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Article

Physicochemical composition and amino acid profile of the beverage of Ungurahua (*Oenocarpus bataua*) from the Amazonian Region of Ecuador.

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ABSTRACT

Oenocarpus bataua, also known as Ungurahua, is a palm species indigenous to Ecuador's Amazon region. The fruit is used for oil extraction and beverage production. This research aimed to evaluate a beverage made from *O. bataua* by characterizing its physicochemical properties, amino acid profile, formulation, and sensory and microbiological properties. The study employed quantitative, exploratory, and experimental methodologies utilizing a bifactorial design (3 × 2). This research investigated the effect of cooking and the type of sweetener on the quality of sweetened products. Six treatments were applied, and sensory analysis was performed to determine the optimal treatment. The most effective treatment was a2b2 (cooked for 30 min at 65 ±3°C and sweetened with panela). Upon further analysis, this treatment had a moisture content of 94.7%, ash content of 0.85%, protein content of 0.59%, ethereal extract EE of 2.18%, fiber content of 0.80%, non-nitrogenous extract-ENN of 0.85%, pH of 4.37, Brix of 1.80°, and titratable acidity of 1.92%. A comparison of *O. bataua* beverages with similar beverages indicated their acceptable nutritional value. Amino acid profile analysis showed the presence of 10 amino acids, of which 8 were essential and 10 were non-essential. Histidine had the highest concentration in the beverage, with an average of 77%. To ensure the safety and quality of the beverage, a microbiological analysis was performed in compliance with NTE-INEN 3028 standards. No mesophilic aerobes, *Salmonella* spp., or total coliforms were detected. Therefore, the proposed beverage is safe and nutritionally valuable because of its high amino acid content, balanced physicochemical composition, and sufficient microbiological composition.

Keywords: Amino acid profile; chemical composition; microbiological analysis; sensory analysis; Ungurahua (*Oenocarpus bataua*).

INTRODUCTION

The Ecuadorian Amazon region has a great diversity of fruit species that indigenous communities use [1]. Their common uses are food, medicine, construction, ceremonies, hunting, and handicrafts[2–5]. *Oenocarpus bataua* is one of the most notable native palm species in the Ecuadorian Amazon [6]. In the local communities, this palm is known by different names: "ungurahua" in Kichwa, "huicocosa" in Secoya, and "pektuwe," "petomo," and "petohue" in Waorani[7]. The palm tree is fully utilized. The fruits are used for food and oil extraction, while the heart of the palm is utilized as a food source. The branches and leaves are used to build huts, and the trunk is a host for *Rhynchophorus palmarum*, which is used as a food source in its caterpillar stage[8]. *O. bataua* belongs to the Arecaceae family and is commonly called palm.

The plant has a single, straight, cylindrical trunk that can grow up to a height of 25-30 m, in height and has a diameter of up to 30 cm. The tree has large pinnate leaves that form a crown on the upper part of the palm trunk, consisting of elongated and pointed leaflets of intense green color. The flowers are small, white, or yellowish with a symmetrical radial structure. These are grouped in clusters between the upper leaves. *O. bataua* produces large oval berries that can grow up to 7 cm long. The berries have a thick, rough shell that turns dark brown or black when ripe. They contain a fleshy, oily yellow or orange pulp. The seeds are oval and have a hard coating. These are found inside the pulp of the fruits.[7,9,10].The tradition of making beverages from *O. bataua* and various fruits of native Amazonian species is an ancestral gastronomic practice rooted in the customs and traditions of the people of the Amazon region. The techniques for these beverages are transmitted from generation to generation. These beverages' use and high nutritional value have long been recognized, but studies on their chemical composition and amino acid profile are limited[11].

MATERIAL AND METHODS

The research lasted approximately 12 months in the laboratories of Escuela Superior Politécnica de Chimborazo (ESOCH), specifically in the Laboratory of Bromatology and Animal Nutrition of the Faculty of Animal Sciences and the Laboratory of Bromatology of the Faculty of Public Health. The laboratories are in Riobamba City, Chimborazo Province, Ecuador. The fruits were collected in the Bobonaza hamlet, canton of Pastaza, province of Pastaza, Ecuador, ripe and free of pathogens.

Formulation of the beverage

The formulation was based on the experiences of several mestizo and kichwa people in the province of Pastaza. The research was developed using a 3*2 bifactorial design. Factor A focused on cooking time and was divided into three levels: a1) Uncooked, a2) Intermediate cooking (30 min at 65 ±3°C), and a3) Complete cooking (60 min at 100 ±3°C). Factor B, linked to the type of sweetener used, was divided into two levels: b1) white sugar and b2) panela. These sweeteners were evaluated to determine their impact on the flavor and organoleptic characteristics of the final beverage.

