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Bactris guineensis, an underutilized Costa Rican palm fruit: juice processing and its nutritional profile*

Bactris guineensis, un fruto de palma costarricense subutilizado: procesamiento del jugo y su perfil nutricional

Carolina Cortés-Herrera[1], Ana M. Pérez[2], Fabrice Vaillant[3]

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[1] Universidad de Costa Rica (UCR), Centro Nacional de Ciencia y Tecnología de Alimentos (CITA), Ciudad Universitaria Rodrigo Facio. San José, Costa Rica. carolina.cortesherrera@ucr.ac.cr (autor para correspondencia; https://orcid.org/0009-0006-2988-4286).

[2] Universidad de Costa Rica (UCR), Centro Nacional de Ciencia y Tecnología de Alimentos (CITA), Ciudad Universitaria Rodrigo Facio. San José, Costa Rica. ana.perez@ucr.ac.cr (https://orcid.org/0000-0003-0940-9796).

[3] Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), UMR 95 QUALISUD–TA B-95/16, 73 rue Jean-François Breton, Montpellier Cedex 5, France. fabrice.vaillant@cirad.fr (https://orcid.org/0000-0001-6318-1353).

Abstract

Introduction. *Bactris guineensis* is a crop that produces visually appealing fruits resembling purple-black grapes with round seeds. This palm species naturally thrives in the lowland regions of tropical America. However, limited information available about this fruit. **Objective**. To investigate the nutritional composition, bioactive compound content, antioxidant capacity, and aroma profile of the huiscoyol fruit grown in Costa Rica, as well as to evaluate the effects of juice processing (enzymatic maceration and thermal treatment) on its bioactive compounds and antioxidant capacity. **Materials and methods.** Fruits were collected from randomly selected palms and bunches in Guanacaste Conservation Area, specifically in Palo Verde and Cañas, during peak harvest years (2007, 2011, 2014, and 2016). Nutritional composition, bioactive compound content, antioxidant capacity, and aroma and polyphenol profiles were analyzed. Juices were prepared using thermal treatment, enzymatic maceration, and a combination of both methods. The bioactive compound content and antioxidant capacity were assessed following each treatment. **Results.** Huiscoyol fruit exhibited high fiber content [7.3 ± 2.5 g per 100 g of fresh weight (fw)], and significant potassium content (307 ± 98 mg per 100 g fw). Anthocyanin levels ranged from 28.3 to 47.9 mg per 100 g fw, with cyanidin-3-O-rutinoside as the predominant compound. Total polyphenol content varied between 219 and 1,013 mg gallic acid equivalents per 100 g fw. Vitamin C content reached a maximum of 48 mg per 100 g fw. Antioxidant capacity, as measured by H-ORAC, ranged from 6,690 to 14,688 μmol Trolox equivalents per 100 g fw. Enzymatic maceration and thermal treatments applied to the juice did not significantly affect the bioactive compounds content or antioxidant activity ($p > 0.05$). **Conclusion.** Huiscoyol fruit demonstrate nutritional and antioxidant potential, making it promising ingredient for funtional beverages. Its bioactive components, such as polyphenols and anthocyanins, showed remarkable stability under thermal and enzymatic processing conditions.

Keywords: bioactive food compounds, thermal treatment, phenolic compounds, *Arecaceae*.

Resumen

Introducción. *Bactris guineensis* es un cultivo que produce frutos atractivos, similares a uvas de color negro-púrpura, con semillas redondas. Esta especie de palma prospera naturalmente en las regiones bajas de América tropical. Sin embargo, existe poca información disponible sobre este fruto. **Objetivo.** Investigar la composición nutricional, el contenido de compuestos bioactivos, la capacidad antioxidante y el perfil de aroma del fruto huiscoyol cultivado en Costa Rica, así como evaluar los efectos del procesamiento del jugo (maceración enzimática y tratamiento térmico) sobre sus compuestos bioactivos y capacidad antioxidante. **Materiales y métodos.** Los frutos se recolectaron de palmas y racimos seleccionados aleatoriamente en el Área de Conservación Guanacaste, durante los años de cosecha pico (2007, 2011, 2014 y 2016). Se analizaron la composición nutricional, el contenido de compuestos bioactivos, la capacidad antioxidante y los perfiles de aromas y polifenoles. Los jugos se prepararon mediante tratamiento térmico, maceración enzimática y una combinación de ambos métodos. El contenido de compuestos bioactivos y la capacidad antioxidante se evaluaron después de cada tratamiento. **Resultados**. El fruto de huiscoyol presentó un alto contenido de fibra [7,3 ± 2,5 g por 100 g de peso fresco (pf)] y un contenido significativo de potasio (307 ± 98 mg por 100 g pf. Los niveles de antocianinas variaron entre 28,3 y 47,9 mg por 100 g pf, con cianidina-3-O-rutinósido como compuesto predominante. El contenido total de polifenoles osciló entre 219 y 1013 mg de equivalentes de ácido gálico por 100 g pf. El contenido máximo de vitamina C fue de 48 mg por 100 g pf. La capacidad antioxidante, medida por H-ORAC, varió entre 6690 y 14 688 μmol de equivalentes de Trolox por 100 g pf. Los tratamientos de maceración enzimática y térmicos aplicados al jugo no afectaron significativamente el contenido de compuestos bioactivos ni la actividad antioxidante ($p > 0,05$). **Conclusión.** El fruto de huiscoyol demostró un potencial nutricional y antioxidante, lo que lo convierte en un ingrediente prometedor para bebidas funcionales. Sus componentes bioactivos, como los polifenoles y las antocianinas, mostraron una notable estabilidad frente al procesamiento térmico y enzimático.

Palabras clave: compuestos bioactivos, tratamiento térmico, compuestos fenólicos, *Arecaceae*.

Introduction

The *Bactris guineensis* (L.) H.E. Moore (Arecaceae) palm is commonly known as “huiscoyol”, “uvita”, “uvita de monte”, “güiscoyol” or “vizcoyol” in Central America and “corozo” or “corozo de lata” in Colombia (Brieva-Oviedo et al., 2020; Chízmar Fernández, 2009; Erşan et al., 2020; Quesada et al., 2020). The fruit is a single-seeded drupe that reaches maturity two months after flowering (Brieva-Oviedo et al., 2020). The fruit can be found in markets from Nicaragua to northern Colombia and Venezuela and is usually consumed as juice or in beverages, candied fruit, and jams. It can also be fermented to produce an alcoholic beverage (Chízmar Fernández, 2009; Rojano et al., 2012).

Some edible palms grow in humid lowlands in tropical America where they are often used as natural fences near rivers beds and in pastures. They produce several stems that grow in dense clusters. The fruits of some edible palms, such as açaí and coconut, are widely consumed and play a significant role in the diet of people in some tropical regions. *Bactris guineensis,* the most significant fruit-yielding palm in the Caribbean coast region of Colombia, holds great potential for agroforestry systems. Its adaptability and suitability for reintroduction in abandoned pastures, offer new opportunities for large-scale cultivation in the area (Brieva-Oviedo et al., 2020). Unlike açaí, which has been extensively studied for its health benefits, huiscoyol remains relatively understudied as a crop.

In Costa Rica, *B. guineensis*, commonly known as huiscoyol, is a nontraditional fruit. The stem and side leaves of the plant are 50-60 cm long and covered with thin yellowish spines with a black apex. The adult palm tree can

reach 2.0 to 3.5 m in height and individual stems are 2.6 to 3.0 cm in diameter. One plant can produce several stems and 10 to 15 fruit clusters, which is equivalent to 1.5 to 3.75 kg of fruit, in one harvest season. With a planting density of 270-400 plants ha^{-1}, production can reach 675 to 1,000 kg ha^{-1} in one harvest season or 1,350 to 2,000 kg ha^{-1} per year (Chízmar Fernández, 2009).

