Another study showed that the incorporation of mango flour in the preparation of instant kunun-zaky flour mixes was proportional to the sensory preference of the judges.[29] However, numerous studies indicate that children and adolescents show a low level of acceptance of fruit-based foods, due to their preference for processed snacks rich in sugar.[30–32] In this respect, the socio-economic conditions of children at school, the time of consumption and presentation are factors that could influence their preferences[33,34] and a study of new functional products is needed.

Therefore, because of the nutrition deficiency in the children population of the Piura region, the objective of this research was to know the bioactive, nutritional potential and level of sensory acceptance of a children's food made from Andean pseudocereals and tropical fruits from the Piura region, Peru.

Materials and Methods

Materials and Reagents

To develop the research, the Agroindustria La Perla del Huascarán S.R.L. (Huaraz, Peru) provided the quinoa and kiwicha flours. The mango and banana flours were produced at the Functional Food and Bioprocesses Laboratory of the Universidad Nacional de Frontera (Sullana, Peru). Pasteurised milk, cocoa powder, skimmed milk, sugar and olive oil were obtained from the local market (Sullana, Peru).

Various reagents were used, following the procedures of a previous study,[12] to determine antioxidant capacity, total phenolic content,[23] vitamin C10 and physicochemical characteristics.[23]

Mango and Banana Flour Production

Unripe mango and banana fruits were stripped of their peel. The pulp was sliced in 2.5 mm thick. The slices were immersed in 1% citric acid solution. They were then dried in a convection dehydrator at different temperatures, 60 ºC (mango pulp) and 80 ºC (banana pulp), until reaching a humidity of <10%. Finally, the dried fruit pulp was pulverized in a knife mill and sieved with a 212 µm mesh ASTM sieve. The flours were packed in polypropylene bags and stored in ambient conditions (temperature 20°C and humidity 65%) with ventilation.[23]

Infant Food Formulation (If)

The formulation was developed as established by Hidalgo-Piamba *et al*[35] and Kamishikiriyo and Olivares,[36] who established the basic criteria for the formulation of mixtures looking for the optimal complementation point.

Table 1: Ingredients used in the formulation of infant food

Base (25%)	Mango *(Mangifera indica)* Flour	Banana *(Musa paradisiaca)* Flour	Quinoa *(Chenopodium quinoa)* Flour	Kiwicha *(Amaranthus caudatus)* flour	Treatment
Skimmed milk	15%	30%	15%	15%	T1
Cocoa powder	15%	15%	15%	30%	T2
Sugar	30%	15%	15%	15%	T3

Table 1 shows the experimental design (Completely Randomized Design - CRD) with the different formulations using mango, plantain, quinoa and kiwicha flour at different percentages, incorporated into a base formula, which included cocoa powder, skim milk and sugar in all treatments. The foods were vacuum-packed in polypropylene bags (250 g capacity) for subsequent physicochemical, compositional, functional properties and sensory analysis.

Physicochemical Analysis of Soluble Solids (Ss), Ph, and Titratable Acidity (Ta)

The determination of soluble solids (SS), pH and titratable acidity (TA) were carried out as reported by Padhi and Dwivedi.[37]

100 mL of distilled water was added to 10 g of infant feed (AI), heated for 30 min and filtered using Whatman paper No. 1. For pH analysis, 20 mL of the filtered solution was used with the aid of a pH meter (HANNA-HI991001) calibrated by direct immersion of the electrode to be measured. For the determination of SS, two to three drops of the filtered solution were used and with the help of a refractometer (HANNA-H196801) the measurement was carried out. The titratable acidity was estimated by titrating 20 mL of the filtrate with 0.1N NaOH, for which phenolphthalein was used as an indicator. The end point of the titration was the color change to pink at pH 8.3. The TA determination was estimated according to Equation (1).

$$TA\ (\%) = \frac{\text{Spent Volume} \times \text{NaOH normality} \times \text{citric acid equivalent}}{\text{Sample weight} \times \text{aliquot taken} \times 1000} \times 100 \qquad \text{...(1)}$$

Chemical Composition Analysis

The contents of moisture, proteins, lipids, crude fiber, ash and the nitrogen-free extract (NFE) were determined according to methods 950.46, 984.13, 2003.05, 962.09 and 942.05 respectively (AOAC, 2005). The carbohydrate content was assessed by multiplying the protein and carbohydrate content in grams (4 kcal/g). The amount of fat was measured in grams and multiplied by 9 kcal/g and, finally, the results were summed to obtain the total energy expressed in kcal/100g.[38]

