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Development of a beverage from pitahaya *Hylocereus ocamponis* esweetened with yacon (*Smallanthus sonchifolius*) syrup: effect on bioactive compounds and sensy properties

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Abstract

The production of pitahaya (*Hylocereus ocamponis*) in Peru has been increasing due to its health benefits, attributed to its bioactive compounds. On the other hand, yacon (*Smallanthus sonchifolius*), due to its fructooligosaccharides (FOS), presents prebiotic activity with great potential for health. Thus, the objective of the study was to evaluate the bioactive compounds and sensory characteristics of pitahaya juice drink sweetened with yacon syrup, using a Completely Random Design with Factorial Arrangement (3x3), for the dilution of pitahaya juice of 1:2.5, 1:3.0 and 1:3.5 and the concentration of yacon syrup of 30, 40 and 50 °Brix. Vitamin C, total polyphenol compounds, antioxidant capacity, FOS, pH, soluble solids and titratable acidity were evaluated. Sensory characteristics of color, odour, flavor and appearance were also evaluated. The treatment at 50°Brix and 1:2.5 dilution presented a higher content of Vitamin C ($P \leq 0.05$) of 0.589 ± 0.028 mg/100mL, antioxidant capacity 560.9 ± 1.6 µg Trolox/100mL, FOS of 296 ± 0.003 µg FOS/100mL, while the treatment at 30°Brix and 1:2.5 dilution had higher values ($P \leq 0,05$) of 117.9 ± 0.2 mg EAG/100 mL for phenolic compounds and the best sensory characteristics. This study shows that this drink could be a potential functional food.

Keywords: Functional drink, pitahaya juice, yacon syrup, fructooligosaccharides, total polyphenols

Introduction

Currently, consumers are seeking products that contribute to their health and well-being, foods with bioactive compounds (BC), which attribute them pharmacological, nutraceutical, and technological properties. These foods are also referred to as functional foods (León-Roque et al. 2023), whose consumption is constantly increasing, with the aim of preventing diseases, gaining importance due to the benefits conferred to their BC (Montero et al. 2022; Pérez-Gregorio 2021).

In this way, the food and beverage industry currently faces new challenges in designing functional foods, with beverages being one of the categories with the highest acceptance by consumers due to the ease of logistics, distribution, and consumption. Moreover, they are an excellent means of supplying nutrients and BC that can easily be incorporated as functional ingredients (Corbo et al. 2014; Pérez-Gregorio 2021).

Pitahaya is a crop that has increased its production in the arid regions of the world for being a rich source of BC such as polyphenols and betalains (Lira et al. 2023; Luu et al. 2021), which can help reduce the risk of chronic diseases; however, being seasonal, there is no continuous availability of the fruit (Jalgaonkar et al. 2022). Its pulp is used in beverages by adding water or prepared as ice cream (Castro et al. 2018). Currently, there are few processed products derived from pitahaya on the market (Jalgaonkar et al. 2022).

Pitahaya, also known as pitaya or dragon fruit, is the name given to the fruits of the genus Hylocereus, which comprises approximately 16-18 species of cacti native to Central America and the Caribbean, the most common varieties being red and yellow (de Mello et al. 2015; Luu et al. 2021; Vargas Gutierrez y Lopez Montañez 2020).

The red pulp and red shell pitahaya fruit is a variety

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with thorns, unlike other red shell varieties. This species is distributed in the wild on the Pacific slope in Mexico. Its fruits are rich in Vitamin C and other antioxidants, mainly phenolic compounds and betalains (Mercado-Silva 2018). The combination of antioxidants, vitamins, and fiber makes dragon fruit a valuable addition to a balanced diet. It potentially can be used in antidiabetic, anticancer, and nutraceutical preparations, playing a promising role in the development of functional foods (Kumari et al. 2025). Currently, they are cultivated worldwide, especially in Vietnam, China, Israel, and even Australia, being native to the American tropics (Sosa et al. 2020). Its original distribution ranges from Mexico to Peru and Bolivia; most of its species are found in southern Mexico and northern Central America (Mercado-Silva 2018).

In Peru, in recent years, pitahaya production has increased due to the benefits conferred by its CBs. However, there are few studies on its phenolic compounds, flavonoids, vitamins, as well as its antioxidant capacity in products such as drinks based on this fruit.