The carotenoid and polyphenol profiles and the mineral content of *B. guineensis* fruits grown in Costa Rica have been studied (Erşan et al., 2020). Twenty-four soluble free and six insoluble bound phenolic compounds were found in the edible exo- and mesocarp. The soluble free phenolic fraction consisted of anthocyanins, catechin mono- and oligomers, quercetin O-glycosides, and apigenin- and luteolin C-glycosides. The insoluble-bound phenolic fraction was composed of phenolic acids. Cyanidin 3-O-rutinoside was the most abundant anthocyanin in the exocarp, followed by peonidin 3-O-rutinoside. Among the carotenoids present, the major ones were (all-E)-β-carotene and (all-E)-lutein. The α-tocopherol was found in quantifiable concentrations. Finally, they concluded that the fruit is rich in magnesium and iron.

Anthocyanins have been the most studied compounds in fruits of *B. guineensis*. Six anthocyanins were identificated with the aid of high-speed countercurrent chromatography and the chemical structures of cyanidin-3-sambubioside, peonidin-3-glucoside, peonidin-3-rutinoside and cyanidin-3-(6-O-malonyl)glucoside, cyanidin-3-glucoside and cyanidin-3-rutinoside were elucidated by nuclear magnetic resonance spectroscopy (NMR) techniques (Osorio et al., 2010). Diaz-Uribe et al. (2020) found three major anthocyanins in huiscoyol, cyanidin-3-rutinoside (75.7%), cyanidin-3-glucoside (13.4%), and peonidin-3-rutinoside (7.7%). Two new anthocyanin pigments in methanolic extracts of *B. guineensis* fruits cultivated in the Northern region of Costa Rica were isolated and identified as cyanidin 3-O-(6”-O-(α-D-rhamnopyranosyl))-β-D-glucopyranose and 3-O-(4”-O-(α-D-rhamnopyranosyl))-β-D-glucopyranose (Bagnarello et al., 2014).

The antioxidant activity of *B. guineensis* was measured using stabilized free-radical spectroscopy (Osorio et al., 2011). The extract exhibited a higher radical scavenging activity compared to pure anthocyanins when tested against ABTS [2,20-azino-bis(3-ethylbenzothiazoline-6-sulfonate)] and DPPH (1,1-diphenyl-2-picrylhydrazyl) free radicals (Osorio et al., 2011). Several studies have reported additional biological activities in pulp extracts from *B. guineensis*, like neuroprotective (López et al., 2017), cytotoxic (Sequeda-Castañeda et al., 2016) and antiviral properties (Jaimes-Gualdrón et al., 2022). Furthermore, strong cytotoxic activity was discovered against hepatic and colorectal carcinoma cell lines. An early apoptotic effect (20-50 %) was observed in cancer cell lines such as human metastatic colorectal adenocarcinoma (SW-620) and human colorectal adenocarcinoma (HT-29) (Quesada et al., 2020).

Currently, the market for functional foods containing bioactive compounds with positive health benefits is experiencing substantial growth, with new products being launched to meet consumer demands (Topolska et al., 2021). Consumers with the highest level of nutritional education show a preference for functional foods with added fiber or antioxidant. Functional beverages with health claims have become a prevailing trend in the packaged beverage market, particularly among individuals interested in a healthy diet and lifestyle (Baker et al., 2022). Anthocyanins are extensively found in berries and are associated with various health benefits. Therefore, these bioactive compounds could be utilized in the development of functional foods and beverages (Temple, 2022).

The aim of this research was to investigate the nutritional composition, bioactive compound content, antioxidant capacity, and aroma profile of the huiscoyol fruit grown in Costa Rica, as well as to evaluate the effects of juice processing (enzymatic maceration and thermal treatment) on its bioactive compounds and antioxidant capacity. This information is crucial for assessing the potential of this fruit as a valuable ingredient in the food industry. These results will enable the food industry to evaluate other alternatives for the use of huiscoyol as a raw material in beverage production. The data generated would encourage the cultivation of this underutilized fruit in Costa Rica.

Materials and methods

Sample processing

The preparation of fruit samples and the processing of juices were carried out at a pilot plant level in the National Center for Food Science and Technology (CITA), University of Costa Rica. The physicochemical and proximal characterization analysis (moisture, sugars, ash, protein, fat, minerals), bioactive compound analysis (dietary fiber, organic acids, vitamin C, total polyphenols, total anthocyanins), and antioxidant capacity analysis were carried out at a Chemical Laboratory of the National Center for Food Science and Technology (CITA), University of Costa Rica. The polyphenols and aroma profile were carried out at Research Center in Natural Products (CIPRONA), University of Costa Rica.

Fruit samples

B. guineensis fruits were identified according to the plant morphology (Chízmar Fernández, 2009) and were collected from randomly palms and racemes growing near roads or on cattle ranches in dry transition forests at altitudes ranging from sea level to 600 meters above sea level within The Guanacaste Conservation Area, in the western region of the Volcanic Cordillera. Fruit batches were specifically harvested in Palo Verde, Bagaces, in March 2007, and in Cañas in March 2007, July 2011, March 2014, September 2014, and August 2016.

Fruit clusters were of different sizes with weights ranging from 150 g and 250 g per cluster. The 2007, 2011 y 2016 harvests were approximately 3 kg each of fruit (12-16 clusters) and the 2014 harvests were each 10-15 kg of fruit (30-40 clusters per harvest). The bunches were free of surface damage and microbiological deterioration and were transported in iceboxes to CITA´s Pilot Plant. The fruit were manually separated from the bunches and remained at -20 °C until processing.

A sub-sample of 500 g of fruit was washed by immersing in potable water and disinfectant solution (peracetic acid 1400 mg kg^{-1}) for 20 min. Fruits were processed manually by separating the seed from edible part. The sample was divided into two portions of 200 g, one of them was lyophilized. Both samples (fresh and freeze-dried) were stored in vacuum-sealed laminated bags and frozen at –20 °C to prevent deterioration until physicochemical analysis.

The physicochemical analysis on fresh fruit samples were moisture, total soluble solids (°Brix), total titratable acidity, pH, color, vitamin C and aroma profile. On a freeze-dried material fruit the analysis were: ash, crude fat, protein, mineral content, total dietary fiber, sugar profile, total polyphenols content (TP), total anthocyanin content (TA), organic acids profile, polyphenols profile and hydrophilic oxygen radical absorbance capacity (H-ORAC).

Preparation of processed juice

Three different batches of fruits harvested in Cañas, Guanacaste, were processed: one in March 2014 and two in September 2014 in order to produce different processed juices. Each batch consisted of 10 kg of fruit, which was washed by immersing in potable water and disinfectant solution (peracetic acid) for 20 min. For each batch, the pulp was separated from the seeds using a finisher (Carver Brand, Model: 3351-0) with a mesh size of 3.17 mm. Different treatments were applied to the mixture of pulp and skin from the same batch of fruits to produce four juices. The treatments were: 1) pressing to obtain juice A, 2) enzymatic maceration to obtain juice B, 3) thermal treatment to obtain juice C and 4) the combination of enzymatic and thermal treatment to obtain the juice D.

Treatments

(1) pressing: A 5 kg of sample (pulp with the skin homogenized) was pressed at (3.0 x 10^5 Pa) for 5 min in a 40 L waterpress (Enotecnica Pillan SRL, Carezza model). The solids were separated with a cloth filter medium which pore opening was less than 1 mm. The liquid (juice A) was collected in a container and stored in 250 mL metalized bags at –20 °C until analysis.

