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Stability of an isotonic beverage based on sweet whey permeate added with cape gooseberry (*Physalis peruviana* L.)

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Estabilidad de una bebida isotónica a base de permeado de lactosuero dulce adicionada con uchuva (*Physalis peruviana* L.)

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ABSTRACT

Carbohydrate and mineral content in whey permeate is similar to that of commercially available sports drinks, most of which are formulated without functional ingredients. The aim of this study was to evaluate the physicochemical stability of two formulations of isotonic beverage from whey permeate obtained by membrane separation (ultrafiltration), added with cape gooseberry fruit (*Physalis peruviana* L.). Physicochemical and microbiological stability, total polyphenol and carotenoid content, antioxidant activity (ABTS and DPPH) and sensory profile were evaluated during two-months of refrigerated storage at 4 °C. The results showed high physicochemical stability (pH, acidity, and total soluble solids) for the functional beverage. Important differences were observed in osmolality, which increased from 304.83 to 324.13 mOsm kg^{-1} for the non-hydrolyzed drink (BIUN) and from 330.1 to 350.53 mOsm kg^{-1} for the hydrolyzed drink (BIUH). The average content of total phenols was 9.64 and 9.72 mg-AG.100 g^{-1} for the BIUN and BIUH beverages, respectively. There was a reduction in the antioxidant activity of the drinks by both DPPH and ABTS analysis during storage time. Total carotenoid content decreased from 0.095 to 0.076 mg β-carotene.100 g^{-1} and from 0.115 to 0.076 mg β-carotene.100 g^{-1} for the BIUN and BIUH beverages, respectively. The sensory profile showed that both drinks had high overall quality.

Keywords:
Antioxidant capacity
Hydrolysis
Osmolarity
Sports drink
Storage
Ultrafiltration

RESUMEN

El contenido de carbohidratos y minerales en el permeado de lactosuero es similar al de bebidas deportivas o isotónicas disponibles a nivel comercial y que, en su mayoría, están formuladas con saborizantes y colorantes artificiales. El objetivo de este trabajo fue evaluar la estabilidad fisicoquímica de dos formulaciones de bebidas isotónicas a partir de permeado de lactosuero obtenido por separación por membranas (ultrafiltración) con adición de uchuva (*Physalis peruviana* L.). Se evaluó la estabilidad fisicoquímica y microbiológica, el contenido de polifenoles y carotenoides totales, la actividad antioxidante (ABTS y DPPH) y el perfil sensorial durante dos meses de almacenamiento bajo refrigeración a 4 °C. Los resultados indicaron una alta estabilidad fisicoquímica (pH, acidez, sólidos solubles totales) para las dos bebidas. Se observaron diferencias en la osmolalidad, la cual incrementó de 304,83 a 324,13 mOsm kg^{-1} para la bebida no hidrolizada (BIUN) y de 330,1 a 350,53 mOsm kg^{-1} para la bebida hidrolizada (BIUH). El contenido de fenoles totales fue 9,64 y 9,72 mg-AG 100 g^{-1} para las bebidas BIUN y BIUH, respectivamente. Se presentó una reducción de la capacidad antioxidante de las bebidas tanto por radicales DPPH como ABTS durante el tiempo de almacenamiento. El contenido de carotenoides totales disminuyó de 0,095 a 0,076 mg β-caroteno 100 g^{-1} y de 0,115 a 0,076 mg β-caroteno 100 g^{-1} para las bebidas BIUN y BIUH, respectivamente. A nivel sensorial, ambas bebidas presentaron una percepción de un producto de alta calidad.

Palabras clave:
Capacidad antioxidante
Hidrólisis
Osmolaridad
Bebida Isotónica
Almacenamiento
Ultrafiltración

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Sports drinks are non-carbonated water-based beverages, they are generally composed of varying types of monosaccharides, disaccharides, and sometimes maltodextrins, and contain small amounts of minerals (electrolytes) such as sodium, potassium, chloride (Maughan and Murray 2001). Functional sports drinks play an important role in hydrating, improving athletic performance, and preventing or helping specific health conditions (Orrù et al. 2018). The carbohydrate (sugar) concentration and the type of carbohydrate used, the electrolyte content, the osmolality, and the flavoring components can be manipulated to alter the functional characteristics of these beverages (Maughan 2009).

Whey is the liquid obtained after the coagulation of milk proteins during the production of cheese or caseinates (Smithers 2008). It is composed of lactose (5%), water (93%), protein (0.85%), minerals (0.53%), and fat (0.36%) (Pescuma et al. 2010). The composition of whey permeate is similar to that of electrolyte beverages commercialized as sports drinks (Geilman et al. 1992; Silva et al. 2023). Opposite to commercial hydrating drinks that only provide minerals such as sodium, potassium, and chlorine; drinks formulated with whey or whey permeate contain additional electrolytes such as calcium, magnesium, phosphorus, and zinc (El-khair 2009).