On the other hand, the yacon (*Smallanthus sonchifolius*) is native to the Andean region and has spread throughout South America, Europe, and Japan (Paredes et al. 2018). In South America, it is cultivated in Colombia, Peru, Ecuador, Bolivia, Argentina, and Brazil. It has a sweet flavor (Simanca-Sotelo et al. 2021) and belongs to the botanical family Asteraceae. It contains a high content of carbohydrates and differs from most roots by containing, in addition to the most common carbohydrates, fructooligosaccharides (FOS), approximately 37% on a dry basis (MS) of its root (Paredes et al. 2018). The importance of FOS is that they are not hydrolyzed by human digestive enzymes, which is why they are classified as dietary fiber (Kumari et al. 2025)0. Short-chain FOS are called fructans (Kumari et al. 2025)1, which are considered prebiotics for stimulating the selective growth of bacteria in the colon (Kumari et al. 2025)2. However, there are few studies with yacon that report FOS content and the use of this raw material in beverages.

Therefore, the present work aimed to formulate a drink from different concentrations of pitahaya juice (Kumari et al. 2025)3, sweetened with yacon syrup (Kumari et al. 2025)4, as well as studying the effect of the formulations on their BCs, antioxidant capacity, and sensory characteristics.

Materials and Methods

Chemicals

All chemical reagents were of analytical or reagent grade, Potassium hexacyanoferrate (II) trihydrate, Zinc acetate dihydrate, 96% ethanol, 3,5-Dinitrosalicylic acid, Rochelle salt (tartrato de sodio y potasio tetrahidratado), citric acid were acquired from Merck. Folin-Ciocalteau, glucose standard, ascorbic acid, 2,6 – Dichlorophenolindophenol, 2,2 – Diphenyl - 1 - picryl - hydrazyl (DPPH), 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox) were acquired from Sigma Aldrich.

Plant materials

The yacon was acquired from the district of Molinopampa and the pink-skinned, pink/red-pulped pitahaya from the district of Churuja, province of Chachapoyas, department of Amazonas, Peru.

The yacon roots were received, weighed, selected, and classified, then washed with a jet of water to remove the soil covering the roots and submerged in a solution of 200 ppm of sodium hypochlorite. The peeled samples were submerged in a solution of 0.13% ascorbic acid, blanched at 65°C/5 min, and then the juice was extracted by separating the pulp from the bagasse. It was filtered to separate the coarse particles from the juice and the yacon syrup was concentrated (YS) until obtaining soluble solids (SS) of 30 °Brix (B30), 40 °Brix (B40), and 50 °Brix (B50).

The commercially mature pitahayas were received, weighed, selected, classified, washed with a jet of water, and disinfected at 200 ppm with sodium hypochlorite. They were peeled, the juice was extracted, filtered to remove the seeds and coarse particles, resulting in concentrated pitahaya juice.

Beverage preparation

For the formulations, a Completely Random Design (DCA) with Factorial Arrangement (3x3) was applied, with factor A being yacon syrup (YS) concentrated at 3 levels of °Brix 30, 40, and 50, and factor B being the dilution of pitahaya juice (DPJ) at 3 levels of (juice:water) D1:2.5; D1:3.0; D1:3.5, resulting in a total of 9 formulations (YS30_D1:2.5; YS30_D1:3.0; YS30_D1:3.5; YS40_D1:2.5; YS40_D1:3.0; YS40_D1:3.5; YS50_D1:2.5; YS50_D1:3.0; YS50_D1:3.5). Finally, the formulations were standardized, homogenized, and pasteurized at 90°C/10 min, packaged and sealed at 85°C, cooled, and stored.

Physicochemical analysis of yacon juice, the pH was determined by potentiometry using the AOAC 981.12 – ISO 11289:1993 method. The titratable acidity was determined by titrimetry using the AOAC942.15(2012) method, and the determination of SS (°Brix) was measured following the AOAC 932.12 – ISO 2173:1978 –

Refractometry method.