(2) enzymatic maceration: A 5 kg of sample (pulp with the skin homogenized) was placed in a stainless-steel container and treated with 200 mg L^{-1} of Pectinex Ultra SP (Novozymes, Denmark), a blend of pectinases, hemicellulases and beta-glucanases, at 30-35 °C with constant stirring for 1 h. The sample was then pressed with waterpress at 3.0 x 10^5 Pa for 5 min. The liquid (juice B) was collected in a container and stored in 250 mL metalized bags at –20 °C until analysis.

(3) thermal treatment: 500 mL juice (A and B separately) was placed in a stainless-steel beaker and heated to 85 °C for 2 to 5 s with constant stirring. Each thermal treatment sample was packaged hot, using a funnel, in 250 mL glass bottles, previously disinfected, that were capped and immediately inverted to sterilize the cap. The bottles were immersed in an ice water bath and cooled to room temperature. Each thermal treatment sample (C and D) was transferred to 250 mL metalized bags and stored at –20 °C until analysis.

The physicochemical analysis on juice samples were moisture, total soluble solids (°Brix), total titratable acidity, pH, color, vitamin C, total polyphenols content, total anthocyanin content and hydrophilic oxygen radical absorbance capacity.

Physicochemical analysis

Ash was determined by AOAC method 940.26 (Association of Official Analytical Chemists [AOAC], 2023). The crude fat content was measured by the method described by Carpenter et al. (1993). Protein content was measured by AOAC method 920.152 (AOAC, 2023). Mineral content (Ca, Fe, K, and Na) was analyzed using AOAC methods 985.35 and 999.11 (AOAC, 2023), and total dietary fiber was measured by AOAC method 985.29 (AOAC, 2023).

Moisture was determined by AOAC method 920.151 (AOAC, 2023), Total soluble solids were measured as °Brix by AOAC method 932.12 (AOAC, 2023). Total titratable acidity was assessed by titration with sodium hydroxide (0.1 N) and expressed as succinic acid as described by AOAC 942.15 (AOAC, 2023). The pH was measured by AOAC method 981.12 (AOAC, 2023). Color analysis was determined measuring L*, a*, b*, C* and h° parameters using a colorimeter (ColorFlex EZ, Hunter Lab).

Sugar profile analysis

A 0.5000 ± 0.0001 g subsample of freeze-dried material fruit was extracted with 100.0000 ± 0.0001 g ultrapure water (type I, 0.055 µS cm^{-1} at 25 °C, 5 µg L^{-1} TOC). The mixture was stirred for 20 min, centrifuged, and filtered through a 0.45-µm pore size membrane. The analysis was performed on a Shimadzu HPLC system (Shimadzu, Kyoto, Japan) equipped with a refractive index detector (RID-10A), column compartment (CTO-20A), autosampler (SIL-20A HT) and a quaternary pump (LC-20AT). An amino column (Zorbax Carbohydrate 5 μm, 150 mm x 4.6 mm, Agilent Technologies) was used with a flow of 1.2 mL min^{-1} at 30 °C. The eluent was a mix of acetonitrile: water (75:25), isocratic condition for 20 min. The analysis was performed in duplicate.

Sugars (sucrose, fructose, and glucose) were identified by comparing the retention times with standards and quantified using external calibration curves with a linearity range of 0.1-1.0 % sugar. Good correlation was obtained (r^2 = 0.9996).

Ascorbic acid and dehydroascorbic acid (vitamin C) analysis

Ascorbic acid (AA) and dehydroascorbic acid (DHA) contents were determined as described by Hernández et al. (2006) and Lykkesfeldt (2000). A 5-10 g subsample was mixed with 15-20 mL extractant solution (0.04 % metaphosphoric acid), homogenized with a vortex for 1 min, and then centrifuged at 4 500 rpm (4 °C) for 10 min. This procedure was repeated, and the two resulting supernatants were brought to 50 mL with extractant solution. An aliquot of the extract was filtered and transferred to a 2 mL vial using a syringe with a micropore filter (0.45 or 0.20 µm).

To reduce AA to DHA, 500 μL of extract were added to 500 μL of Tris [2-carboxyethyl] phosphine hydrochloride (40 mM) and incubated at 30 ºC for 40 min. The extract and the reduced extract were injected into a Shimadzu HPLC system (Shimadzu, Kyoto, Japan) equipped with a photodiode array detector (SPD-M20AV), column compartment (CTO-20A), autosampler (SIL-20A HT) and a quaternary pump (LC-20AT). AA and DHA were analyzed on a C18 column (Phenomenex Luna 5 μm, 100 Å, 250 mm x 4.60 mm). The analytical conditions were as follows: oven heat 30 °C, flow 0.8 mL min^{-1}; eluent H_2SO_4 (1.8 mM, pH 2.60), isocratic condition for 20 min at 245 nm.

Ascorbic acid and dehydroascorbic acid were identified by comparing the retention times with standards and quantified using external calibration curves with a linearity range of 7.5-150 ppm of AA. Good correlation was obtained ($r^2 = 0.9996$).

Polyphenolic rich extract

Extracts were prepared as described by Georgé et al. (2005). A 0.5 -1.0 g subsample was extracted with 30 mL of acetone solution (70/30 distilled water). The mixture was magnetically stirred for 15 min and then sonicated for 15 min. Mixture supernatants were recovered by filtration and evaporated under vacuum at 40 °C until almost all the solvent was removed. The remaining extract was transferred to a 25 mL volumetric flask and made-up with water type I. This polyphenolic rich extract was used on different analysis: Total polyphenols content (TP), total anthocyanins content (TA), antioxidant activity (H-ORAC), organic acid profile and polyphenols profile. The extracts were stored at -20 °C until their respective analyses.

Total polyphenols content (TP)

Total polyphenols were determined using the modified Folin–Ciocalteu spectrophotometric method described by Georgé et al. (2005). Gallic acid was used as the standard. Ascorbic acid and reducing sugar interferences were eliminated using OASIS® cartridges. The absorbance was measured in a UV-1700 Shimadzu spectrophotometer UV-1700 (Shimadzu, Kyoto, Japan) with a wavelength of 765 nm against a reagent blank. The polyphenols were quantified using an external calibration curve of gallic acid with a linearity range of 10-80 mg L^{-1}. Good correlation was obtained ($r^2 = 0.9996$) and the concentration of total polyphenols was reported as milligrams (mg) of gallic acid equivalents (GAE) per 100 g of fresh sample. All analyses were performed in triplicate.

Total anthocyanin content (TA)

The total monomeric anthocyanin content of the juice was determined using the pH differential method (Moyer et al., 2002). The polyphenolic-rich extract was diluted 1:5 in 25 mM potassium chloride buffer at pH 1.0 and 0.4 M sodium acetate buffer at pH 4.5. The absorbance of the solutions was measured spectrophotometrically at 510 and

700 nm. The total anthocyanin concentration C (mg L^{-1}) was expressed as mg cyanidin-3-O-glucoside equivalents (C3GE). All analyses were performed in triplicate.

Organic acid profile

A 500 μL aliquot of polyphenol-rich extract was extracted with OASIS® cartridges with 2.5 mL of ultrapure water (type I, 0.055 µS cm^{-1} at 25 °C, 5 µg L^{-1} TOC). The filtrate was injected into a Shimadzu HPLC system (Shimadzu, Kyoto, Japan) equipped with a photodiode array detector (SPD-M20AV), column compartment (CTO-20A), autosampler (SIL-20A HT) and a quaternary pump (LC-20AT). Organic acids were analyzed on an ion-exchange column (Hi-Plex H 300 mm x 7.8 mm, 8 μm). The analytical conditions were as follows: flow 0.6 mL min^{-1}, 60 °C; eluent H_2SO_4 (2.25 mM), isocratic condition for 40 min at 210 nm. The analysis was performed in triplicate. Organic acids were identified by comparing the retention times with standards and quantified using external calibration curves with a linearity range of 50.0-1000.0 mg L^{-1}. Good correlation was obtained ($r^2 = 0.9996$).