Analysis of Functional Properties of Infant Food

Determination of Total Ascorbic Acid

The determination of the total content of AA was carried out by titrating 2,6 dichlophenolindophenol according to the method described by Hung and Yen.[39] About 1 g of the infant food was mixed with 10 mL of 0.4% oxalic acid and centrifuged at 4000 rpm for 20 min and a solution was obtained. Next, 200 µL of the solution was reacted with

1800 µL 2,6 dichlorophenolindophenol and the absorbance values were recorded in a UV-Visible spectrophotometer (Genesys, S-150, 6287015), at a wavelength of 520 nm. For the quantification of AA, the Eq. (2) was used.

$$Abs_{520} = Abs_{Control} - Abs_{Sample} \qquad ...(2)$$

Where the control absorbance was obtained by the reaction of 200 µL of 0.4% oxalic acid, with 1800 µL of 2,6 diclophenolindophenol.

Determination of Total Phenolic Content (TPC)

The TPC was determined according to the method described by Cornelio-Santiago *et al.*[40] To obtain the extracts, approximately 1 g of IF was weighed, 5 mL of methanol was added in a 10 mL capacity tube, and then it was homogenized in a vortex mixer at 2500 rpm for 20 min. Subsequently, it was centrifuged at 4500 rpm for 20 min at laboratory room temperature (20 °C) and the first supernatant was recovered. With the residue obtained, the previous steps were repeated, obtaining a second supernatant; both recovered were mixed and homogenized.

For the colorimetric assay, the mixture of 1.364 mL of distilled water and 0.30 mL of methanolic extract (ME) was reacted with 136 µL of Folin-Ciocalteu reagent. The resulting solution was allowed to stand at room temperature (20°C) for 8 min in a dark room. Later, 1.2 mL of 7.5% sodium carbonate (Na2CO3) was added, the reaction was completed after remaining 2 h in the dark at room temperature, observing a dark blue color. The absorbance was recorded in a UV-Visible spectrophotometer (Genesys, S-150, 6287015) at 760 nm. The results were expressed as mg gallic acid equivalents (GAE)/100g.

Determination of Antioxidant Capacity (AC)

The 2,2-diphenyl-1-picrylhydrazil (DPPH) assay was carried out to measure the AC according to Tian *et al.*[41] The assay consisted of reacting 100 µL of EM with 2 mL of DPPH solution (0.8 mmol/L). The necessary reaction time was 60 min of rest at room temperature in the dark. The absorbance values were measured at 517 nm using a UV-Visible spectrophotometer (Genesys, S-150, 6287015). The results were expressed in (%) percentage of inhibition of the DPPH radical, and it was calculated using the Eq. (3).

$$\% \text{ DPPH inhibition} = (\text{Abs C} - \text{Abs M})/(\text{Abs C}) \times 100\% \qquad ...(3)$$

Where:

Abs. C: absorbance of DPPH solution at 0.8 mmol/L
Abs. M: sample absorbance after 60 min rest.

Determination of Water (Wai), Oil (Oai) and Milk (Mai) Absorption Indexes

WAI, OAI and MAI were determined according to the methods previously described in the literature.[21,42] In a 100 mL flask, 1 g of IF was mixed with 35 mL of distilled water to determine WAI, oil for OAI and milk for MAI respectively. Subsequently, the mixture was stirred in a vortex mixer at 700 rpm for 40 min, then incubated for 1 hour under ambient conditions. Later, the solution was centrifuged at 4000 rpm for 20 min; Afterwards, the supernatant was removed and the centrifuged pellet was allowed to rest at a 45º inclination for 30 min. To determine the absorption rate of water, oil and milk, Eq. 4.

$$\text{WAI/OAI/MAI} = (\text{Weight of the centrifuged precipitation} - \text{Weight of sample})/(\text{Weight of sample}) \qquad ...(4)$$

Determination of Apparent Viscosity

The method used to determine the apparent viscosity of food mixtures was that described by a previous investigation.[43] The mixtures were reconstituted by adding 100 mL of water for every 10 g of sample. For commercial food (kiwicha and oatmeal), the proportion mentioned in the preparation instructions was used. The mixtures were heated in a water bath with constant stirring until boiling (100 ºC) for 1 min. Then, they were cooled to room temperature and viscosities were measured using a digital viscometer (Bluged, BGD 152). The analyzes were carried out using spindle No. 3, at rotation speeds of 6, 12, 30 and 60 rpm for T1, T2 and T3. Due to the behavior of the commercial food, it was measured at speeds of 30 and 60 rpm.