Vitamin C quantification

The 2,6-dichlorophenolindophenol method (cromóforo) by UV-visible Spectrophotometry (Spectrophotometric method, ISO 6557/2:1986), a modification of the original method that spectrophotometrically measures absorbance at 520 nm, is based on the ability of ascorbic acid to reduce the chromophore. Ascorbic Acid (AA) was used as a standard at concentrations of 1 to 5 ppm, Vitamin C was expressed as mg of AA in 100 mL of beverage (mg AA/100 mL) using the equation of the line obtained from the standard y = 0.0442x + 0.0153 and R2 = 0.9917.

Total phenolic compounds

Total polyphenols were determined by UV-Vis Spectrophotometry using the Folin-Ciocalteau reagent (Singleton, Vernon; Orthofer, Rudolf; Lamuela-Raventós, 1999). Prior to this, a calibration curve was constructed, and absorbances were obtained at 765 nm. Gallic acid was used as a standard (2 – 20 ppm), yielding the equation y = 0.0184x + 0.0075 and R2 = 0.991. The results are expressed in mg of equivalent gallic acid (AGE) per 100 mL of beverage (mg AGE/100 mL).

Antioxidant capacity against DPPH

The antioxidant capacity against DPPH (2,2-difenil-1-picrilhidrazilo) was measured using the method described by Brand-Williams et al. (1995) with some modifications. The results were expressed in µg Trolox/100mL of beverage, estimated using a calibration curve with Trolox as the standard (50 mg/100 mL) with the straight-line equation y = -0.00192x + 0.4027 and R2 = 0.9951. For this, aliquots of the Trolox standard (0.1 – 0.6 mL) were taken and 6.25 mL of the DPPH solution (40 ppm) was added. It was then incubated in a water bath with agitation at 37 °C for 2 hours, and the reading was taken at 517 nm on the UV-Vis spectrophotometer.

Fructooligosaccharides quantification (FOS)

The FOS were determined by the method described by Vargas (2009), glucose (G) and fructose (F) were quantified as direct reducing sugars (DRS) using the Miller method (1959). Glucose was determined by the Trinder method (1969), fructose was determined by the difference between A DRS and G

$$DRS_L = G_L + F_L \quad (1)$$

$$F_L = DRS_L - G_L \quad (2)$$

Where the subscript (L) indicates the species in a "free" state.

To quantify the FOS, the DRS as well as glucose (G) and fructose (F) were quantified. From this, the Average Degree of Polymerization (ADP) of the FOS and the Average Molecular Weight (AMW) were determined.

$$ADP_{FOS} = (F_{FOS} + G_{FOS}) / G_{FOS} \quad (3)$$

$$AMW_{FOS} = ADP_{FOS} \times 162 \quad (4)$$

162 = Molecular weight of each of the glucose or fructose residues that make up the polymer.

Sensory analysis

The sensory analysis was conducted with 8 trained panelists evaluating the attributes of color (copper, coffee, amber, dark green), odour (of caramel, of syrup, odorless), flavor (sweet, bland and astringent) and appearance (Cloudy and clean) of the beverage. The attributes that judged characteristics of each beverage were evaluated, using a 9-point hedonic scale. A Completely Randomized Block Design was applied, through a two-way ANOVA, followed by the application of Tukey's multiple comparison of means test. All statistical evaluations were conducted at a significance level ($P \leq 0.05$).

Statisticall analysis

The two-way (as explained in the item Beverage preparation) analysis of variance (ANOVA) was applied for the factorial experiment, followed by the Tukey test where significance was found ($P \leq 0.05$). Then Principal Component Analysis (PCA) was performed, the PCA was applied after standardizing the variables to avoid the effect of different units of measurement. Hierarchical clustering of the principal components was then performed (HCPC), which consists of grouping based on the principal components. Finally, a Pearson correlation network was executed to understand the possible relationships between the response variables.

The statistical analyses were performed in the R program (A Language and Environment for Statistical Computing).

Results and Discusion

Características fisicoquímicas del jugo de yacón y pitahaya

The SS of yacon juice was 9.89±0.82 °Brix, this value falls within the range according to Perussello et al. (2014), who reported SS contents for yacon from 9 to 12 °Brix. Gonzáles-Marlo et al. (2019) also had similar results of 9 °Brix. The titratable acidity (TA) was 0.410%±0.052, which was higher than reported by Perussello et al. (2014) and the pH of 5.24±0.067 was lower than reported (**Table1**).