Hydrophilic antioxidant capacity (H-ORAC)

The hydrophilic oxygen radical absorbance capacity (H-ORAC) was determined as described by Huang et al. (2002) and Ou et al. (2001). A spectrofluorometer (Synergy HT, BioTek Instruments) was used with 96-well polypropylene plates and fluorescein as the indicator of peroxyl radical damage. The excitation wavelength was 493 nm, and the emission wavelength was 515 nm. Solutions were prepared with phosphate buffer (75 mM, pH 7.4). Each well was filled with 150 μL of fluorescein and 25 μL of buffer (blank), a standard Trolox solution, or a sample of an appropriate dilution. The plates were incubated at 37 °C for 30 min. After incubation, 25 μL of 2,2'-Azobis(2-amidinopropane) dihydrochloride (AAPH) solution were added and plates were shaken. The fluorescence decay was measured every minute for 45 min at 37 °C. The H-ORAC was expressed as micromoles (µmol) of Trolox equivalents (TE) per 100 g of fresh sample using an external calibration curve of Trolox (4.0-32.3 µmol TE L^{-1}) with good correlation (r^2=0.9993).

Polyphenols profile analysis by UPLC-DAD/ESI-Q-TOF/MS

The remaining polyphenol-rich extract was transferred to an Amberlite XAD-7 column to eliminate ascorbic acid, reducing sugars, and amino acid interference and concentrating the extract. It was eluted with a mixture of 80:20 methanol/water and evaporated under vacuum at 40 °C until almost all the methanol was removed. The remaining solution was freeze-dried. Analysis was performed in series using a Waters Acquity Ultra Performance Liquid Chromatography system (UPLC) equipped with a Diode Array Detector (DAD) ACQ- PDA and coupled with Electrospray Ionization (capillary voltage 2.3 kV, dry temperature 270 °C) and Quadrupole Time-Of-Flight Mass Spectrometer (ESI-Q-TOF/MS).

Mass spectrometry data were acquired in positive ionization mode. Full scan was measured from 70 to 5 000 m/z. Separation was performed using a reversed phase C-18 column (2.1 mm x 100 mm, 1.7 μm) using water/formic acid (99.9:0.1, v/v) as solvent A and acetonitrile/water/formic acid (99:0.9:0.1) as solvent B at a flow rate of 0.3 mL min^{-1} at 30 ºC. The gradient for samples was 0-2 min 98 % A, 2-5 min 90 % A, 5-12 min 90 % A, 12-16 min 75 % A, 16-18 min 2 % A, 18-19 min 2 % A, 19-20 min 98 % A, 20-22 min 98 % A.

Analysis of aroma compounds

Extracts of aroma compounds were obtained by mixing 40 g of sample, 4 g of sodium chloride, 60 mL of water type I, and 300 mL of 1:1 pentane/ether. The mixture was magnetically stirred for 4 hours. The internal standard

was 1-octanol (30 μg). Volatile compounds were separated with a Hewlett-Packard 6890 gas chromatograph coupled to a Hewlett-Packard 5973 quadrupole mass spectrometer with electron ionization mode (EI) generated at 70 eV and a DB-WAX column (J&W Scientific, Folsom, CA, USA), 0.25 μm particle size, 30 mm length, 0.32 mm i.d. The injection volume was 1.0 μL.

The chromatographic conditions were as follows. The ion source and quadrupole temperatures were 230 ºC and 150 ºC, respectively. The oven temperature gradient was: 3 min at 40 ºC; increase from 40 ºC to 185 ºC at a rate of 3 ºC min^{-1}; 185 ºC for 30 min. The injector temperature was 250 ºC, spitless mode. Helium was used as carrier gas at a flow rate of 1.1 mL min^{-1}. Electron impact mass spectra were recorded in the 40-600 a.m.u. range.

Compounds were identified by linear retention indices on a DB-wax column and EI mass spectra (Wiley 275 L library) from the literature. For quantification, response factors were taken as 1.0 for all compounds concerning the internal standard. Amounts were expressed as μg of 1-octanol equivalents per 100 g of fresh weight. A series of n-alkanes (i.e. C10-C22) were used as a reference to calculate linear retention indices.

Statistical analysis

To determine the effects of fruit processing on bioactive compounds and antioxidant capacity, an unrestricted random design was used with four treatments corresponding to each type of juice: pressed juice (A), enzymatic treated juice (B), thermal treated juice (C), enzymatic and thermal treated juice (D). The response variables were total polyphenol content, total anthocyanin content, total vitamin C content and antioxidant activity by the H-ORAC method. For each treatment, the mean and standard deviation were calculated for each variable. Significant differences between means ($p \leq 0.05$) were determined by ANOVA. A Tukey test was applied to verify significant differences among means of the response variables in each treatment; differences were indicated with different letters. Statistical analyses were performed using the JMP-SAS version 9 program.

Results

The fruits of *B. guineensis* grow in clusters (one to three clusters per stem) and are similar in appearance to grapes, which explains the vernacular name of "uvita" or "small grapes". It was determined that most of the fruits have an ovoid geometry with a diameter of around (1.5 ± 0.1) cm. The weight of each fruit was relatively homogeneous around (3.6 ± 0.6) g. The single seed represented 34 % of the fruit weight. The edible part of the fruit included the pulp, and the thin skin represented 66 % of the total weight of the fruit. The color parameters of the edible part of the fruit ranged from (16.6-20.8) for L*, (14.9-27.5) for a*, (2.8-9.5) for b*. The C* value was (15.1-29.1) and h° value was (70.9-79.2).

The nutritional composition and main bioactive compound in the edible part of the huiscoyol palm fruit were shown in Table 1.

The profile of polyphenols presents in the fruit were shown in the chromatogram in Figure 1. Signals were observed in both negative (Figure 1 A) and positive (Figure 1 B) modes to cover all types of ionizations of the different families of polyphenols. The MS/MS fractionation patterns, the original ion $[M-H]^-$ or $[M-H]^+$ of each of the signals, and tentative identification of each compound were shown in Table 2 and Table 3.

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Table 1. Main physicochemical, nutritional composition and antioxidant activity of the edible part of the *B. guineensis* (n= 6) fruit grown in Costa Rica. Chemistry Laboratory of the National Center for Food Science and Technology, Universidad de Costa Rica, San José, Costa Rica. 2016.

Cuadro 1. Principal composición fisicoquímica, nutricional y actividad antioxidante de la parte comestible del fruto *B. guineensis* (n= 6) cultivado en Costa Rica. Laboratorio de Química del Centro Nacional de Ciencia y Tecnología de Alimentos, Universidad de Costa Rica, San José. Costa Rica. 2016.