The combinations of various factors and their respective levels are listed in Table 1. The experiment used 500 ml of water, 200 g *O. bataua* pulp, and 15 g of sweetener.
The process of producing each beverage began with the acquisition of fruit. The selected fruits were then thoroughly washed with drinking water. The fruits were boiled in water. However, this step was omitted for

treatments T1 and T2. After cooking, the pulp was manually separated from the seeds, gradually crushed with water until the mixture was homogeneous, and then filtered to separate solids. Sweetener was added and mixed until it was completely dissolved. Finally, the beverage was packaged in pre-sterilized plastic bottles and sealed for preservation. Figure 1 illustrates the process.

Organoleptic characterization

After preparing the beverages for the proposed treatments, we started a sensory evaluation to identify the best treatment. This evaluation was carried out with 20 people who regularly consumed this beverage, and the Method used to evaluate the sensory acceptability of the beverage was based on a hedonic scale ranging from 1 to 5[12]. The Participants were assigned a score according to their personal preference, where 1) meant extreme dislike, 2) indicated that they did not like it, 3) reflected neutrality, 4) indicated liking, and 5) expressed a robust taste. The variables evaluated were color, acidity, consistency, fragrance, and flavor. The evaluation of the sensory properties of the beverage identified the most suitable treatment in terms of color, acidity, consistency, aroma, and flavor. The top-ranked treatment was characterized physicochemical and microbiologically. It was also tested to evaluate its amino acid profile, determine nutritional composition, and ensure its safety.

Physicochemical characterization

Physicochemical analysis of the beverage was based on evaluating several vital parameters, and the oven-dry Method determined the sample's moisture content at 105°C[13]. The quantification of ash was by high-temperature combustion of the sample[14]. The solvent extraction method was used to extract the fat[15]. The fiber was evaluated using the acid-alkali digestion method to decompose fiber components present in the sample[16]. The protein content was determined using the Kjeldahl method[17]. pH was measured using a pH electrode in an aqueous beverage solution. The total soluble solid content was evaluated by measuring the Brix degree, using a refractometer to determine the contents of sugars and other soluble compounds[18]. Titratable acidity was determined by acid-base titration, using an alkaline solution to neutralize the acids present in the beverage[19].

Amino acid profile

The EZ:faast™ GC kit was used to detect and measure the quantity of amino acids in the *O. bataua* beverage. The chromatographic conditions were adapted from the recommendations provided in the kit. The analysis was performed using only analytical grade reagents to ensure optimal precision and purity of the results obtained[20].

Microbiological characterization

The Method used to identify mesophilic aerobes and Salmonella was the plate count (PCA) method described in the Ecuadorian Technical Standards INEN 4832[21] and INEN 4833[22], respectively. The Method for identifying and quantifying the presence of coliforms in the beverage *O. bataua* was the Most Probable Number (MPN), NTE INEN 6579[23]. Table 2 lists the technical standards used to determine the methods of the different physicochemical tests, amino acid profile analysis, and microbiological evaluations performed on the beverage that was selected as the best treatment.

Statistical analysis

The statistical analysis involved a meticulous review of the collected data, including sensory evaluation and measurement of the physicochemical properties of the six treatments derived from the experimental design. The information was then organized and structured in tables and graphs using Excel according to the predefined research variables. Finally, the data were analyzed using the Minitab 19 software to interpret the results. The data were replicated three times to ensure a 95% confidence level.

RESULTS

Design treatments

In Table 1, the treatment used to prepare the beverage is described. The design comprises two factors: A (cooking mode) and B (sweetener use). A specific cooking time is used for factor A, with the control being uncooked. Factor B involves the use of sweeteners (panela and white sugar).

N° Treatment	Factor combination	Factor A (Cooking)	Factor B (Sweetener type)
T1	a1b1	Uncooked (a1)	White sugar (b1)
T2	a1b2	Uncooked (a1)	Panela (b2)
T3	a2b1	Intermediate cooking (30 min, 65 ±3°C) (a2)	White sugar (b1)
T4	a2b2	Intermediate cooking (30 min, 65 ±3°C) (a2)	Panela (b2)
T5	a3b1	Complete cooking (60 min, 100 ±3°C) (a3)	White sugar (b1)
T6	a3b2	Complete cooking (60 min, 100 ±3°C) (a3)	Panela (b2)

Table 1. Experimental treatment design for crafting a beverage from *O. bataua* fruits.

Flowchart for the Preparation of the Beverage

Figure 1 shows the steps followed in all treatments to prepare the *O. bataua* beverage. The flowchart illustrates the sequential process, from ingredient selection to quality control, ensuring consistency and safety in the preparation of the beverage.