Sensory Analysis

Sensory Evaluation by Attributes with Semi-Trained Judges

The three treatments plus the commercial feed were subjected to sensory analysis. The attributes analyzed were aroma, flavor, texture and general appearance. The sensory evaluation was carried out at the Universidad Nacional de Frontera (Sullana, Peru) in the Functional Foods and Bioprocesses laboratory between 10:00 and 11:00 am. The 30 semi-trained judges were given 4 samples of 50 mL of reconstituted food, coded with random numbers. Additionally, they were given the tasting sheet to evaluate the attributes of aroma, flavor, texture and general appearance on a 5-point hedonic scale (1 = I don't like it very much, 5 = I like it very much).[44]

Sensory Analysis of Acceptance in Children

The sensory analysis of consumer preference was carried out based on what was reported by Schouteten *et al.*[45] 35 students aged 4 and 5 years from the Educational Institution 1140 Villa Perú Canada (Sullana, Peru) participated. They were given infant food (reconstituted mazamorra type) that corresponded to treatment T1 whose proportion of flour was as follows: 30% banana flour, 15% mango flour, 15% quinoa flour, 15% kiwicha flour and 25% basis. The evaluation was carried out in the morning hours between 10:00 am and 11:00 am, in school classrooms. Children were instructed to taste the food samples and indicate their liking on a 3-point scale (1 I like, 2 I neither like nor dislike, and 3 I do not like). Each point on the scale was linked to an emoji that made the children's interaction easier. The token used is shown in Figure 1. The order of the emojis was not random to make the task easier for the children and avoid fatigue. Once the children selected the emoji that represented how they felt about the food they tasted, the child marked the token with the corresponding emoji.

Data Analysis

Each infant food formulation was prepared and analyzed in triplicate (n=3) comparing with the commercial food. The mean values and standard deviation of all compositional, physicochemical parameters, functional properties and scores given on the sensory preference of the product were analyzed. Wilcoxon test ($p<0.05$) and Friedman test were performed to establish the significant difference of the treatments studied. Data analysis was performed using the SPSS STATISTIC 22 software to Windows (SPSS Inc., Chicago, IL) and the graphs were produced using Microsoft Excel MSO (version 2019; 16.0.10390.20024; Microsoft Office Standard 2019).

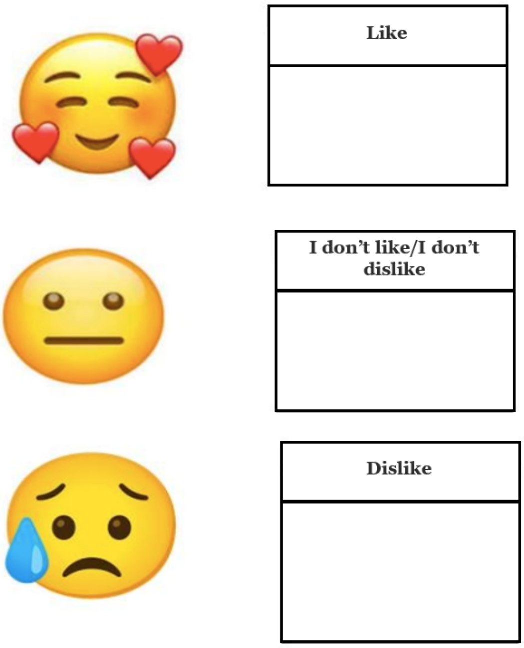

Fig. 1: Sensory evaluation sheet for sensory preference analysis

Ethical Considerations

The project was approved with Organizing Committee Resolution No. 432-2021-UNF/CO; student data and informed consent were treated according to the Declaration of Helsinki and its subsequent revisions. Semi-trained judges signed an informed consent, as did the parents of the participating children, who authorized their inclusion in the study.

Results

Soluble Solids (SS), pH and Titratable Acidity (TA)

The values of the physicochemical analyses (soluble solids, pH and titratable acidity) of the 3 formulations of the manufactured infant feed compared to the commercial feed showed significant differences, in terms of SS, pH and TA, see Table 2.