Component	Value range in fresh weight content
Moisture (g 100 g^{-1})	65.5-84.0
Ash (g 100 g^{-1})	0.59-1.50
Protein (g 100 g^{-1})	0.60-2.09
Crude fat (g 100 g^{-1})	0.04-0.10
Total carbohydrates (g 100 g^{-1})	17-35
Simple sugars (g 100 g^{-1})	
Sucrose	ND[a]-3.6
Fructose	3.0 - 11.0
Glucose	4.1 - 11.0
Dietary fiber (g 100 g^{-1})	2.8 – 10.0
Total soluble solids (° Brix)	15 - 32
pH	2.5 - 3.4
Acidity (g succinic acid 100 g^{-1})	1.9 - 3.8
Organic acids (mg 100 g^{-1})	
Citric acid	30 - 240
Malic acid	37 - 1 000
Succinic acid	1 000 -1 580
Minerals (mg 100 g^{-1})	
Sodium	0.42-10.30
Potassium	248-421
Calcium	16-21
Iron	0.66-0.77
Vitamin C (mg 100 g^{-1})	ND[b]- 48
Total polyphenols (mg GAE 100 g^{-1})	219 - 1 013
Total anthocyanins (mg C3GE 100 g^{-1})	30 – 48
H-ORAC (μmol Trolox equivalents 100 g^{-1})	6 690 – 14 688

ND[a]: Not detected, less than 0.01 g 100 g^{-1}: ND[b]: Not detected, less than 14.3 mg 100 g^{-1}. GAE: gallic acid equivalents; C3GE: cyanidin-3-O-glucoside equivalents. / ND[a]: No detectado, menos de 0.010 g 100 g^{-1}: ND[b]: No detectado, menos de 14,3 mg 100 g^{-1}. GAE: equivalentes de ácido gálico; C3GE: equivalentes de cianidin-3-O-glucósido.

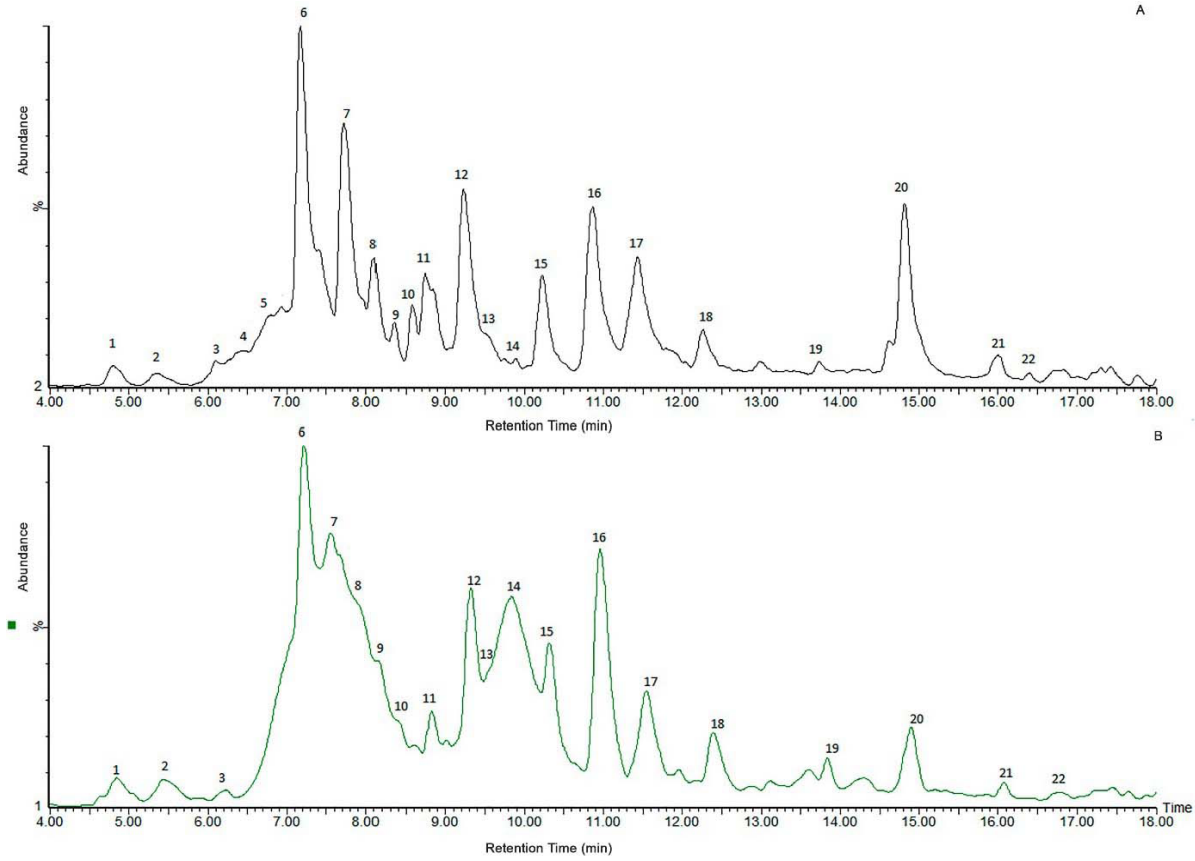

Figure 1. Polyphenolic compounds profile of huiscoyol fresh fruit by UPLC-ESI-Q-TOF/MS in negative mode (A) and positive mode (B) using C-18 column, gradient form water/formic acid at 0.3 mL min^{-1} and 30 ºC. Research Center in Natural Products, CIPRONA, Universidad de Costa Rica, San José, Costa Rica. 2016.

Figura 1. Perfil de compuestos polifenólicos de fruta fresca de huiscoyol por UPLC-ESI-Q-TOF/MS, en modo negativo (A) y modo positivo (B) usando una columna C-18, gradiente de agua/ácido fórmico a 0.3 mL min^{-1} y 30 ºC. Centro de Investigación en Productos Naturales, CIPRONA, Universidad de Costa Rica, San José, Costa Rica. 2016.

The total volatile compound content of *B. guineensis* was 286 μg/100 g. The chromatogram obtained from the separation and quantification of the profile of volatile compounds associated with aromas were shown in Figure 2. The tentative identification of the signals obtained, summarized in Table 4, was based on bibliographic references and the library of the GC-MS.

This research specifically focused on the unit operations used to obtain juice and their effects on bioactive compounds. The content of bioactive compounds and antioxidant activity expressed as H-ORAC were analyzed and the results were summarized in Table 5.

The statistical analysis revealed that the thermal treatment, the enzymatic treatment, and the combination of both did not generate significant changes in the content of total polyphenols ($p > 0.05$) or the content of total anthocyanins ($p > 0.05$). There was also no significant difference in the total vitamin C content ($p > 0.05$). Therefore, the antioxidant activity H-ORAC was not expected to change significantly with the different treatments ($p > 0.05$).

Table 2. Tentative identification of flavonols and anthocyanins present in a purified polyphenol extract of the huiscoyol fruit analyzed by UPLC-ESI-Q-TOF/MS. Center for Research in Natural Products, CIPRONA, Universidad de Costa Rica, San José, Costa Rica, 2016.

Cuadro 2. Identificación tentativa de flavonoles y antocianinas presentes en un extracto purificado del fruto huiscoyol analizado por UPLC-ESI-Q-TOF/MS. Centro de Investigación en Productos Naturales, CIPRONA, Universidad de Costa Rica, San José, Costa Rica, 2016.

N°	Compound	RT (min)	UV (nm)	$[M-H]^-$ (m/z)	MS/MS^- (m/z)	$[M-H]^+$ (m/z)	MS/MS^+ (m/z)
1	kaempferol-3-diglucoside-7-glucoside	5.0	210; 280	773.2321	593; 447; 285	757.2246	595;449;287
2	kaempferol-3-O-glucosyl-rhamnosyl-glucoside	5.7	210; 280	773.2410	611; 447; 285	757.2249	595;449;287
4	peonidin 3-O-rutinoside	6.4	210; 280	609.1265	475;287	-	-
5	peonidin 3-O-rutinoside	6.8	210; 280	609.1265	475;283	-	-
6b	cyanidin-3-O-rutinoside	7.2	518		-	595.1575	449; 287
10	taxifolin deoxyhexosyl- hexoside	8.6	210; 280	611.1757	475;285	-	-
20	quercetin-3-O-rutinoside	14.9	210; 280	609.1537	300	-	-

N°: number of peak in chromatogram Figure 1. TR: retention time; $[M-H]^-$ molecular ion in negative mode; $[M-H]^+$ molecular ion in positive mode; MS/MS^- fragment pattern in negative mode, MS/MS^+ fragment pattern in positive mode. / N°: número de pico en el cromatograma Figura 1. TR: tiempo de retención; $[M-H]^-$ ion molecular en modo negativo; $[M-H]^+$ ion molecular en modo positivo; MS/MS^- patrón de fraccionamiento en modo negativo, MS/MS^+ patrón de fraccionamiento en modo positivo.