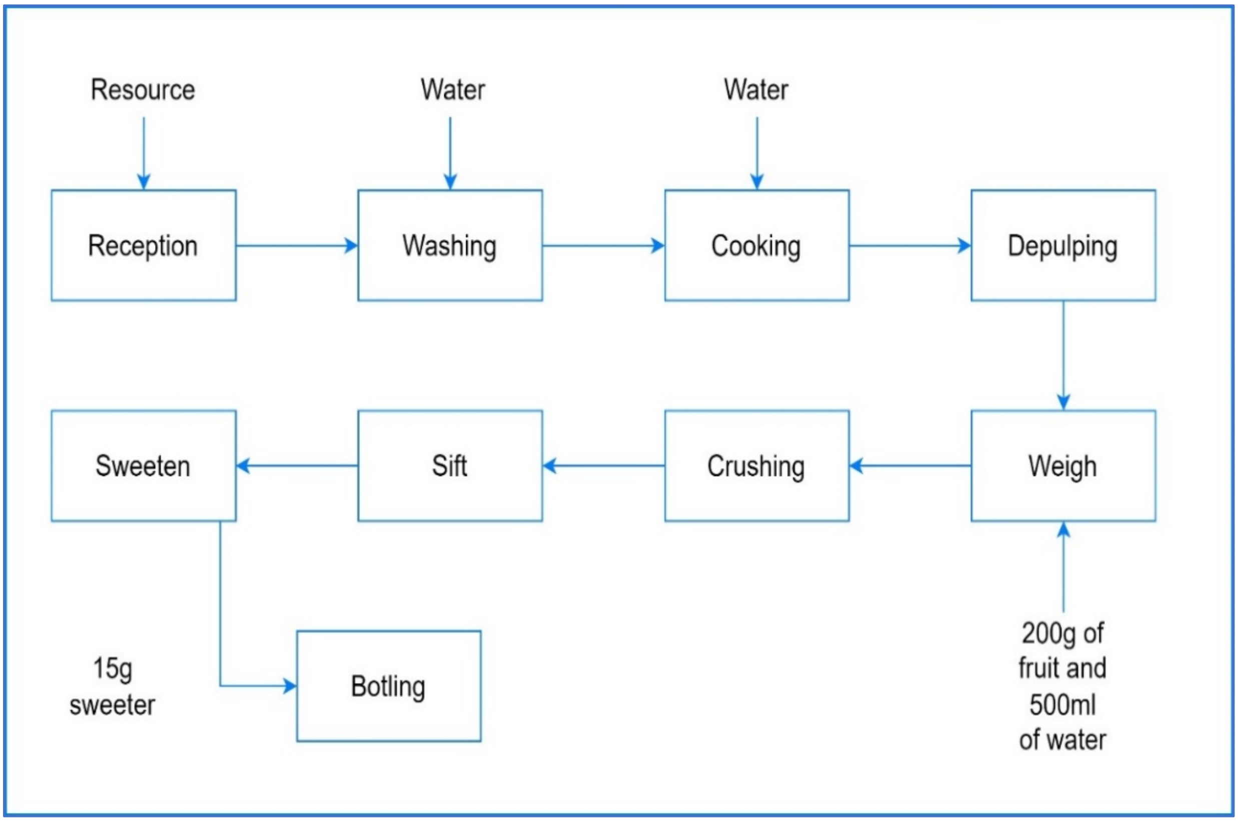

Figure 1. The beverage production process of *O. Batua* fruits.

Norms and Evaluation Methods

Table 2 describes the research aim and the different analyses to be performed on each indicator, using methodologies adapted to national and international standards.

Variable type	Category	Indicator	Units	Method
Independent variable	Craft Beverage Formulation	Water	ml	Combination testing
		O. bataua pulp fruit	g	
		Sweetener	g	
Dependent variable	Organoleptic characterization	Scent	1-5	Sensory evaluation (5-level hedonic scale)[12]
		Taste		
		Color		
		Consistency		
		Acidity		
	Physicochemical characterization	Humidity	%	AOAC-930.15, 2000[24]
		Ash	%	NTE-INEN-401: 2013[25]
		Grease	%	NTE-INEN 2814[26]
		Fiber	%	NTE-INEN-ISO 3720[27]
		Protein	%	NTE-INEN-ISO 20483[28]
		Amino acid profile	g/100g	EZ-Faast amino acid analysis[20]
		pH	0-14	AOAC 942.15, 2016[29]
		Brix degrees	%	NTE-INEN-ISO 2172[30]
		Titratable acidity	%	NTE-INEN-ISO 750[31]

	Microbiological characterization	Mesophilic aerobes	CFU/g	NTE-INEN-4832[21]
		Total coliforms	NMP/ml	NTE-NE-6579[23]
		Salmonella	CFU/ml	NTE-INEN-4833[22]

Table 2. Operationalization of variables.