Table 1. Physicochemical characteristics of yacon and pitahaya juice

Characteristic	Yacón juice	Pitahaya juice
Titratable acidity (%)	0.410±0.052 a	0.294±0.035 b
pH	5.24±0.07 a	5.00±0.11 b
Soluble solids (SS-°Brix)	9.89±0.82 b	14.89±0.33 a
Maturity index	24.69±5.07 b	51.15±5.52 a

Mean ± SD (n = 3), different letters in the same line indicate difference (P ≤ 0.05) between yacon and pitahaya juice, by the T-test for independent samples.

The pitahaya juice had a pH of 5.00±0.11 and TA of 0.294%±0.035, these values were similar to those reported by Santarrosa (2013), of 4.65 for pH and 0.111% for TA. These values were also similar to the pH and TA of the white pulp and pink shell varieties from India Hirehalli white of 4.80±0.2 pH and 0.23%±0.12 TA and the Andaman white variety of 4.93±0.2 pH and 0.18±0.06 TA but differ from the red pulp and pink shell variety from India of Hiriyur red with pH values of 5.37±0.1 and 0.10%±0.01 TA and Kagwada red of pH 5.20±0.0 and 0.12%±0.02 TA reported by Arivalagan et al. (2021) and to the pH of 5.54± 0.04 in red pitahaya pulp Hylocereus polyrhizus reported by Nur et al. (2023).

On the other hand, the soluble solids (SS) of the studied pitahaya juice had values of 14.89±0.33°Brix. These values were similar to those reported by Mercado-Silva (2018) who also worked with pitahaya pulp but of the Hylocereus undatus variety, obtaining 12 to 14 °Brix of SS. However, these values were higher than those reported by Nur et al. (2023) of SS 10.78±0.20 °Brix. Meanwhile, other authors who worked with fresh whole fruit obtained lower values, for example, Arivalagan et al. (2021) obtained 9.20±0.82 °Brix for whole Hiriyur red fruit and 10.2±2.0 for Kagwada red.

According to Dasenaki Thomaidis (2019), total soluble solids (which includes dissolved sugars, organic acids and other soluble materials present in fruit) are parameters of sweetness that influence consumer acceptability. This corroborates the results of our pitahaya drink sweetened with yacon syrup.

Physicochemical beverage characterization

The concentration of yacon syrup (YS) and dilution of pitahaya juice (DPJ) influenced (P≤0.05) the pH and TA. When we evaluated the interactions, for pH, it was observed that DPJ did not influence (P>0.05) within each Brix level, on the other hand, the increase in YS concentration promoted an increase in pH compared within the same dilution (**Table 2**). Regarding the TA, its value decreases (P≤0.05) with the increase in dilution, on the other hand, TA generally increases with the increase in dilution.

These three parameters (pH, SS y TA) were within the acceptable limits by the Peruvian Technical Standard

Table 2. Physicochemical characterization of the pitahaya drink sweetened with yacon syrup.

concentration of yacon (°Brix)	Dilution of pitahaya juice (juice:wather)	pH	Soluble solids (°Brix)	Titratable acidity (%)
30	D1:2.5	4.13 ± 0.03 B;a	13.17 ± 0.29 A;a	0.427 ± 0.015 AB;a
30	D1:3.0	4.11 ± 0.02 B;a	13.13 ± 0.23 A;a	0.375 ± 0.015 A;ab
30	D1:3.5	4.08 ± 0.02 B;a	12.67 ± 0.29 B;a	0.341 ± 0.015 A;b
40	D1:2.5	4.07 ± 0.02 C;a	13.07 ± 0.4 A;a	0.401 ± 0.015 B;a
40	D1:3.0	4.16 ± 0.02 A;a	13.33 ± 0.29 A;a	0.393 ± 0.015 A;a
40	D1:3.5	4.16 ± 0.02 A;a	13.28 ± 0.26 AB;a	0.35 ± 0.03 A;b
50	D1:2.5	4.18 ± 0.02 A;a	13.37 ± 0.22 A;a	0.444 ± 0.03 A;a
50	D1:3.0	4.17 ± 0.02 A;a	13.42 ± 0.52 A;a	0.401 ± 0.015 A;b
50	D1:3.5	4.19 ± 0.02 A;a	13.43 ± 0.51 A;a	0.367 ± 0.015 A;b

Mean ± SD (n = 3). Different uppercase letters in the same column indicate a difference (DPJ) between the °Brix within the same dilution, by the Tukey test. Different lowercase letters in the same column indicate a statistical difference (DPJ), between the dilutions of pitahaya juice, within each level of °Brix of YS by the Tukey test.