Nutritional Chemical Composition and Total AA Content

Significant differences ($p<0.05$) were observed between the chemical nutritional composition values (moisture, protein, fat, carbohydrate, crude fiber, ash, nitrogen free extract and energy) of the 3 infant food formulations.

Table 2: Analysis of soluble solids, pH and titratable acidity of infant food

Description	T1	T2	T3	KO
SS (ºBrix)	4.00 ± 0.10^{b}	2.20 ± 0.10^{c}	6.00 ± 0.24^{a}	1.00 ± 0.20^{b}
pH	5.26 ± 0.10^{c}	5.53 ± 0.05^{b}	4.88 ± 0.11^{d}	6.25 ± 0.09^{a}
TA (%)	0.14 ± 0.02^{b}	0.15 ± 0.01^{b}	0.20 ± 0.02^{a}	0.03 ± 0.01^{c}

T1: 15% mango flour, 30% banana flour, 15% quinoa flour, 15% kiwicha flour
T2: 15% mango flour, 15% banana flour, 15% quinoa flour, 30% kiwicha flour
T3: 30% mango flour, 15% banana flour, 15% quinoa flour, 15% kiwicha flour.
KO: Commercial food (pre-cooked kiwicha and oatmeal)

Table 3: Analysis of soluble solids, pH and titratable acidity of infant food

Description	T1	T2	T3	KO
Humidity (%)	6.80 ± 0.09^{bc}	6.69 ± 0.11^{c}	6.98 ± 0.10^{b}	8.72 ± 0.10^{a}
Protein (Nx6.25) %	6.81 ± 0.04^{c}	8.17 ± 0.12^{b}	6.45 ± 0.10^{d}	13.13 ± 0.15^{a}
Fat (%)	2.64 ± 0.05^{c}	3.40 ± 0.20^{b}	2.95 ± 0.16^{bc}	8.21 ± 0.23^{a}
Carbohydrates (%)	82.00 ± 0.12^{a}	79.95 ± 0.20^{b}	81.88 ± 0.07^{a}	68.48 ± 0.55^{c}
Crude Fiber (%)	1.36 ± 0.06^{bc}	1.68 ± 0.07^{a}	1.51 ± 0.09^{ab}	1.28 ± 0.04^{c}
Ash (%)	1.76 ± 0.04^{a}	1.79 ± 0.06^{a}	1.74 ± 0.06^{a}	1.46 ± 0.08^{b}
NFEa (%)	80.64 ± 0.63^{a}	78.27 ± 1.02^{b}	80.38 ± 0.40^{a}	67.22 ± 1.01^{c}
Energy (Kcal/100 g)	378.94 ± 0.43^{c}	383.12 ± 0.66^{b}	379.87 ± 1.90^{b}	400.33 ± 0.43^{a}

a Nitrogen-free extract

Table 4: Analysis of ascorbic acid, total phenolic compounds and antioxidant capacity

Sample	AA (mg/100g)	TPC (mg GAE/100g)	AC (%)
T1	18.32 ± 0.37^{b}	233.86 ± 2.32^{a}	71.57 ± 1.22^{b}
T2	7.8 ± 0.71^{c}	107.35 ± 1.45^{c}	59.26 ± 0.73^{c}
T3	48.61 ± 2.29^{a}	160.36 ± 3.34^{b}	82.45 ± 2.81^{a}
KO	2.12 ± 0.21^{d}	8.95 ± 0.91^{c}	30.31 ± 0.42^{c}

The superscripts $^{a, b, c}$ and ^{d} indicate a significant difference (p value <0.05) among the samples according to the analysis developed. AA: ascorbic acid. TPC: total phenolic compounds. AC: Antioxidant capacity. GAE: Gallic acid equivalents

All the formulations of the processed infant food exceeded the AA values compared to the commercial food. T3 showed higher values than all the other feeds evaluated; due to the fact that T3 contains a higher proportion of mango flour (30%), which would explain the results, see Table 3.

Analysis of AA, TPC, antioxidant capacity (AC)

The AA content in T1 was higher than in T2 and KO, which indicates that the AA content in the different mixtures was contributed by the fruit flours, mainly mango flour.

The TPC values observed in the prepared formulations were higher than KO. The T1 is the best treatment, whose TPC content was 233.86 mg GAE/100 g.