Organoleptic characterization

ANOVA results for the variables color, acidity, consistency, fragrance, and flavor showed that the T1 treatment had high acidity, unattractive color and unfavorable fragrance. This was similar to treatment T2, which differed mainly in its darker color. In contrast, the treatments T3 and T4 showed better acceptance due to their lower acidity, pleasant scent, and light and brown color; these treatments showed significant statistical differences with $p < 0.05\%$ and 95% confidence level (Figure 2). This means that the variables evaluated (cooking and sweetener) directly impacted the evaluation of the sensory characteristics of the drink. Finally, treatment 4 was the best, as the evaluators considered it to have a better taste, scent, and consistency, with a statistically significant difference from the other treatments.

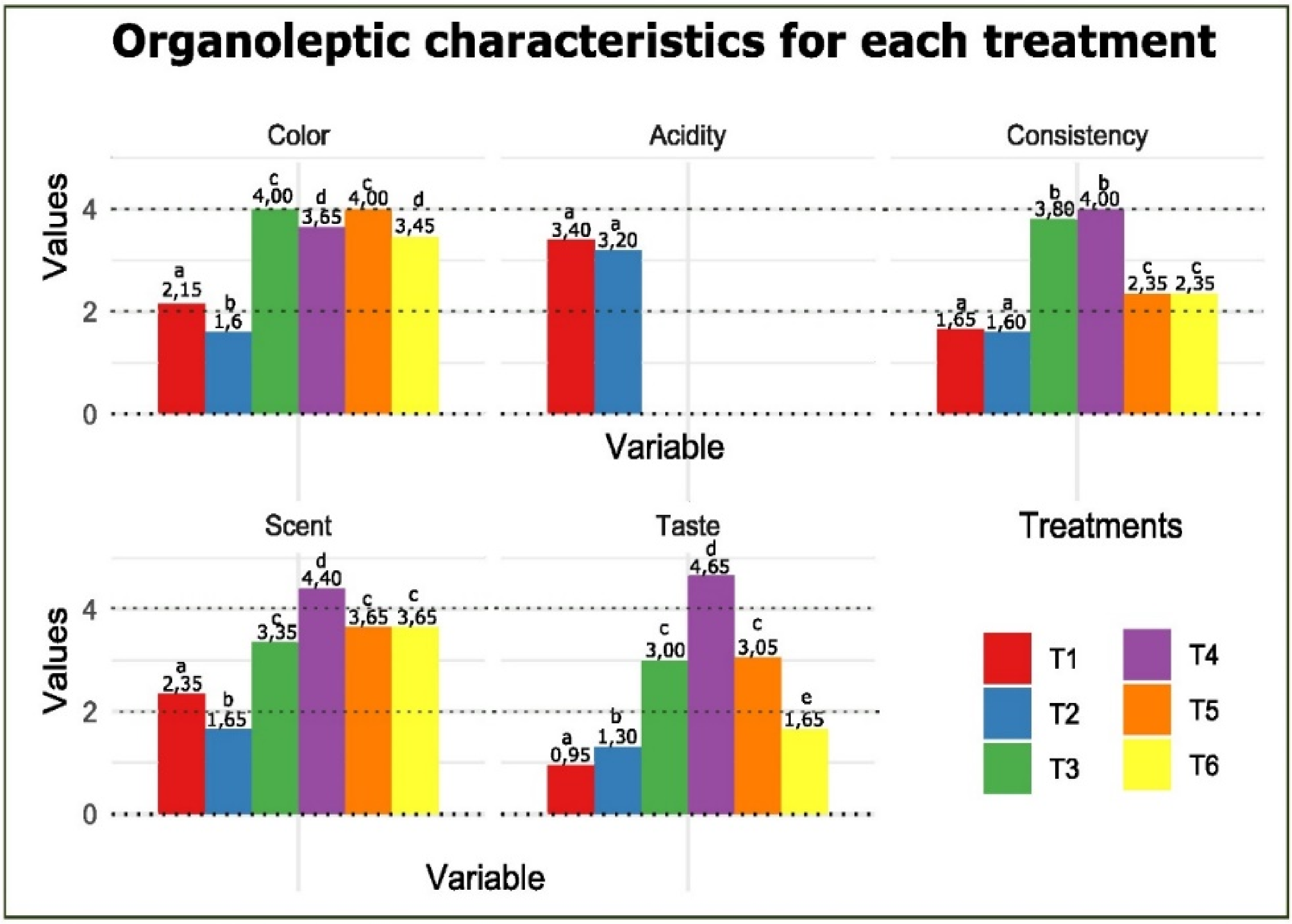

Figure 2. Organoleptic characteristics for each treatment: T1: No cooking and white sugar, T2: No cooking and panela, T3: Intermediate cooking and white sugar, T4: Intermediate cooking and panela, T5: Complete cooking and white sugar, T6: Complete cooking and panela.