There is a limited availability of sports drinks without artificial flavors and colors on the market (Galaz 2013). Citrus flavors have been used in whey-based beverages and have been shown to be very effective in masking the undesirable odor of cooked milk and the salty-sour taste of fresh whey (Chavan et al. 2015). Cape gooseberry (*Physalis peruviana* L.) is considered an exotic fruit with an acidity comparable to that of passion fruit (*Passiflora edulis*), which can be processed for the development of refreshing beverages and other food products (Mendoza and Rodriguez 2012). In addition, this fruit can provide functional compounds due to its high content of total phenols, carotenoids, and considerable antioxidant activity (Rockenbach et al. 2008; Rinaldi et al. 2022).

Membrane technologies are separation methods that have been used in the dairy industry where ultrafiltration is one of the technologies most used for the recovery of whey proteins (Duke and Vasiljevic 2015). Multiple studies have been conducted to increase the value of the permeate produced by whey ultrafiltration; combined with nanofiltration, they have been used to concentrate lactose and demineralize whey (Cuartas-Uribe et al. 2009; Hofmann and Hamel 2023). The use of whey permeate as a source of oligosaccharides has also been studied (Barile et al. 2009). Different proportions of water-whey and water-permeate have been used in the formulation of sports drinks (Beucler et al. 2006; Petrus et al. 2005; O'Donoghue and Murphy 2023). Valadão et al. (2016) developed a sports drink based on hydrolyzed whey from ricotta cheese with an osmolality of 306 mOsm kg^{-1}, including approximately 37% whey, approximately. Ferreira et al. (2020) obtained a beverage with an osmolality of 316 mOsm kg^{-1} using non-hydrolyzed whey permeate. These results indicate the potential of whey permeate as an alternative in the production of isotonic beverages.

Considering the high nutraceutical and functional potential of cape gooseberry fruit (pulp and skin) and the need to develop products that take advantage of whey permeate as a basis for food formulation, this study proposes the formulation of an isotonic beverage using whey permeate (hydrolyzed and non-hydrolyzed) obtained by ultrafiltration and adding cape gooseberry fruit as a nutraceutical source. The stability of the beverages was assessed for two months under refrigeration conditions at 4 °C.

MATERIALS AND METHODS

Raw materials

Sweet whey was provided by AURALAC S.A. (Antioquia, Colombia). Products such as sucrose, stabilizer, and commercial flavoring were supplied by Tecnas S.A. (Medellín, Colombia). Cape gooseberry fruits (*Physalis peruviana* L.) were purchased from a local supplier and selected in compliance with resolution 3929 of 2013 of the Ministerio de Salud y Protección Social de Colombia. The fruit selected had a state of maturity based on color of 4, 5, and 6 (NTC 4580).

The whey presented the following physicochemical characteristics: Acidity: 0.09±0.006% lactic acid (AOAC 947.05), pH=6.53±0.067 (NTC 4592), soluble solids 6.97±0.239 °Bx (AOAC 932.12), lactose 47.9±0.273 g L^{-1} protein 0.85±0.066% (AOAC 990.03), ashes 0.54±0.038% w/w, calcium 366.64±46.817 mg kg^{-1} (NTC 5151), magnesium 72.62±10.153 mg kg^{-1} (NTC 5151). The lactose was quantified by high-performance liquid chromatography (HPLC) using a chromatograph AGILENT TECHNOLOGIES 1200 series with an AMINEX HPX-87H ion exchange column (300x7.8 mm), and as a mobile phase solution of H_2SO_4 0,008 N at a constant flow of 0.6 mL min^{-1} (Pérez-Escobar et al. 2020). The cape gooseberry whole pulp presented the following physicochemical characteristics: total soluble solids of 15.17±0.10 °Bx (NTC 4580), acidity of 1.636±0.095% citric acid (NTC 4580), pH of 3.46±0.01 (NTC 3651), phenolic acids of 84.14±4.83 AGE 100 g^{-1}, total carotenoids of 33.59±1.278 mg kg^{-1} antioxidant capacity with ABTS 53.6±5.11 mg trolox 100 g^{-1} and DPPH 38.73±5.05 mg Trolox 100 g^{-1}. In addition, products such as sucrose, stabilizer (CMC FGHH, provided by Tecnas S.A.), and commercial flavoring (Passion Fruit MN-Y, provided by Tecnas S.A.) were provided by local companies in the city from Medellin.