The AC values observed in the prepared formulations were higher than KO. All the samples studied were statistically different. T3 obtained values of 82% and showed the highest antioxidant capacity, see Table 4.

Water absorption index (WAI), Milk absorption index (MAI), Oil absorption index (OAI) and Viscosity

The water retention capacity of the prepared formulations ranges from 2.07 to 2.19 g water/g of flour, which were lower than KO value. No significant difference was observed among the different flour mixtures. The formulated mixtures had a particle size <212 µm; but KO had a much larger particle size. However, the low WAI values (<3 g water/g flour) of the formulated mixes allows the incorporation of more flours to help to process nutrient-rich products. This allows for greater feed consumption with less added water.

The OAI of the prepared and KO formulations was found in the range of 1.6 to 1.88 g oil/g flour. No significant difference was observed among the different samples evaluated ($p > 0.05$).

The values of the developed mixtures range from 1.11 to 1.35 g milk/g flour, and the values are slightly lower than those demonstrated by KO. Among T1, T2 and T3 there was no significant difference; in the same way for T2 and KO. Interestingly, a higher proportion of Kiwicha flour from 15 to 30% led to the increase in MAI, see Table 5.

Table 5: Functional properties: WAI, OAI, MAI and apparent viscosity

Sample	WAI (g water /g flour)	OAI (g oil /g flour)	MAI (g milk/ g of flour)	Viscosity (cps)	
				30 rpm	60 rpm
T1	2.07 ± 0.05^{b}	1.6 ± 022^{a}	1.15 ± 0.05^{b}	2600 ± 17.43^{a}	1690 ± 5.10^{a}
T2	2.19 ± 0.10^{b}	1.76 ± 0.12^{a}	1.35 ± 0.22^{ab}	$2022 .86 \pm 13^{b}$	1306.5 ± 1.91^{b}
T3	2.16 ± 0.12^{b}	1.64 ± 0.03^{a}	1.11 ± 0.07^{b}	1061.33 ± 2.31^{c}	719.25 ± 29.39^{c}
KO	3.00 ± 0.10^{a}	1.88 ± 0.06^{a}	1.61 ± 0.07^{a}	744 ± 0.00^{d}	487.64 ± 63.38^{d}

The superscripts a, b, c and d indicate a significant difference (p value <0.05) between the samples according to the analysis developed. MAI: Milk absorption index. OAI: Oil absorption index.

The viscosity values obtained at two rotation speeds 30 and 60 rpm. were statistically different ($p<0.05$) in all samples. The viscosities ranged between 7400 and 2400 cp and between 487.64 and 1690 cp, respectively. The maximum viscosity values were observed at T1, when the proportion of plantain flour increased from 15 to 30%.

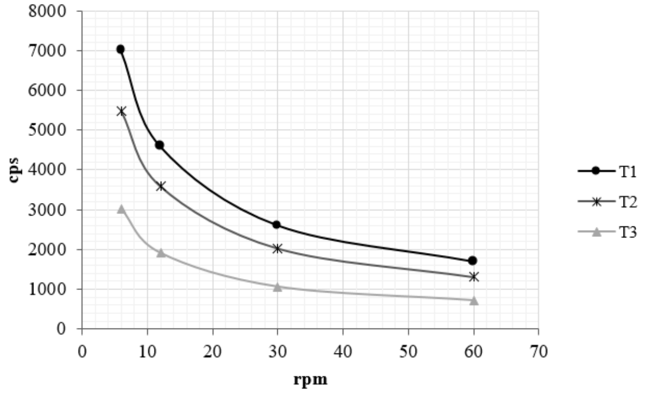

Fig. 2: Viscosity kinetics for different rotational speeds in infant food

Viscosity was evaluated at different rotation speeds (6, 12, 30 and 60 rpm) (Figure 2) and this behavior was also observed in Table 5, with T1 having the highest values. In addition, a significant amplitude is observed in the curve drawn by T2 with respect to T3. The curves in Figure 2 show a decrease in viscosity as the rotational speed of the viscometer increases. This inversely proportional relationship is characteristic of pseudoplastic fluids.