Physicochemical analysis

The physicochemical analyses were carried out using the Method presented in Figure 3. Moisture, ash, protein, ethereal extract (EE), fiber, non-nitrogenous extract (ENN), pH, Brix, and titratable acidity were determined with three replicates (R1, R2, R3) under treatment 4.

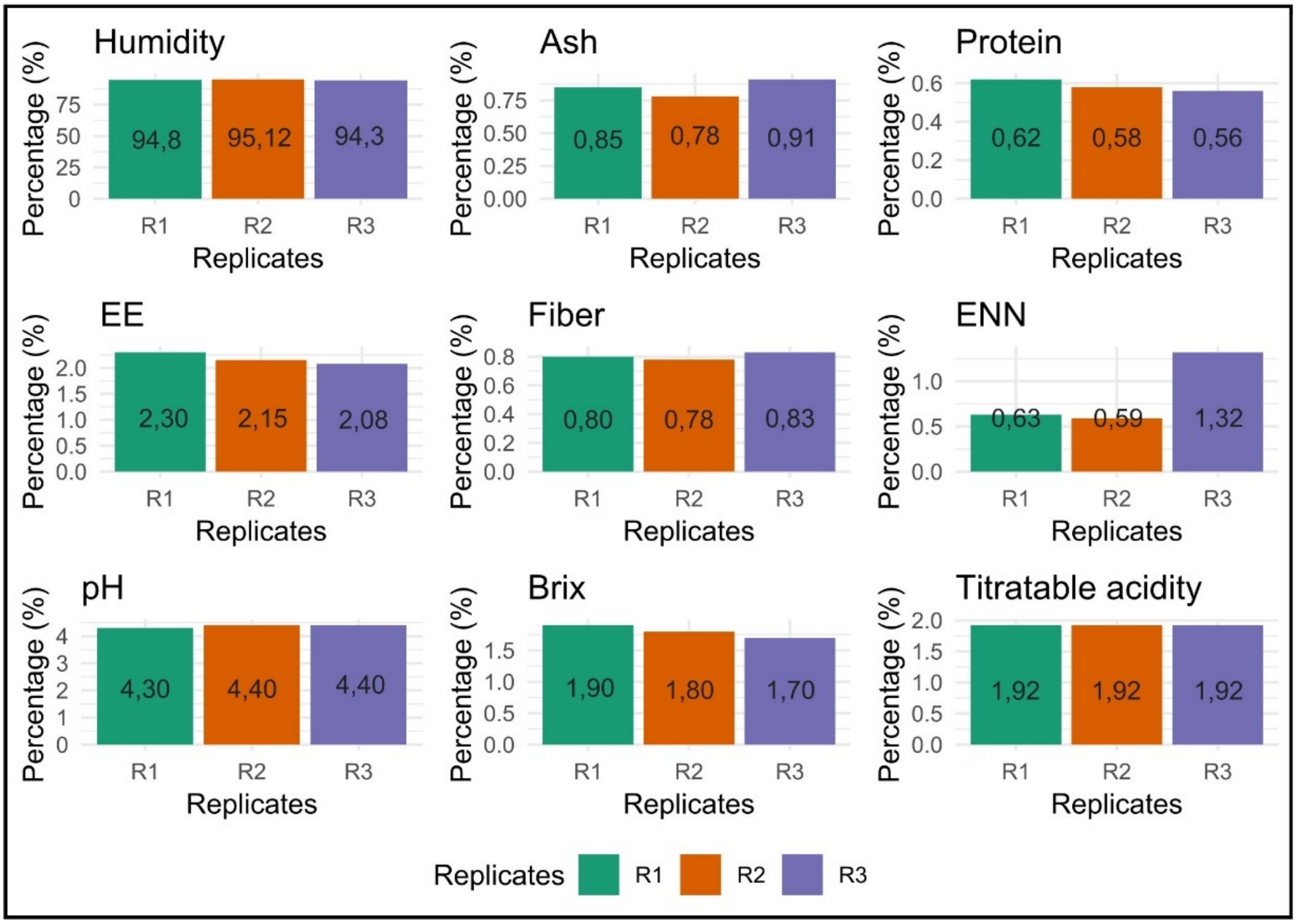

Figure 3. Bromatological composition for treatment 4.

Amino acid analysis

The gas chromatography analysis identified 18 amino acids in samples from treatment 4 of the *O. bataua* beverage. The body cannot synthesize essential amino acids and must obtain them from the diet. The 8 essential amino acids in *O. bataua* beverage confirm its nutritional value. It can be classified as a potential protein source.