Table 3. Tentative identification of proanthocyanidins present in a purified polyphenol extract of the huiscoyol fruit analyzed by UPLC-ESI-Q-TOF/MS. Center for Research in Natural Products, CIPRONA, Universidad de Costa Rica, San José, Costa Rica, 2016.

Cuadro 3. Identificación tentativa de proantocianidinas presentes en un extracto purificado del fruto huiscoyol analizado por UPLC-ESI-Q-TOF/MS. Centro de Investigación en Productos Naturales, CIPRONA, Universidad de Costa Rica, San José, Costa Rica, 2016.

N°	Compound	RT (min)	UV (nm)	$[M-H]^-$ (m/z)	MS/MS^- (m/z)	$[M-H]^+$ (m/z)	MS/MS^+ (m/z)
6a	epigalocatequin-catequin	7.2	280	593.1656	577; 407; 289	-	-
7	procyanidin trimer	7.8	210; 280	865.2147	695; 577; 407	-	-
8	procyanidin tetramer	8.1	210; 280	1153.2466	865; 575; 287	-	-
9	procyanidin dimer	8.3	210; 280	577.1481	451; 407; 289	-	-
11	procyanidin trimer	8.8	210; 280	865.2188	-	867.2231	697; 579; 409; 274
12	procyanidin dimer	9.4	210; 280	577.1425	407; 289	579.1500	409; 287
13	procyanidin tetramer	9.6	210; 280	-		1155.2938	867;633;325
14	procyanidin tetramer	9.9	210; 280	1153.2817	865; 593; 473; 284		
15	procyanidin tetramer	10.3	210; 280	1153.2787	685; 651; 593; 284	1155.2936	867; 633; 595; 579; 409; 247
16	procyanidin tetramer	10.9	210; 280	1153.2787	865; 651; 593; 284	595.1650	287
17	procyanidin trimer	11.6	210; 280	865.2189	695; 577; 407; 289	867.2219	579; 409; 247
18	procyanidin tetramer	12.4	210; 280	1153.2214	865; 575; 407; 287	1155.2927	867; 579; 409; 289;247
19	procyanidin tetramer	13.9	210; 280		-	1155.2922	867; 606; 579
22	procyanidin tetramer	16.1	210; 280	-	-	1155.2922	867; 579; 287

N°: number of peak in chromatogram Figura 1. TR: retention time; $[M-H]^-$ molecular ion in negative mode; $[M-H]^+$ molecular ion in positive mode; MS/MS^- fragment pattern in negative mode, MS/MS^+ fragment pattern in positive mode. / N°: número de pico en el cromatograma Figura 1. TR: tiempo de retención; $[M-H]^-$ ion molecular en modo negativo; $[M-H]^+$ ion molecular en modo positivo; MS/MS^- patrón de fraccionamiento en modo negativo, MS/MS^+ patrón de fraccionamiento en modo positivo.

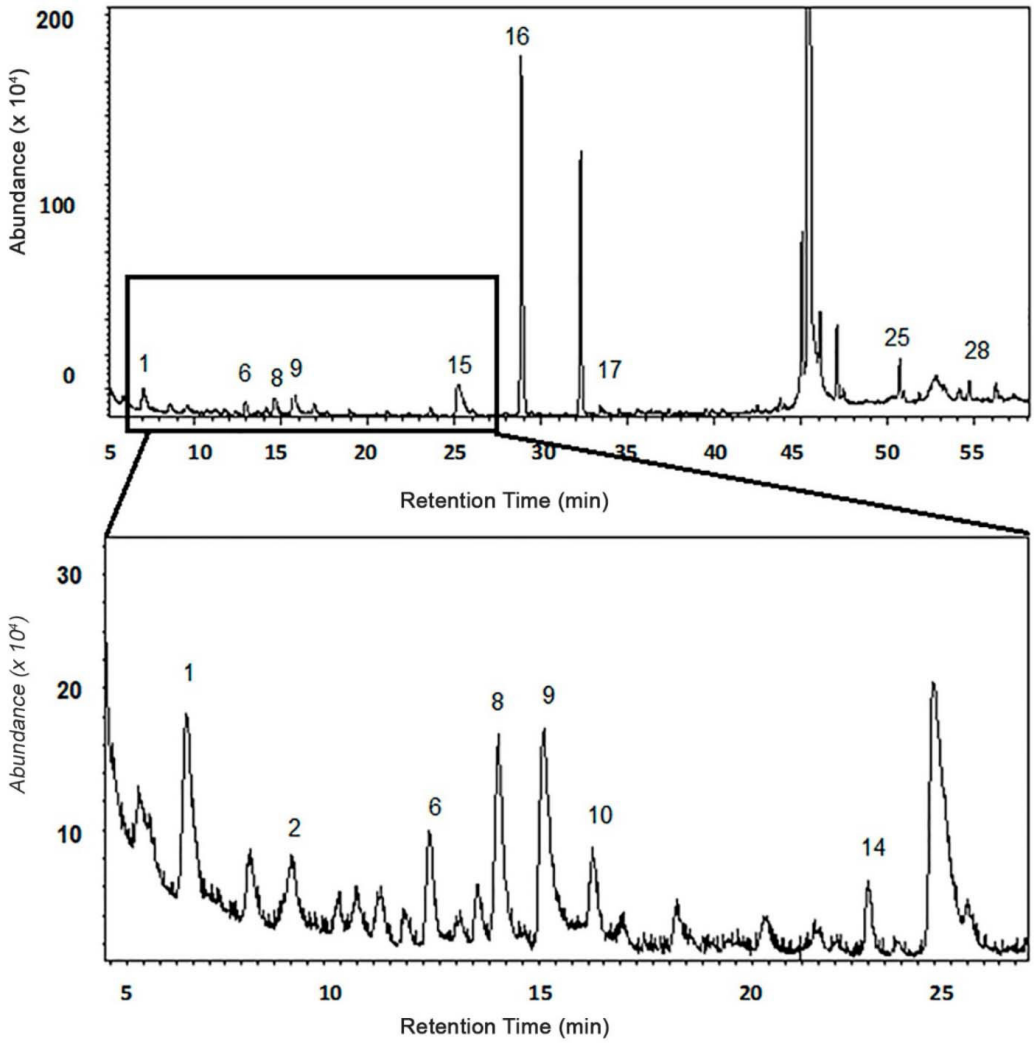

Figure 2. Elution profile of aroma volatile compounds by GC-MS chromatography using DB-WAX column (0.25 μm x 30 mm x 0,32 mm). Research Center in Natural Products, CIPRONA, Universidad de Costa Rica, San José, Costa Rica, 2016.

Figura 2. Perfil de compuestos volátiles de aroma por cromatografía de gases GC-MS. Centro de Investigación en Productos Naturales, CIPRONA, Universidad de Costa Rica, San José, Costa Rica, 2016.

Table 4. Volatile compounds tentative profile present in huiscoyol fruit analyzed by GC-MS its relative percent, concentration, and odor attribute compared with references. Research Center in Natural Products, CIPRONA, Universidad de Costa Rica, San José, Costa Rica, 2010.