Table 6: Sensory evaluation by semi-trained judges

Attribute	T 1	T2	T3	KO	Friedman's test sig.
Flavor	3.67 ± 0.80^{a}	4.13 ± 0.68^{a}	3.47 ± 1.358^{b}	4.00 ± 0.78^{a}	0.000
Aroma	3.67 ± 0.54^{b}	4.03 ± 0.71^{a}	3.83 ± 1.08^{ab}	3.47 ± 0.97^{b}	0.000
Texture	3.33 ± 0.92^{a}	3.40 ± 0.81^{a}	3.13 ± 1.00^{a}	3.93 ± 0.82^{a}	0.183
General appearance	3.80 ± 0.61^{a}	3.83 ± 0.64^{a}	3.57 ± 1.07^{a}	3.83 ± 1.05^{a}	0.448

Different superscripts (a and b) within rows in the overall analysis indicate statistical difference ($p<0.05$), results obtained from the Wilcoxon test.

Sensory Analysis

The affective sensory method was carried out to measure the preference of the three formulations in addition to a control sample of a product on the market. The test was applied to 30 semi-trained judges from the Faculty of Food Industries and Biotechnology Engineering of the Universidad Nacional de Frontera, as shown in the Table 6.

The Friedman test was applied to establish the significant difference between the treatments studied, according to the sensory characteristics evaluated. With respect to flavor, it was observed that treatments T1, T2 and KO did not present a significant statistical difference according to the Wilcoxon test. T2 was the treatment with the highest preference in aroma. Regarding texture and general appearance, no statistical difference was observed between the treatments studied and the control.

It was observed that treatments T2 and T1 were the best rated. T2 presented a higher percentage of Kiwicha flour in its composition, which obtained a higher preference in flavor and aroma. Regarding texture, KO obtained greater preference over the other treatments, and in general appearance the treatments, T1, T2 and KO were statistically similar.

After comparing the result of the sensory evaluation of attributes in adults, proximal chemical analysis and analysis of bioactive compounds, it was determined that T1 was the best treatment to carry out the sensory evaluation in children, considering the bioactive potential for its choice, as well as the proximal chemical profile.

The result showed that 82.86% of the children liked T1, while only 11.43% neither liked nor disliked and 5.71% disliked it (Figure 3).

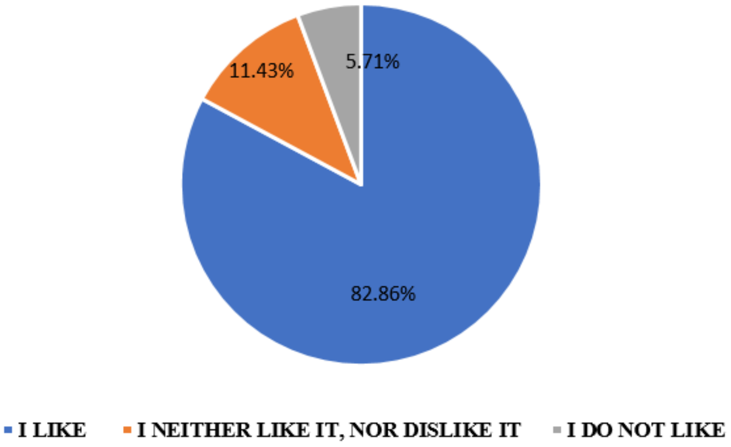

Fig.3: Sensory evaluation of preference by preschool children

Discussion

There are few studies in the scientific literature on instant mixtures based on autochthonous Peruvian cereals. The purpose of this research was to determine the bioactive and nutritional potential and sensory acceptance level of an infant food made from Andean pseudocereals and tropical fruits from the Piura region of Peru.

In terms of soluble solids, T3 has more sugars compared to KO; this may be related to the proportion of mango flour added. Kent mango contains about 15ºBrix composed of fructose, sucrose and glucose.[26] Regarding pH values, the range obtained was between 5.2% and 6.2%, similar to the report of Casas *et al.*[46] When comparing the treatments with KO, all treatments presented lower pH values, which is related to the presence of fruit flours. Consequently, all formulations presented higher acidity values than KO. In T3, the highest acidity value was observed, due to the presence of a higher proportion of mango flour.

It was observed that there were no significant differences in moisture values among the 3 treatments, ranging between 6.69% and 6.98%, respectively. Humidity was within the ranges reported by previous studies 24,47. According to NTP 205.064: 2015, flours must contain a maximum of 15% moisture.[48]

Regarding the protein analysis, the prepared formulations (T1, T2 and T3) presented proteins values that ranged between 6.45 to 8.17% compared to the control that presented 13%, which was mainly contributed by oatmeal. The protein values coincide with the report of Ayoub24. The fat content of the treatments is between 2.6 to 3.4%, while KO showed a higher value (8.21%). The results were higher than those reported in a previous study,[49] due to the fact that the fat content contributed by the Kiwicha amounts to 6.1% fat.[50] However, oats are the component with the highest fat content[51] and in the present study values of 8.21% fat were identified, which would explain the KO values.