Amino Acid	R1 (%)	R2 (%)	R3 (%)	Medium (%)
Alanine (ALA)	1.76	1.14	0.74	1.21
Glycine (GLY)	2.35	2.58	2.94	2.62
Beta-Alanine (ABA)	1.42	0	0.39	0.60
Valine (VAL)*	2.18	1.3	2.3	1.93
Beta-aminoisobutyric acid (BAIB)	0.09	0.25	0.19	0.18
Leucine (LEU)*	2.04	1.44	2.29	1.92
Isoleucine (ILE)*	2.48	1.59	1.33	1.80

Threonine (THR)*	2.73	2.33	2.71	2.59
Serine (SER)	0.33	0.4	0.3	0.34
Asparagine (ASN)	< 0.001	< 0.001	< 0.001	< 0.001
Aspartic Acid (ASP)	2.67	1.76	1.37	1.93
Methionine (MET)*	1.53	0.91	0.8	1.08
Glutamic Acid (GLU)	0	1.64	1.48	1.04
Phenylalanine (PHE)*	2.03	1.32	1.22	1.52
Ornithine (ORN)	0.99	0.31	0.43	0.58
Lysine (LYS)*	0.26	0.39	0.32	0.32
Histidine (HIS)*	73.66	80.48	79.2	77.78
Tyrosine (TYR)	0.32	0.05	0.27	0.21

Table 5. Summary of amino acids present in treatment 4 (* essential amino acids).

Alanine (ALA) (2-aminopropanoic acid) is a non-essential amino acid. Glycine (GLY) (2-aminoethanoic acid) is a nonessential amino acid. Beta-Alanine (ABA) (3-aminopropanoic acid) is a nonessential amino acid. Valine (VAL) (2-amino-3-methylbutanoic acid) is an essential amino acid. Beta-aminoisobutyric acid (BAIB) (3-amino-2-methylpropanoic acid) is a non-essential amino acid. Leucine (LEU) (2-amino-4-methylpentanoic acid) is an essential amino acid. Isoleucine (ILE) (2-amino-3-methylpentanoic acid) is an essential amino acid. Threonine (THR) (2-amino-3-hydroxybutanoic acid) is an essential amino acid. Serine (SER) (2-amino-3-hydroxypropanoic acid) is a non-essential amino acid. Asparagine (ASN) (2-amino-3-carbamoylpropanoic acid) is a nonessential amino acid. Aspartic acid (ASP) (2-aminobutanedioic acid) is a nonessential amino acid. Methionine (MET) (2-amino-4-(methylthio)butanoic acid) is an essential amino acid. Glutamic acid (GLU) (2-aminopentanedioic acid) is a nonessential amino acid. Phenylalanine (PHE) (2-amino-3-phenylpropanoic acid) is an essential amino acid. Ornithine (ORN) (2,5-diaminopentanoic acid) is a non-essential amino acid. Lysine (LYS) (2,6-diaminohexanoic acid) is an essential amino acid. Histidine (HIS) (2-amino-3-(1H-imidazol-5-yl) propanoic acid) is an essential amino acid. Tyrosine (TYR) (2-amino-3-(4-hydroxyphenyl)propanoic acid) is a non-essential amino acid..

Microbiological analysis

The *O. bataua* beverage (T4) analysis showed a total coliform concentration below 10 CFU/ml. Without specific regulations for this beverage, the regulation for non-fermented soy beverages was used as a reference, where a level of less than 10 CFU/ml was considered acceptable. The results obtained comply with the requirements of the Ecuadorian Technical Standard INEN-3028. In addition, the beverage was tested for the presence of *Salmonella* spp. since *O. bataua* fruit grows outdoors and may be in contact with *Salmonella* spp. carrying birds.

The result was favorable since the absence of this parameter was evidenced, guaranteeing the safety of the beverage. It was found that 200 CFU/ml in the sample was outside the range established by NTE-INEN 3028, which establishes a minimum limit of 1,000 and a maximum of 20,000 CFU/ml.

Parameters	Results	Units
Total coliforms	< 10	CFU/ml
***Salmonella* spp.**	Absent	Detection /25ml
Mesophilic aerobes	2.0x102	CFU/ml

Table 6. Summary of microbiological analysis.

DISCUSSION

Physicochemical analysis

The physicochemical analysis presents the percentages of different nutritional components and physical properties of the *O. bataua* beverage in three replicates (R1, R2, R3). The moisture values are consistent among the replicates: 94.8% (R1), 95.12% (R2), and 94.3% (R3), indicating high water retention, which is typical for fruit-based beverages due to their water content [33,34]. In comparison, Souza RS et al. (2012) reported a moisture content of 83.54% in mechanically obtained pulp and 38.06% in manually obtained pulp of *O. bataua*, highlighting the beverage's higher water content than the dry fruit pulp [33]. The ash content varies between 0.85% and 0.91%, reflecting the presence of essential minerals and contributing to its nutritional value. Souza RS et al. in 2012 found similar ash contents, with values around 1.84% on a dry matter basis, supporting the mineral content observed in this research[33].