Cuadro 4. Perfil tentativo de compuestos volátiles presentes en el fruto fresco de huiscoyol analizados por GC-MS, su porcentaje relativo, concentración y atributo de olor comparado con referencias. Centro de Investigación en Productos Naturales, CIPRONA, Universidad de Costa Rica, San José, Costa Rica, 2010.

N°	Tentative identification	RT (min)	LRI DB-wax		Cn µg/100 g fw.	R.P (%)	Odor attribute (reference)
			Cal	Lit.			
1	2-pentanone	7.05	1005	-	13.63 ± 0.55	4.75	Sweet [c]
2	2-methyl-3-buten-2-ol	9.61	1071	-	5.59 ± 0.52	1.96	-
3	hexanal	11.15	1110	1093[g]	2.42 ± 0.19	0.85	grass, fat [b]
5	3-pentanol	12.32	1136	-	2.04 ± 0.02	0.71	-
6	2-pentanol	12.95	1150	-	6.17 ± 0.62	2.16	-
7	1-butanol	14.12	1176	-	2.53 ± 0.16	0.88	alcoholic, pungent [a]
8	2-methyl-2-pentenal	14.63	1188	-	12.56 ± 0.22	4.38	green, fruity [b]
9	heptanal	15.73	1212	-	16.67 ± 1.50	5.84	fat, citrus, rancid[b]
10	3-methyl-1-butanol	16.91	1237	1247[f]	4.21 ± 0.24	1.47	whiskey [b]
11	1-pentanol	18.95	1281	-	2.82 ± 0.27	0.99	mellow, balsamic [c]
12	3-hydroxy-2-butanone	21.07	1328	-	2.12 ± 0.14	0.74	-
14	1-hexanol	23.61	1383	1379[f]	3.39 ± 0.20	1.18	flower, green [b]
15	nonanal	25.19	1419	1415[f]	34.67 ± 0.50	12.12	cucumber, lemon, green, citrus[b]
16	acetic acid	28.84	1503	1477[f]	136.61 ± 3.40	47.75	strong vinegar [d]
18	1,2-propanediol	34.50	1642	-	2.42 ± 0.24	0.85	-
19	nonanol	36.31	1687	-	0.85 ± 0.12	0.30	floral, rose, fresh[b]
21	alpha-ionene	37.34	1714	-	2.04 ± 0.13	0.71	-
23	hexanoic acid	43.77	1890	1872[f]	2.63 ±0.35	0.92	vinegar, green[e]
24	heptanoic acid	47.42	1996	-	2.73 ± 0.22	0.96	-
25	octanoic acid	50.90	2102	2098[f]	2.74 ± 0.27	0.96	fatty, waxy, rancid vegetable oil [d]
27	nonanoic acid	54.65	2207	-	5.61 ± 0.80	1.95	waxy, fatty, cheesy[d]
28	4-vinyl-metoxyphenol	56.21	2241	2223[f]	8.66 ± 0.59	3.03	-

N°: number of peak in chromatogram Figure 2; TR: retention time; LRI Cal: linear retention index calculated, LRI Lit: linear retention index literature; R.P relative percent. / N°: número de pico en el cromatograma Figura 2; TR: tiempo de retención; LRI Cal índice lineal de retención calculado; LRI Lit: índice lineal de retención de literatura; R.P: porcentaje relativo.
a Yan et al. (2020); b. Tejedor-Calvo et al. (2023); c. Zhu et al. (2018); d. Abouelenein et al. (2023); e. De Freitas Ferreira et al. (2016) f. Culleré et al. (2004); g. Högnadóttir and Rouseff (2003).

Table 5. Average values (n= 3) and standard deviation (±SD) of total polyphenols, total anthocyanins, vitamin C content and antioxidant activity (H-ORAC) of the four huiscoyol juices obtained on a pilot scale. Pressed juice (A), enzymatic treated juice (B), thermal-treated juice (C), enzymatic and thermal-treated juice (D). Chemistry Laboratory of the National Center for Food Science and Technology, Universidad de Costa Rica, San José, Costa Rica. 2016.

Cuadro 5. Valores promedio (n= 3) y su desviación estándar (±SD) de polifenoles totales, antocianinas totales, contenido de vitamina C y actividad antioxidante (H-ORAC) de los diferentes jugos de huiscoyol obtenidos a escala piloto. Jugo prensado (A), jugo con tratamiento enzimático (B), jugo con tratamiento térmico (C) y jugo con tratamiento térmico y enzimático (D). Laboratorio de Química del Centro Nacional de Ciencia y Tecnología de Alimentos, Universidad de Costa Rica, San José, Costa Rica. 2016.

Juice	Total polyphenols (mg GAE 100 g^{-1})	Total anthocyanins (mg C3GE 100 g^{-1})	Vitamin C (mg 100 g^{-1})	ORAC (μmol TE 100 g^{-1})
A	265 ± 14[a]	18.0 ± 2.5[a]	13.1 ± 1.9[a]	5 732 ± 773[a]
B	283 ± 27[a]	19.7 ± 2.3[a]	12.5 ± 2.2[a]	5 128 ± 883 [a]
C	242 ± 11[a]	20.0 ± 1.4[a]	12.03 ± 0.20[a]	5 063 ± 1 080a
D	249 ± 52[a]	23.4 ± 5.4[a]	11.32 ± 0.16[a]	4 525 ± 1 180 [a]

GAE: gallic acid equivalents; C3GE: cyanidin-3-O-glucoside equivalents; TE: Trolox equivalents, values with different letters are significantly different ($p < 0.05$). / GAE: equivalentes de ácido gálico (siglas en inglés); C3GE: equivalentes de cianidin-3-O-glucósido (siglas en inglés); TE: equivalentes de trolox. valores con diferentes letras son significativamente diferentes ($p < 0,05$).

Discussion

The nutritional composition of huiscoyol fruits showed that the dry matter was approximately 30 %. No lipids were detected in the pulp which was uncommon for a palm fruit of the *Bactris* genus, for example, peach palm fruits (*Bactris gasipaes*) from Costa Rica have a high fat content (maximum of 7.22 g 100 g^{-1} fw) (Rojas-Garbanzo et al., 2016). Protein content was relatively high compared to other tropical fruits of Costa Rica (Montero et al., 2022). High ash values were observed for huiscoyol fruit, the ash content of most fruits grown in Costa Rica is less than 1.5 g 100 g^{-1} fw.

Minerals such as sodium, potassium, calcium and iron were quantified in fresh fruits. The sodium content was higher than reported by Erşan et al. (2020). Lower value was obtained for iron and a similar value for calcium compared to the same study. Potassium content was relevant since it represents 12 % of the recommended dietary value. This variability could be because Erşan et al. (2020) analyzed a single geographical area (Bagaces, Guanacaste, Costa Rica) and one harvest time in 2018. Those values obtained in this research correspond to two different growing areas in Guanacaste (Cañas and Bagaces) and four different harvests (2007, 2011, 2014, and 2016). Therefore, differences in climatic conditions and soil composition usually affect the mineral contents.

The huiscoyol fruit presented a maximum value of 35 g per 100 g (fw) of total carbohydrates, of which 68 % are available carbohydrates. The most common fruit sugars, glucose, fructose and sucrose were identified. Sucrose was quantifiable only in the 2007 batch, probably due to the ripening stage of the fruit, but this sugar was detectable (not quantifiable) in fruits harvested in 2011 and 2007, and it was not detectable in the 2014 and 2016 batches. The available carbohydrates value (dietary fiber no included) ranged from 8.4 to 24.1 g per 100 g fw. The high content of fermentable sugars explains the traditional use of the juice for making alcoholic beverages in other countries like Colombia or Nicaragua (Rojano et al., 2012).