Formulation of isotonic beverage

Ultrafiltration permeate (PUF)

Sweet whey was conditioned at 43 °C, skimmed by centrifugation at 8,000 rpm (GEA Westfalia Separator AG, Type: MTA5-00-104), and pasteurized at 63 °C for 30 min. Subsequently, the product was subjected to an ultrafiltration process (Pilot filtration equipment, PERINOX, Series 0114/0115, Model E0FT) at 48 °C, with a concentration factor of 18, pressure and outlet pressure of 1 and 3 bar, respectively. The ultrafiltration pilot plant was equipped with a polyethersulfone spiral semipermeable membrane with a cut size of 10 kDa. The whey permeate by ultrafiltration had the following physicochemical characteristics: Acidity of 0.081±0.004% lactic acid (AOAC 947.05), pH of 66.47±0.15 (NTC 4592), soluble solids of 5.50±0.05 °Bx (AOAC 932.12), lactose of 50.052±0.134 g L^{-1} (Pérez-Escobar et al. 2020), ash of 0.481±0.032% w/w (NTC 5151), protein <2.5% (AOAC 990.03), calcium of 283.063±27.472 mg kg^{-1} (NTC 5151), magnesium of 61.813±5.256 mg kg^{-1} (NTC 5151).

Hydrolyzed PUF

Hydrolyzed permeate was obtained by cold hydrolysis using 0.075 mL L^{-1} of lactase for 20 h, achieving a degree of hydrolysis of approximately 30%. The percentage of hydrolysis was measured using the cryoscopy point method described by Llerena et al. (2019).

Preparation of cape gooseberry (skin and pulp)

The whole fruit was cleaned, disinfected (sodium hypochlorite at 100 mg L^{-1}), and homogenized using an industrial blender (CI TALSA LI30). The resulting product was passed through a USA Standard Mesh (18 mesh=1 mm sieve size) to remove the seeds. The processed fruit was stored frozen at -18 °C for later use.

Preparation of beverages

For the preparation of beverages, preliminary experiments were conducted varying the percentage of PUF and seeking to obtain an osmotic concentration following the regulations for isotonic beverage in normative 2229 of 1994 of the Ministerio de Salud de Colombia. Two formulations were developed: non-hydrolyzed isotonic beverage with cape gooseberry fruit (BIUN) and hydrolyzed isotonic beverage with cape gooseberry fruit (BIUH), formulated with non-hydrolyzed and hydrolyzed PUF, respectively (Table 1). Beverages were prepared by mixing the ingredients and homogenizing at 10.34 MPa (1,500 psi) (Homogenizer, St. Regis CP Division, Series: 3DD13-2941), then pasteurized (62 °C for 30 min), bottled in 250 mL PET flasks, and stored at 4 °C.

Table 1. Formulation of isotonic beverages.

Ingredients	BIUN/BIUH (% w/w)
PUF/hydrolyzed PUF	79.84
Water	14.97
Cape gooseberry (skin and pulp)	2.99
Sucrose	2.00
Stabilizer	0.10
Flavoring	0.10

Physicochemical analysis

Osmolality was determined by cryoscopy procedure and following the NTC 3837 given by ICONTEC (2009), as shown in equation 1:

$$\text{Osmolality}\left(\frac{\text{mOsm}}{\text{kg}}\right)=\left(\frac{\Delta T}{1.858}\right)\times 1{,}000\frac{\text{mOsm}}{\text{kg}} \quad (1)$$

where ΔT is the difference (°C) between the freezing temperature of water and the freezing point of the sample, ΔT was measured with a FUNKE GERBER CryoStar I single sample automatic cryoscope (DIN/ISO/IDF 5764). Determination of pH was measured by potentiometric method, after calibration with buffer solutions of pH=4 and 7 at 20 °C with an OHAUS STARTER 3100 potentiometer (AOAC Method 981.12/90). Acidity was measured by titration (AOAC Method 947.05/90). Total soluble solids (TSS) were expressed as Brix degrees (°Bx) and quantified using a digital refractometer (HI 96801) and following the NTC 4624 given by ICONTEC (1999). Mineral content (calcium, magnesium, potassium, and sodium) was obtained by atomic absorption spectrometry (AOAC 985.35-1988), and total sugars by spectrophotometry UV-VIS (Nielsen 2010). Antioxidant capacity was determined using a modification of the DPPH and ABTS radical cation trapping methods proposed by Bravo et al. (2015). Extraction: 10 g of each sample was taken in a falcon tube and mixed up to 20 mL with solvent (methanol/water, 70:30). The sample was vortexed at 30,000 rpm for 2 min and put in an ultrasonic bath for 10 min, then centrifuged at 8,000 rpm for 15 min. The supernatant was filtered into 25 mL volumetric flasks, completing the volume with solvent. DPPH was determined with 50 µL of the extract were taken in an Eppendorf tube, 950 µL of work solution (0.05 mM DPPH solution) were added, it was stirred at 2,000 rpm in a vortex for 30 s and left to react in darkness for 30 min. The absorbance of the extract was measured at a wavelength of 517 nm using a spectrophotometer (THERMO Scientific, Evolution 60). ABTS was determined with 50 µL of the extract were taken in an Eppendorf tube, 950 µL of work solution (ABTS solution) were added, it was stirred at 2,000 rpm in a vortex and left to react in darkness for 8 min. The absorbance of the extract was measured at a wavelength of 734 nm using a spectrophotometer (THERMO Scientific, Evolution 60). Total phenol content was determined using a modification of the Folin-Ciocalteu reagent method described by Bravo et al. (2015). Finally, 100 µL of the extract were taken in an Eppendorf tube, 400 µL of 0.07 N sodium carbonate solution were added, it was stirred at 15,000 rpm in a vortex, and allowed to stand for 5 min. Then, 500 µL of Folin solution were added and stirred at 15,000 rpm in a vortex. The tube was capped and stored in darkness at room temperature for 2 h. The absorbance of the extract was measured at a wavelength of 760 nm using a spectrophotometer (THERMO Scientific, Evolution 60). Total Carotenoid content was determined using a modification of the method described by Ferreira et al. (2009). A 15 g sample was taken in a falcon tube and stirred with 15 mL of solvent (n-hexane/acetone, 6:4) for 10 min at room temperature and filtered through Whatman No.4 filter paper. The absorbance of the filtrate was measured at a wavelength of 450 nm using a spectrophotometer (THERMO Scientific, Evolution 60).