Table 3. Bioactive compounds of the pitahaya drink sweetened with yacon syrup.

concentration of yacon (°Brix)	Dilution of pitahaya juice (juice:wather)	Vitamin C (mg/100mL)	Total phenolic compounds (mg EAG/100 mL)	Antioxidante capacity – DPPH (µg Trolox/100mL)	Fructooligosaccharides (ug FOS/100mL)
30	D1:2.5	0.498 ± 0.019 B;a	117.9 ± 0.2 A;a	514.9 ± 1.3 B;a	272 ± 0.01 B;a
30	D1:3.0	0.366 ± 0.025 B;b	108.7 ± 0.16 B;a	451.4 ± 1 C;b	257 ± 0.003 B;a
30	D1:3.5	0.301 ± 0.077 B;b	100.0 ± 0.1 C;a	433.1 ± 1.8 C;c	173 ± 0.01 B;c
40	D1:2.5	0.496 ± 0.016 B;a	106.1± 0.1 A;b	461.4 ± 1.3 C;a	25 ± 0.005 C;a
40	D1:3.0	0.426 ± 0.012 AB;b	98.5 ± 0.2 B;b	494.3 ± 1 B;b	257 ± 0.004 B;b
40	D1:3.5	0.353 ± 0.008 AB;c	91.0 ± 0.1 C;b	483.8 ± 1.7 B;c	199 ± 0.004 A;c
50	D1:2.5	0.589 ± 0.028 A;a	98.0.2± 0.2 A;c	560.9 ± 1.6 A;a	296 ± 0.003 A;a
50	D1:3.0	0.483 ± 0.008 A;b	92.6 ± 0.1 B;c	533.5 ± 1.3 A;b	28 ± 0.002 A;b
50	D1:3.5	0.416 ± 0.039 A;b	85.6 ± 0.1 C;c	499.3 ± 2.1 A;c	204 ± 0.012 A;b

Average ± SD (n = 3). Different uppercase letters in the same column indicate a difference (p ≤ 0.05) among the °Brix within the same dilution, according to the Tukey test. Different lowercase letters in the same column indicate a statistical difference (p ≤ 0.05), among the dilutions of pitahaya juice, within each level of °Brix of YS according to the Tukey test.

for Juices, Nectars, and Fruit Drinks (NTP 203.110) INDECOPI (2009), which establishes in its specifications for fruit drinks a pH<4.5, and a minimum of 10 °Brix of SS.

In general, it is observed that formulations with higher Brix values of YS and lower dilutions of DPJ presented the highest values of BCs ($p \leq 0.05$), this shows the significant contribution in BCs by pitahaya and yacon (**Table 3**).

The YS50_D1:2.5 formulation presented the highest value of Vitamin C (0.589±0.028 mg/100mL), and AC (560.9±1.6 µg Trolox/100mL), FOS (296±0.003 µg FOS/100mL). The YS30_D1:2.5 had the highest content of TPC (117.9±0.2 mg EAG/100 mL), our values were higher than those of Arivalagan et al. (2021), who reported for pitahaya with white and red pulp of pink foot TPC from 25 to 55 mg of GAE/100 g of fruit and a maximum of Vitamin C of 6 mg in 100 g of fruit, Nur et al. (Vit. C, TPC, AC, e FOS)0 reports for Vitamin C in red pulp of red shell pitahaya Hylocereus polyrhizus of 10.06±0.46 mg/100 g.

Studies conducted by Angonese et al. (2021) on two species of organic pitahayas, Hylocereus undatus and Hylocereus polyrhizus found in fruits with purple pulp a higher content of bioactive compounds, where its phenolic content is related to positive health effects. This was corroborated by Yen et al. (Vit. C, TPC, AC, e FOS)2 who developed a fruit bar based on pitahaya rich in bioactive compounds being a nutritious product. (Vit. C, TPC, AC, e FOS)3 also studied the nutritional and biochemical composition of these fruits concluding that it is an ideal fruit to maintain good health. (Vit. C, TPC, AC, e FOS)4 studied several species of pitahaya for their health benefits

Beverage sensory evaluation

The pitahaya beverage sweetened with yacon syrup was well received sensorially for its color, odour, flavor, and appearance attributes (**Table 4**). There was little difference ($p \leq 0.05$) between the formulations, especially for odour and flavor.