The protein content is low, ranging from 0.56% to 0.62%, typical of fruit beverages that are not primary protein sources. Méndez-Durazno et al. in 2023 reported similar low protein levels, with values ranging from 0.50% to 1.28% [34]. Ether extract (EE) values are moderate, ranging from 2.08% to 2.30%, indicating the presence of natural fats from the fruits. Souza RS et al. in 2012 reported higher lipid content in the dry pulp, ranging from 58.88% to 70.21% on a dry matter basis, suggesting that while the beverage retains a moderate amount of these fats, the concentration is lower than in the dried fruit pulp [33]. Dietary fiber remains consistent between replicates (0.78%-0.83%), which is crucial for digestive health. Souza RS et al. in 2012 observed higher fiber content in the dried pulp, with values ranging from 3.87% to 7.05% on a dry matter basis, indicating a reduction in fiber content when the fruit is processed into a beverage [33].

Free nitrogen extract (ENN) values show variability (0.59%-1.32%), suggesting differences in non-protein soluble components such as sugars and starches[32-34]. Souza RS et al. (2012) reported that the carbohydrate content in fresh pulp ranges from 3.48% to 5.00%, supporting the observed variability[33]. The pH remains between 4.30 and 4.40, suitable for microbiological stability and beverage flavor. This agrees with Méndez-Durazno et al. in 2023, who reported similar pH values[34]. Brix values (1.70-1.90) indicate low sweetness, which is favorable for low-calorie options. Méndez-Durazno et al. 2023 found Brix values in the range of 1.60 to 2.00, supporting the low sweetness profile observed[34]. Titratable acidity is consistent at 1.92%, ensuring product preservation and quality. Souza RS et al. reported in 2012 that titratable acidity values in *O. bataua* pulp ranged from 1.61% to 2.23%, confirming the stability and quality of the beverage[33].

Amino acid analysis

The present research contrasts with previous research on beverages made from native South American plants, as no existing studies exist on beverages made from *O. bataua*. Cerezal et al. in 2012 reported that their beverage made with carob(*Prosopis chilensis*), lupine(*Lupinus albus*) and quinoa(*Chenopodium quinua*), contains 11 essential amino acids: isoleucine (3.98%), leucine (6.06%), lysine (4.50%), methionine + cysteine (3.22%), phenylalanine + tyrosine (4.88%), threonine (3.38%), tryptophan (1.00%), valine (4.13%) and histidine (0.74)[35]. While Hernández E. et al. in 2019 reported in their study on the beverage made from Aguaymanto (*Physalis peruviana*) and enriched with Kiwicha (*Amaranthus caudatus*) reported eight essential amino acids with the following percentage values: threonine (0.45%), isoleucine (0.40%), lysine (0.74%), methionine (0.25%), leucine (0.67%), phenylalanine (0.49%), valine (0.54%), and tryptophan (0.13%)[36]. In contrast, the amino acid profile of the *O. bataua* beverage in this research identified eight essential amino acids: valine (1.93%), leucine (1.92%), isoleucine (1.80%), threonine (2.59%), methionine (1.08%), phenylalanine (1.52%), lysine (0.32%), and histidine (77.78%). The complete amino acid profile also includes alanine (1.21%), glycine (2.62%), beta-alanine (0.60%), beta-aminoisobutyric acid (0.18%), serine (0.34%), asparagine (<0.001%), aspartic acid (1.93%), glutamic acid (1.04%), ornithine (0.58%), and tyrosine (0.21%).

Amino acids play a crucial role in the functions of the human body[37]. Histidine was the amino acid with the highest concentration in the beverage, with an average of 77%. Histidine is an essential amino acid that has nutritional potential and unique properties. It is used as a nutritional supplement and has been considered to treat various conditions, ranging from rheumatic diseases to neurological disorders. In recent years, the effects of histidine on intense exercise and the aging process have been studied[38]. Additionally, histidine is crucial for individuals with chronic kidney disease (CKD), as it supports globin synthesis and erythropoiesis and improves iron absorption. Histidine's antioxidant capabilities also make it valuable in managing oxidative stress in CKD[39].

Microbiological analysis

The microbiological analysis of the *O. bataua* beverage (T4) demonstrated excellent safety and quality. The total coliforms were below 10 CFU/ml, which complied with the Ecuadorian Technical Standard INEN-3028 and indicated hygienic production practices. The absence *of Salmonella* spp. further ensured the beverage's safety, which was crucial given the outdoor cultivation of the fruit[43]. The research by Sharma C et al. in 2021 on traditional black carrot beverages similarly highlights the importance of maintaining low pathogen levels to ensure consumer safety[44]. Mesophilic aerobes were found at 200 CFU/ml, well within the acceptable range of 1,000 to 20,000 CFU/ml, affirming good microbiological quality and an extended shelf life[43,44]. Low mesophilic aerobe counts are consistent with findings in various studies on fruit juices and beverages, indicating the effectiveness of good manufacturing practices in controlling microbial growth[43].