The crude fiber value ranged from 1.36% to 1.68% in the prepared formulations compared to commercial feed values. These results are within the values reported by a research conducted on mango mesocarp flour.[29] The NFE values ranged from 67% to 80% and are different from a report that showed values between 20% and 25% for different flours.[52] However, the findings of Sengev *et al* l[29] are similar to the results of the present investigation.

Ascorbic acid is very important in the human diet, because its deficiency generates various health problems, such as anemia. Iron deficiency anemia is often caused by a deficiency in iron absorption; However, consuming foods rich in AA improves the fixation of this mineral in the body.[10]

Mango flour can contain from 29.81 to 290.22 mg ascorbic acid/100g of flour; higher value than banana flour,[53,54] which provides the AA value observed at T3. The AA values found in this research were higher than those obtained by Chikpah,[55] on wheat, orange and sweet potato meal mixture (5.90-35.72 mg AA/100g). And those observed by Keyata56 on supplementary weaning meal based on sorghum, soybean and karkade seeds which reported AA contents in the range of 11.0 to 23.9 mg/100g.

On the other hand, considering the recommended daily intake of AA (15mg/day) for children aged one to three years old,[56] the result of this study and those from previous research point out that the formulations T1 and T3 fall within this criterion, demonstrating the bioactive potential of the formulations developed.

The food mixtures developed in this study have demonstrated AA values above products such as puree.[57] Fruit puree is one of the most attractive foods to complement children's diet. However, the thermal treatment to which the product is subjected produces the degradation of 50 to 70% of AA.[57] Furthermore, periods of 2 months of product storage reduce 50% of AA and storage of 4 months reaches the total degradation of AA.[58] The high-water content of this type of products, added to factors such as exposure to light and the oxygen available in the head space of the container, promote the degradation reactions of AA.[59] Therefore, composite flours can be an effective complementary food for infant feeding as they contain a low water content <10%, which reduces AA degradation reactions compared to products such as puree.

Regarding the observed TPC values of the present study, it is consistent with that reported by Singh *et al,*[60] who argue that banana pulp has a high phenolic compound profile. KO (commercial feed) has a content of 8.956 mg GAE/100 g, which is lower than that of the three prepared formulations.

In addition, one study reported that 3% mango pulp was fed to rats, which is equivalent to human consumption, evidencing that mango consumption provided protection against oxidative stress.[61] Shah *et al*[62] and Mauricio-Sandoval *et al*[12] confirm that mango has strong antioxidant activity due to the presence of flavonoids that confer antioxidant potential, even better than AA and tocopherol. Considering these previous findings, it is explained that the incorporation of mango pulp flour makes the treatment has better inhibitory activity compared to the other treatments that did not differ much in their results T1 with 71%, T2 with 59% and KO with 30%. However, KO showed that its content of bioactive compounds is lower than the formulations elaborated with pseudocereals and fruits.

The WAI represents the ability of a substance to associate with water under water-limited conditions. The WAI measurement is useful to indicate whether flours can be associated with aqueous formulations.[63] The WAI values were found within the ranges described by various studies.[56,64,65] It has been reported that WAI is influenced by particle size, the larger the particle size of <212 to 700 µm WAI increases from 2.92 to 4.60 g water/g flour,[42] this would explain the values observed in KO.

Regarding the OAI, the results are in agreement with the values observed by Vicente[66]; these authors related the increase in OAI with a reduction in molecular interactions between starch molecules, and between starch and lipids, as well as with the increase in the hydrophilic nature of the molecules. Mainly, quinoa and kiwicha flours have various groups of fatty acids that contribute to an oil absorption capacity.[64] The fat and protein content of flours has been strongly correlated with OAI.[67] Nevertheless, oil retention capacity also depends on the hydrophobic groups of the material and the ability of the material to form a structural network that traps oil molecules.[68] The amylose presented in green banana flour is characterized by having a loose and hydrophobic structure, contributing to improving the oil retention capacity.[69] A high OAI value allows flours to have functional applications, in the development of pastries and sausages products.[70]