Microbiological analysis

Counts of total coliforms (AOAC 966.23C 2005), fecal coliforms (AOAC 966.24 2005), aerobic mesophiles (AOAC 988.18 2005), molds and yeasts (AOAC 995.21 2005), and Clostridium sulfite reducer spores (AOAC 972.41 2005) were conducted following the NTC 3837. Analyses were made for two months on beverage samples (BIUH and BIUN) for storage times of 4, 19, 39, and 54 days.

Sensory analysis

The sensory profiles of the beverages were evaluated by the multidimensional approach method, following the Colombian Technical Standards NTC 3501 (ICONTEC 2012), NTC 3932 (ICONTEC 1996), and the Colombian Technical Guides GTC 165 (ICONTEC 2014) and GTC 226 (ICONTEC 2012). A set of relevant descriptors were identified and selected; the intensities were assessed by five trained judges, with an age range between 25 and 60 years. The samples were evaluated under the temperature of 23 °C and relative humidity of 61% (room conditions), and the rating scale from 0 to 5 for all the descriptors was established. Overall quality was rated on a scale from 1 to 3, where 3 is high and 1 is low. Student´s t-test for independent samples was used for statistical analysis.

Statistical Analysis

The study was conducted using a completely randomized design with three replicas. The physicochemical properties of each treatment were followed for two months (days 0, 7, 14, 21, 28, 35, 42, 49, and 56). Bioactive compounds were measured at weeks 0, 4, and 8. Results were analyzed using one-way analysis of variance (ANOVA) with $P<0.05$. Means were compared by the least significant difference method (LSD, $P<0.05$), using Minitab® 19.1.1 (Minitab, LLC., 2021).

RESULTS AND DISCUSSION

Mineral and sugar content

Table 2 shows the results of the proximate analyses. There were statistically significant differences ($P<0.05$) in the content of calcium and magnesium between the two beverages —BIUN and BIUH. This difference may be due to the interaction of calcium and magnesium ions with the enzyme used for the hydrolysis of the BIUH beverage (Zolnere et al. 2017), as well as the effect of additional heat treatment applied to the beverage to inactivate the enzyme (De La Fuente et al. 1999; Rojas Silva 2016).

Ferreira et al. (2020) prepared a beverage based on whey permeate and jaboticaba peel, reporting similar values of total sugars (4.8 g), calcium (34.1 mg), and magnesium (6.2 mg). Hattem et al. (2010) prepared a sports drink from whey permeate added to mango and obtained similar contents of total sugars (6.48 g), calcium (25.1 mg), and magnesium (5.2 mg). In this way, it can be observed that minerals such as magnesium, calcium, potassium, and sodium provided by the sweet whey permeate satisfy the requirements for an isotonic beverage according to Colombian regulations NTC 3837.

Table 2. Content of sugars and minerals in BIUN and BIUH (100 g of beverage).

Component	BIUN	BIUH
Total sugars (g)	5.59±0.87^{a}	5.34±0.37^{a}
Calcium (mg)	28.35±0.64^{a}	32.75±1.06^{b}
Magnesium (mg)	7.10±0.14^{a}	6.50±0.14^{b}
Potassium (g)	0.24±0.16^{a}	0.22±0.12^{a}
Sodium (g)	0.31±0.27^{a}	0.31±0.27^{a}

Average values with different letters present a statistically significant difference ($P<0.05$).