Overall, these results confirm that the *O. bataua* beverage meets stringent local and international microbiological standards and is safe for consumption. The low levels of coliforms, absence of Salmonella, and controlled mesophilic aerobe counts highlight the beverage's excellent microbial quality and safety. In addition, food combinations have been shown to increase the protein content of regularly consumed meals[40-42]. Incorporating *O. bataua* beverages into the diet is particularly beneficial for individuals without access to animal-based foods. Combining *O. bataua* with other readily available plant products can help compensate for diets low in essential amino acids. This approach increases nutrient intake and promotes dietary diversity and accessibility. In addition, the use of ungurahua is an ancestral practice of the Kichwa communities and has the potential to be integrated as a beverage into the diet of the inhabitants of the Ecuadorian Amazon. This traditional use underscores its cultural significance and potential for broader dietary incorporation, offering health benefits and connecting indigenous heritages.

Reflective analysis

The study on the *Oenocarpus bataua* beverage provides valuable insights into its nutritional and microbiological qualities, underscoring its potential as a beneficial dietary component, especially for populations with limited access to animal-based foods[32]. Nevertheless, future research must address several limitations to realize its potential and broaden its application fully. As Meilgaard et al. in 2015 observed, the limited sample size in the sensory evaluation limits the generalizability of the findings[46]. Increasing the sample size in future studies will result in more statistically significant results, providing a clearer picture of consumer preferences. Moreover, the absence of a control group using different fruits or ingredients limits our ability to compare the sensory characteristics and nutritional value of *O. bataua* with other beverages. Including such control groups would enhance the comprehensiveness of future studies [47].

CONCLUSIONS

The research provides a comprehensive analysis of the nutritional and microbiological quality of the *O. bataua* beverage, highlighting its potential as a nutritious beverage alternative, particularly for populations without access to animal-based foods. The amino acid profile of the drink, with eight essential amino acids, underscores its significant nutritional value. This includes histidine, which was found to have an exceptionally high concentration (77.78%) and plays a critical role in various physiological functions and disease prevention. A comparison with other plant-based beverages, such as carob, lupine, and quinoa, shows that the *O. bataua* beverage holds its own essential amino acid content despite differences in specific amino acid concentrations.

The physicochemical analysis confirms the high water content of the beverage, consistent with fruit-based beverages, and highlights its balanced mineral content through the measured ash percentage. Despite its low protein content, typical of fruit drinks, the *O. bataua* drink provides moderate amounts of natural fats and dietary fiber, contributing to its overall nutritional profile. These findings are supported by comparative studies of similar beverages, which reinforces the reliability of the results.

Microbiological assessments demonstrate the excellent safety and quality of the beverage, which meets stringent local and international standards. The low levels of coliforms, absence of Salmonella and controlled mesophilic aerobic counts ensure the product's consumption safety and validate the production processes' effectiveness. These results are consistent with studies on other traditional fruit-based beverages, further confirming the microbiological integrity of the beverage.

In addition, incorporating *O. bataua* beverages into the diet is particularly beneficial for individuals without access to animal-based foods. Combining *O. bataua* with other readily available plant products can help compensate for diets low in essential amino acids. This approach increases nutrient intake and promotes dietary diversity and accessibility. Furthermore, using ungurahua is an ancestral practice of the Kichwa communities and has the potential to be incorporated as a beverage into the diets of those living in the Ecuadorian Amazon. This traditional use underscores its cultural significance and potential for broader dietary incorporation, offering health benefits and a connection to indigenous heritage.

In the future, it will be essential to fully assess the digestibility of *O. bataua* beverages to understand their nutritional potential and practical applications. Digestibility studies will help determine how efficiently the body can break down and absorb the nutrients in the beverage, which is crucial for populations that rely on it as a primary nutrient source. This information will be vital for developing dietary recommendations and ensuring the beverage effectively meets nutritional needs, especially in communities with limited access to diverse food sources.

Authors' contributions:

Conceptualization: DHC and MJAA; methodology: IGT and DHC; software: FPA, DFA; validation: FPA, DHC, and LTJ; formal analysis: DHC; research: DHC and FPA; data cleaning: DHC; writing-preparation of the original draft: DHC, FPA and IGT; review and editing, LTJ, MJAA and IGT; visualization: LTJ, FPA, DFA; supervision: MJAA and IGT; project administration: DHC; fund acquisition: DHC. All authors have read and agreed to the publication of this manuscript.

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Conflict of interest:

The authors declare no conflicts of interest.

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