Regarding the milk absorption capacity, the amylose content available in flours plays an important role in the formation of complexes with milk proteins; the higher the presence of amylose and amylopectin, the higher the milk retention.[71] In addition, higher moisture content (>10%) leads to higher MAI. However, a greater amount of water available reduces the shelf life of this type of food.[72] Flour sugars and added sucrose also contribute to the MAI increase. High MAI values are important in infant foods because the population desire for practical foods, ready for consumption with instant or semi-instant preparation.[73]

Likewise, banana flour has a significant content of polysaccharides, which favors the association of starch molecules, causing an increase in viscosity.[74] However, this capacity is reduced as the mango flour increases, this could explain the difference in the chemical compositions of the flours used. Viscosity is among the important parameters of rheological attributes,[74] it reflects the ability of flour to transform into a sticky paste after cooking and cooling and is frequently used to describe the quality of starch-based flour.[75] In general, the results are within the range reported by Sodipo & Fashakin[65] and Chikpah.[55] A low viscosity of flour or a mixture of flours is ideal for making cookies.[55] Nevertheless, the viscosity of the flour mixtures in this study is ideal for the production of infant food, which can usually be consumed to complement breakfast. The role of fruit flours in the formulation of this type of food is linked not only to indigestible carbohydrates, but also to antioxidant compounds that can affect certain functionality of the food and improve nutraceutical characteristics in a variety of foods.[76] Previous research reported that thicknesses <4 mm retain a higher antioxidant capacity in banana flour, so in an instant mix banana flour performs favorably.[23]

The result of the sensory evaluation of this research differs from the report of Chlopicka *et al*[77] on the preparation of bread incorporating kiwicha flour, whose results were unfavorable.

We observed that yogurts have been developed with different recipes, in which more than 90% of young children had a positive or very positive reaction to all recipes, in addition to a high estimated intake (>68% of young children consumed the yogurt sachets in their entirety)[78] The findings suggest that a reduction in the amount of processed ingredients may be a realistic approach that does not jeopardize the acceptance of these products in the market. Also, Chanadang and Chambers[79] argue that children may increase their liking for some food products after repeated exposure and may increase their liking for some food products more than others over a prolonged period.

Conclusion

This study is important because of the opportunity to valorize surplus mango and banana fruits by incorporating them in the elaboration of a functional food sensorially acceptable to the infant population, whose consumption can be channeled by the different government programs. It was demonstrated that these fruits in combination with some foods such as quinoa, kiwicha, a milk base and cocoa, conserved their functional properties (high AA content, total phenolic compounds and high antioxidant capacity) with respect to a commercial food based on oats and quinoa (control). These results showed that there are no relevant differences between them from the physicochemical point of view. The analysis of TPC and antioxidant activity showed that treatment T1 has the highest content of total phenolic compounds and a high antioxidant activity compared to the other treatments. Likewise, mango flour contributes to improve AA content, while banana flour contributes to water and oil absorption capacity and viscosity. Finally, the addition of quinoa and kiwicha flour improves milk absorption capacity. In general, the characteristics of the prepared mixes allow incorporating more food and less water to result in an acceptable viscosity. The sensory analysis of acceptability carried out on adults and children showed an acceptance of this processed food (TI).

Quinoa and kiwicha are foods with a high content of amino acids such as lysine and arginine, which are useful for brain development in the infant stage, whose behavior in mixtures with fruits could be studied.

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Conflict of Interest

The authors declare that the research was conducted in the absence of commercial or financial relationships that could be construed as a potential conflict of interest. Furthermore, they declare that Dr. Luis Espinoza's participation in the research began and ended when he was affiliated with the Universidad Nacional de Frontera, Sullana and his contribution to the preparation of the manuscript continued during his recent incorporation to the Universidad Nacional de Barranca, Lima, and represents his current affiliation. The authors declare this information to avoid any conflict of interest.

Authors' Contribution

LE-E: Conceptualization, investigation, fundraising, methodology, supervision and review, TA-D: Research and preparation of original draft, LR-F: Research, writing, data curation and formal analysis. LM-Q: Data curation, fundraising, review, research and visualization. MA-P, JV-M: Supervision, review and visualization. DP-L and HC-Q: methodology, review. All authors contributed to the article and approved the submitted version.

Data Availability Statement

The manuscript includes all data produced during the course of this research, for further information please contact the corresponding author.

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