Physicochemical stability

According to Figure 1, the osmolality of the hydrolyzed beverage (BIUH) was higher ($P<0.05$), this is due to the lactose hydrolysis process increasing the concentration of solutes in the beverage. An increase in the osmolality of both beverages was observed over time ($P<0.05$): from 304.83 to 324.13 mOsm kg^{-1} for the BIUN beverage and from 330.1 to 350.53 mOsm kg^{-1} for the BIUH beverage. This increase is due to the usual hydrolysis of sucrose and other more complex carbohydrates present in the samples during storage (Sollanek et al. 2019). Ferreira et al. (2021) obtained similar values to BIUN in osmolarity for an isotonic beverage made from whey permeate and pequi powder.

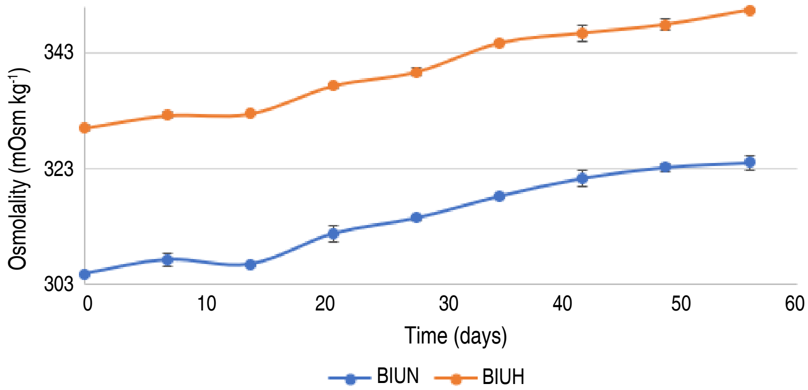

Figure 1. Osmolality stability during storage at 4 °C (confidence intervals).

There were no statistically significant differences (*P*>0.05) in the beverages during the storage time to total soluble solids (TTS). Figure 2 shows that during the first week, there was a slight increase in TSS in the drinks (between 3 and 4%). This can be attributed to the partial enzymatic hydrolysis of complex carbohydrates present in the samples (Naik et al. 2009). In the second week, the values remained stable between 6.9 and 7.1 °Bx for both drinks.

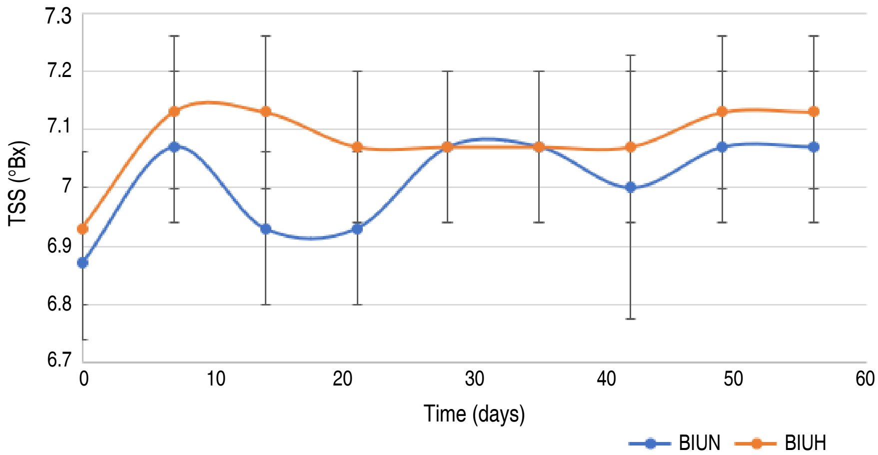

Figure 2. Total soluble solids (TTS) stability during storage at 4 °C (confidence intervals).

According to Figure 3, there were no statistical significance (*P*>0.05) in the lactic acid content in both beverages nor in storage time. It can be seen that the acidity remained around 0.11% v/v lactic acid during the storage time. Naik et al. (2009) reported comparable results in a whey drink added with watermelon pulp, the slight increase in acidity after 30 days of storage was attributed to the conversion of lactose into lactic acid.

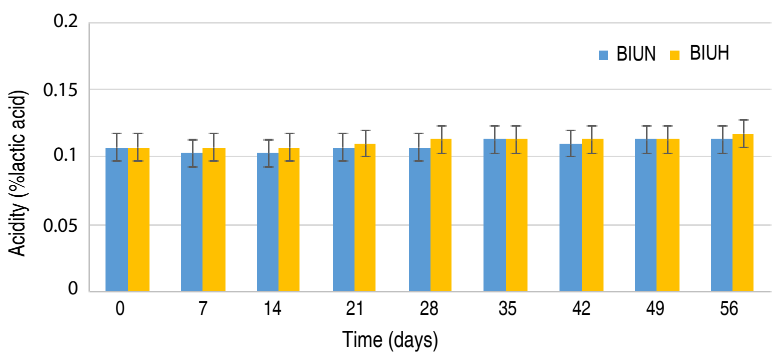

Figure 3. Acidity stability during storage at 4 °C (confidence intervals).