Dietary fiber is a nutrient that plays a crucial role in maintaining a healthy digestive system. Dietary fiber is associated with functional foods and had become a trending consumer preference (Dreher, 2018). Huiscoyol fresh fruit contained an average of 7.3 g per 100 g fw, which is relatively high compared to that reported in other tropical

fruits from Costa Rica (Montero et al., 2022) and represent a valuable source of dietary fiber. However, the fiber content was about twenty times lower in pressed juice. This outcome was expected, as the fibrous components in the pulp and peel remained in the residue after the juice extraction process.

Ascorbic acid was not detected in aqueous extracts of four of the six batches; only the 2014 batches showed 48 mg 100 g^{-1} fw. This content was comparable to that found in grapefruit, mandarin clementine, or melon (Fenech et al., 2019; Feszterová et al., 2023) but was lower than that of another fruit belonging to the same family, "tucum-do-cerrado" or "tucum amarelo" or "Natal coconut" (*Bactris setosa* Mart.) (Rosa et al., 2016). This vitamin was not significantly affected by processing (Table 5) due to the presence of dehydroascorbic acid, the oxidized form of ascorbic acid, which was the active species in both the juice and the fruit.

The total polyphenol content of huiscoyol grown in Costa Rica was lower than that reported for "tucum-do-cerrado" (Rosa et al., 2016). However, it was comparable to the total polyphenol content of blueberries, blackberries, strawberries, and raspberries (Mikulic-Petkovsek et al., 2012; Skrovankova et al., 2015). Polyphenol profile analysis was carried out in a ketone extract of the fruit and with the help of UPLC-MS, twenty-two signals were detected, of which twenty compounds were tentatively identified in comparison with the help of databases and research reports (Erşan et al., 2020; Quesada et al., 2020). Some of the identified compounds were part of the flavonoid and anthocyanin family, but most of these compounds were condensed tannins.

Based on spectroscopic analysis and fragmentation patterns, signals 1 and 2 (Table 2) indicate the presence of glycosylated kaempferol derivatives (m/z 287 [M+H]+; m/z 285 [M-H]-). The m/z 595 $[M - 162]^+$ fragment showed a loss of a hexose and m/z 449 $[M - 308]^+$ showed the loss of a disaccharide. These fragmentation patterns were reported previously where m/z 771 $[M-H]^-$ and m/z 773 $[M-H]^+$ with ions of m/z 611, m/z 449 and m/z 285 indicated that it corresponded to kaempferol-3-diglucoside-7-glucoside (Olsen et al., 2009). A tropical purple radish (*Raphanus sativus*) from Africa was characterized by Koley et al. (2020) and tentatively identified fragments m/z: 757.2190 and m/z: 757.1996 of kaempferol-3-O-glucosyl-rhamnosyl-glucoside and kaempferol-3-O-p-coumaroyl-diglucoside.

An important group of compounds present in huiscoyol were proanthocyanidins: dimeric (peaks 9, 12), trimeric (peaks 7, 11,17) and tetrameric (peaks 8, 13, 14, 15, 16, 18, and 22) procyanidins were found. These types of polyphenols were consistent with other studies in *B. guineensis* (Erşan et al., 2020; Quesada et al., 2020) and in the *B. setosa* (Rosa et al., 2016). The fractionation patterns observed for this type of compound correspond mostly to epicatechin ions and polymeric derivatives (Quesada et al., 2020). Signal 12 exhibited m/z 577 $[M-H]^-$ and m/z 579 $[M+H]^+$, along with fragments $[M - 170]^+$ and $[M - 292]^+$. These characteristics tentatively correspond to the procyanidin B2 (dimer) reported by Erşan et al. (2020).

The total anthocyanin content in huiscoyol was like that found in cherries and raspberries (Castañeda-Sánchez & Guerrero-Beltrán, 2015). Signal 6 presented a maximum absorption spectrum at 518 nm, a $[M+H]^+$ of 595.1574, with a fractionation m/z 449 ([M - 146]+ showing the loss of a hexose and m/z 287 (M- 308]+ showing the loss of a disaccharide. This compound corresponds to cyanidin-3-O-rutinoside, the identification was validated by injecting an analytical standard. Peonidin 3-O-rutinoside was also found (signal 4 and 5), as reported by Osorio et al. (2011), Erşan et al. (2020) and Quesada et al. (2020).

The radical scavenging properties of the huiscoyol fruit evaluated by the H-ORAC method were within the ranges reported by Rojano et al. (2012). The antioxidant capacity was like that of blackberries and higher than that of other Costa Rican tropical fruits evaluated by Montero et al. (2022). This antioxidant property is related to the high content of total polyphenolic compounds and anthocyanins since the edible part of the fruit is relatively low in vitamin C. The antioxidant capacity of the huiscoyol juices produced in this study was higher than that of other commercially available juices derived from red fruits containing anthocyanins, such as blackcurrant, pomegranate, and grape (Matute et al., 2021).

The enzymatic treatment improved juice extraction yield by 4 % since the use of pectinases by degrading pectic substances in the cell wall of fruit achieves partial or complete liquefaction of fruit pulp, thereby increasing

the yield (Nighojkar et al., 2019) and the bioactive compound content (Guler, 2023). But this treatment did not significantly affect the content of bioactive compounds. These findings contrast with those reported by Soto et al. (2016), who observed that enzymatic treatment of pressed blackberry juice increased total anthocyanin and ellagitannin contents. It is possible that heating the pulp to 37 °C to activate the commercial enzyme preparation prevented oxidation of bioactive compounds by inactivating endogenous enzymes in the pulp, which is an advantage since a greater amount of juice is obtained without affecting the compounds.

The thermal treatment in our study did not generate significant differences in the content of polyphenols or anthocyanins. This was contrary to what is reported in literature where thermal treatments could enhance or decrease the content of bioactive compounds (Petruzzi et al., 2017). This treatment led to the loss of antioxidant compounds such as polyphenol and vitamin C, this loss was often due to reactions Maillard or oxidative degradation (Nayak et al., 2015). The main anthocyanin in huiscoyol juice was cyanidin-3-rutinoside, which is a thermally stable compound (Sui et al., 2014). Flavonoids such as catechin and kaempferol derivatives, also found in this juice, exert a co-pigmentation phenomenon that may explain the thermal stability of this anthocyanin (Trouillas et al., 2016).

The volatile compound profile of huiscoyol was primarily composed of organic acids, with acetic acid being the major component. Long-chain acids such as hexanoic, heptanoic, octanoic, and nonanoic acids were present. These organic acids, mainly derived from yeast fermentation processes, serve as the initial substrate for the formation of ethyl esters during the fermentation process (Carpena et al., 2021). Carbonyl compounds such as aldehydes and ketones, with alcohol, are responsible for the green notes in the huiscoyol fruit aroma. Compounds such as 1-butanol, isoamyl alcohol, and 1-hexanol are characteristic in fermentation (Padilla et al., 2016). The content of reducing sugars, moisture, and organic acids make huiscoyol a suitable substrate for alcoholic fermentation by microorganisms (Herazo et al., 2011).

Conclusion

The *B. guineensis*, indeed present a remarkable opportunity for the development of functional foods in Costa Rica. Its nutritional profile, highlighted by high dietary fiber and potassium levels, along with low fat content, positions this palm fruit as valuable addition to health-conscious diets. The presence of proanthocyanidins, flavanols, anthocyanins and vitamin C not only enhance its antioxidant properties but also suggests potential health benefits. The stability of these bioactive compounds during processing means that the beneficial properties of huiscoyol can be retained in juice. Promoting this underutilized fruit could not only diversify the local agricultural landscape but also contribute to economic development through innovative food products.

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Conflict of interest

The authors have no conflict of interest to report.

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