There were statistically significant differences in the pH values during the storage time (*P*<0.05) but not between the two treatments (Figure 4). The variation in pH can be attributed to the formation of lactic acid during storage; it was observed that the pH of the beverages decreased over time (1.1%). These results differ slightly from those reported by Hattem et al. (2010), when studying sports drinks based on whey permeate and mango and strawberry pulp, pH decreased by around 5% in 15 days of storage at 4 °C. Elsabie and Aziz (2011) found a pH decrease of 10% in a beverage based on permeate and sweet potato after three weeks of storage at 7 °C. These differences may be due to better hygiene conditions during the preparation of the beverages and to lower storage temperature.

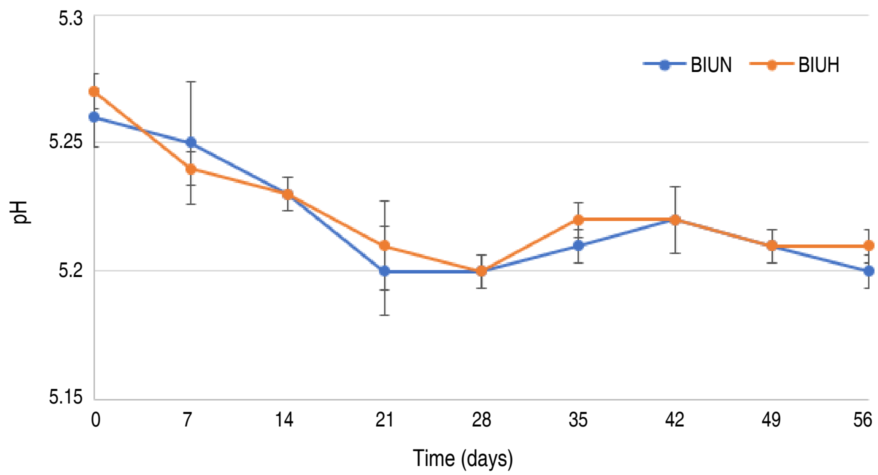

Figure 4. pH stability during storage at 4 °C (confidence intervals).

Bioactive compounds

There were no significant differences (*P*>0.05) in the content of total phenols between the two treatments (Figure 5). The BIUN beverage presented an average content of 9.64 mg-GAE 100 g^{-1}, while the average content in the BIUH beverage was 9.72 mg-GAE 100 g^{-1}. Porfírio et al. (2020) developed a soft drink with jaboticaba (*Plinia cauliflora*) extract obtaining a 5-fold greater amount of total phenols (48.56 mg-GAE 100 g^{-1}), while Atallah (2015) reported a beverage with mango pulp with 50% less total phenols (4.32 mg-GAE 100 g^{-1}) than the developed beverages.

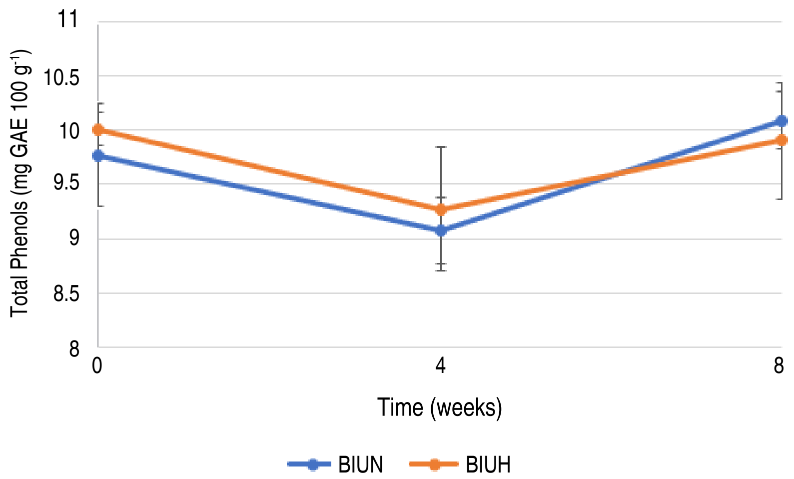

Figure 5. Total phenols stability during storage at 4 °C (confidence intervals).

Statistically significant differences (*P*<0.05) were found in the total carotenoid content of the BIUH beverage throughout the storage time (Figure 6). However, there was no effect due to the hydrolysis treatment of the beverages (*P*>0.05). A decrease in the content of total carotenoids is observed during the study, this may be due to the fact that these chemical compounds are susceptible to oxidation and isomerization reactions during storage, due to their highly unsaturated structure (Ferreira et al. 2021). The total carotenoid content decrease in the non-hydrolyzed beverage was about 20%, while the hydrolyzed beverage showed a decrease close to 34%.

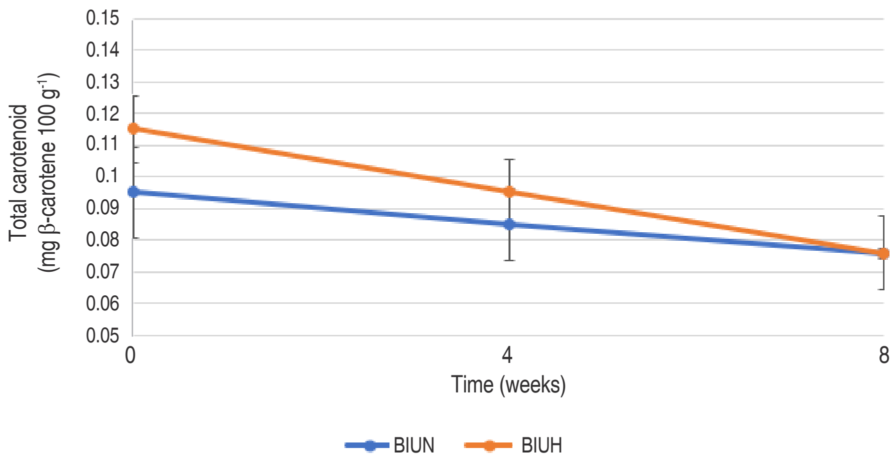

Figure 6. Total carotenoid stability during storage at 4 °C (confidence intervals).

There were no significant differences (*P*>0.05) in the antioxidant capacity, for both DPPH (Figure 7A) and ABTS radicals (Figure 7B) between the two treatments. During storage under refrigeration, there was a decrease of approximately 30 and 12% for DPPH and ABTS radicals, respectively, after the first 4 weeks; between weeks 4 and 8 there were no differences. The decrease in the antioxidant capacity may be due to the relatively low pasteurization temperature, since it may have not been enough to sufficiently inactivate the enzymes of the food matrix, leading to an alteration of the nutritional properties (Santander et al. 2017).

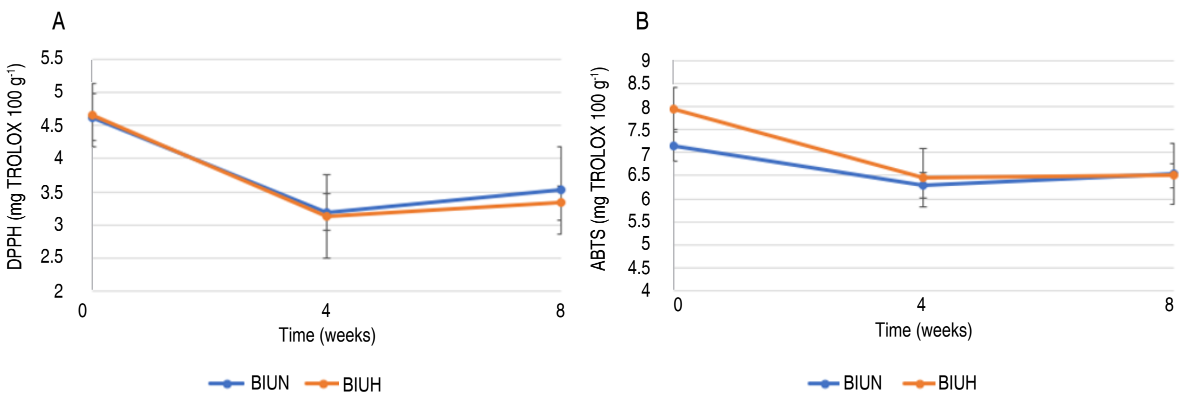

Figure 7. Antioxidant capacity during storage at 4 °C: A. Antioxidant activity by DPPH radical; B. Antioxidant activity by ABTS radical (confidence intervals).

The results found are similar to those reported by Santander et al. (2017), who found that the antioxidant capacity of a whey-based beverage added with tamarillo *(Solanum betaceum)* decreased gradually during storage at 4 °C as storage time increased, and after one month the loss of antioxidant capacity was close to 30%. Other studies such as that of Ferreira et al. (2021) have found that the addition of fruits enriched these types of drinks with nutraceutical components such as antioxidants.

Microbiological stability

According to Table 3, the beverages met the microbiological requirements established in the Colombian technical standard NTC 3837/2009 and normative 2229 (1994) of

Table 3. Microbiological results for isotonic beverages (BIUH and BIUN).

Day	Beverage	Total Coliform count g^{-1}	Escherichia coli count g^{-1}	Aerobic mesophilic count g^{-1}	Molds and Yeasts count g^{-1}	Sulphite-reducing clostridia spore count g^{-1}
4	BIUH	<10	<10	<10	<10	<10
	BIUN	<10	<10	<10	<10	<10
19	BIUH	<10	<10	<10	<10	<10
	BIUN	<10	<10	<10	<10	<10
39	BIUH	<10	<10	<10	<10	<10
	BIUN	<10	<10	<10	<10	<10
54	BIUH	<10	<10	<10	<10	<10
	BIUN	<10	<10	<10	<10	<10

Ministerio de Salud de Colombia. This shows that the use of LTLT (low temperature/long time) pasteurization as heat treatment was sufficient to ensure the safety of both beverages.

Sensory analysis

A set of relevant descriptors that give the maximum information on the sensory attributes of beverages were identified and selected. Aiming to establish a sensory profile, the intensities were assessed by trained judges on a rating scale from 0 to 5 for all the descriptors. Overall quality was rated on a scale from 1 to 3, where 3 is high and 1 is low. Figure 8 shows the sensory profile of the samples.

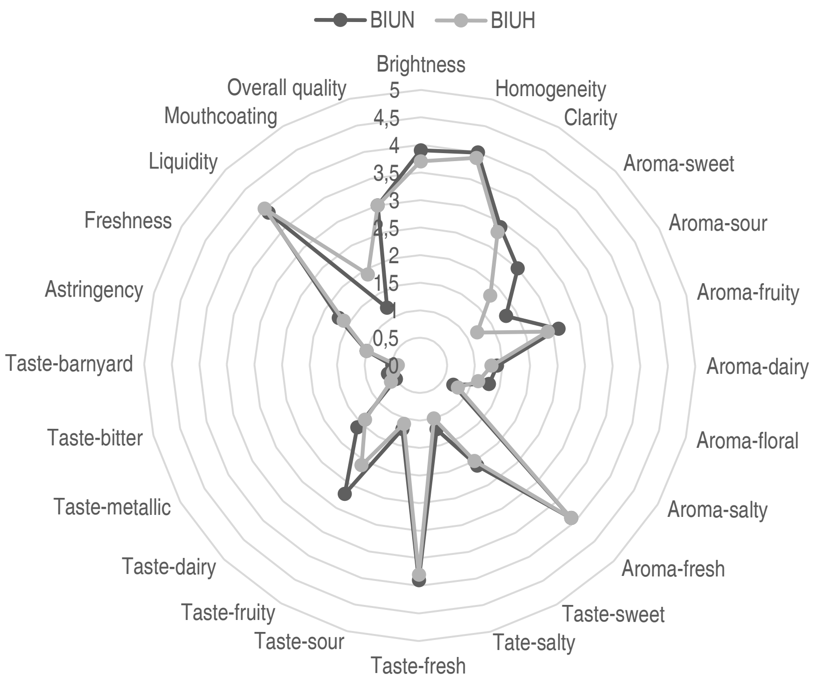

Figure 8. Sensory profile by multidimensional approximation for BIUN vs. BIUH samples.

The BIUN beverage sample presented a fruity flavor of cape gooseberry, yellow fruits, sweet granadilla, and passion fruit, and a balanced flavor. In the first olfactory phase, fruity notes of passion fruit, and dairy, a fruity smell similar to soursop were perceived. The fruity smell was more intense than the taste. The beverage was of high overall quality and had a good balance of notes. The BIUH beverage sample presented fruity notes of cape gooseberry, granadilla, passion fruit, and a slight barnyard flavor that persists over time. The olfactory perception of the fruity attribute was higher than the taste; metallic taste, residual milky notes, and fewer astringent sensations were perceived. Statistically significant differences (P<0.05) were found in the attributes of sweet and sour aromas, fruity flavor, and mouth coating, thus obtaining a higher score for the attributes described above in the non-hydrolyzed isotonic beverage sample. Beucler et al. (2006) and Nemati et al. (2020) compared sensory attributes of hydrolyzed and non-hydrolyzed whey permeate and found significant differences in acid, sweet, and astringent taste.

CONCLUSION

The degree of hydrolysis of the whey permeates significantly affected the osmolality of the beverages, this being higher for the hydrolyzed beverage during the entire storage time. Differences in calcium and magnesium content were also found due to the possible interactions of lactase with these minerals. On the sensory profile, the non-hydrolyzed beverage obtained a higher rating in attributes such as sweet and acid smell, fruity flavor, and mouth coating. During storage, the behavior of the beverages was not affected by the degree of hydrolysis, and both beverages presented good physicochemical and microbiological stability but with a tendency to lower the antioxidant capacity properties.

Given the popularity of sports drinks among teenagers and adults, increasing urbanization rates and the proliferation of fitness centers, future studies can be directed to explore new hydrolytic process in whey together the addition of other fruits and vegetables juices or aromatic herbs.

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