When evaluating the intensity of the different sensory characteristics of color (copper, coffee, amber, dark green), odour (of caramel, of syrup, odorless), flavor (sweet, bland and astringent), and appearance (Cloudy and clean), it was observed that there was no intensity difference between each of them (**Figure 1**c), in the treatments where these were detected.

Regarding color, according to the intensity, the beverage presented a coffee to amber color with a moderate to high intensity, some formulations presented a copper color with a moderate to high intensity. In terms of odour, the beverage presented a syrup odour followed by a caramel odour with a moderate to high

Table 4. Sensory characteristics of the pitahaya beverage sweetened with yacon syrup.

Treatments	Intensity of the Sensory Characteristics											
	Color Copper	Color coffee	Color amber	Color dark green	Odour of caramel	Odour of syrup	Odorless	Sweet flavor	Bland flavor	Astringent flavor	Cloudy appearance	Clean appearance
YS30_D1:2.5	6 ± 1.73 a	7.5 ± 0.71 a	6.7 ± 2.08 a		8.3 ± 0.5 ab	6.5 ± 2.12 a	3.5 ± 2.12 a	9 ± a		6.5 ± 0.71 a	6.4 ± 1.9 a	
YS30_D1:3.0		5.6 ± 2.07 a	5.3 ± 2.31 a		8.2 ± 1.3 a	5.5 ± 2.12 a	2.5 ± 0.71 a	7 ± 1.41a	6 ± 2.83 a			6.5 ± 2.12 a
YS30_D1:3.5	6.6 ± 1.6 a				7 ± 2.65 ab	7.7 ± 0.58 a	3 ± 2.83 a	6.25 ± 1.5a	7.5 ± 0.71 a		6.9 ± 1.86 a	
YS40_D1:2.5		7.5 ± 0.71 a	6.5 ± 1.91 a	5.3 ± 2.08 a	6.8 ± 1.92 ab	7.5 ± 0.71 a	2.5 ± 0.71 a	6.5 ± 2.38a	3.5 ± 0.71 a		7 ± a	6 ± 2.65 a
YS40_D1:3.0		6.7 ± 2.08 a	7 ± 2.16 a	4 ± 1 a	5.3 ± 2.52 b	7 ± 2.16 a	1.5 ± 0.71 a	7.67 ± 1.53a	3.5 ± 0.71 a		7 ± 0 a	3.5 ± 0.71 a
YS40_D1:3.5	6.5 ± 0.71 a	6.3 ± 2.52 a	5.8 ± 2.22 a		6 ± ab	7.5 ± 1.29 a	4 ± 2.65 a	7.2 ± 1.1a	4.7 ± 2.08 a	5.5 ± 0.71 a	7.5 ± 0.71 a	
YS50_D1:2.5	7.3 ± 1.53 a	4.5 ± 0.71 a	5.5 ± 2.12 a	3.5 ± 0.71 a	5.7 ± 2.08 b	6 ± 1 a	3.5 ± 2.12 a	7.5 ± 0.71a	7.5 ± 0.71 a		5.6 ± 1.67 a	
YS50_D1:3.0	6.3 ± 1.15 a	7.5 ± 1.29 a	9 ± a		6.5 ± 0.71 ab	7 ± 0.82 a	2.5 ± 2.12 a	8.5 ± 0.71a		6.5 ± 2.12 a	6.6 ± 1.99 a	
YS50_D1:3.5	7 ± 0 a	6.8 ± 0.96 a	7.5 ± 2.12 a		7.3 ± 1.15 ab	6.3 ± 1.53 a	2.5 ± 0.71 a	7 ± 1a			5 ± 1.73 a	6.5 ± 0.71 a

Intensity of sensory characteristics: 1=Low intensity and 9=High intensity. Different lowercase letters in the same column indicate statistical difference ($p \leq 0.05$) among treatments.

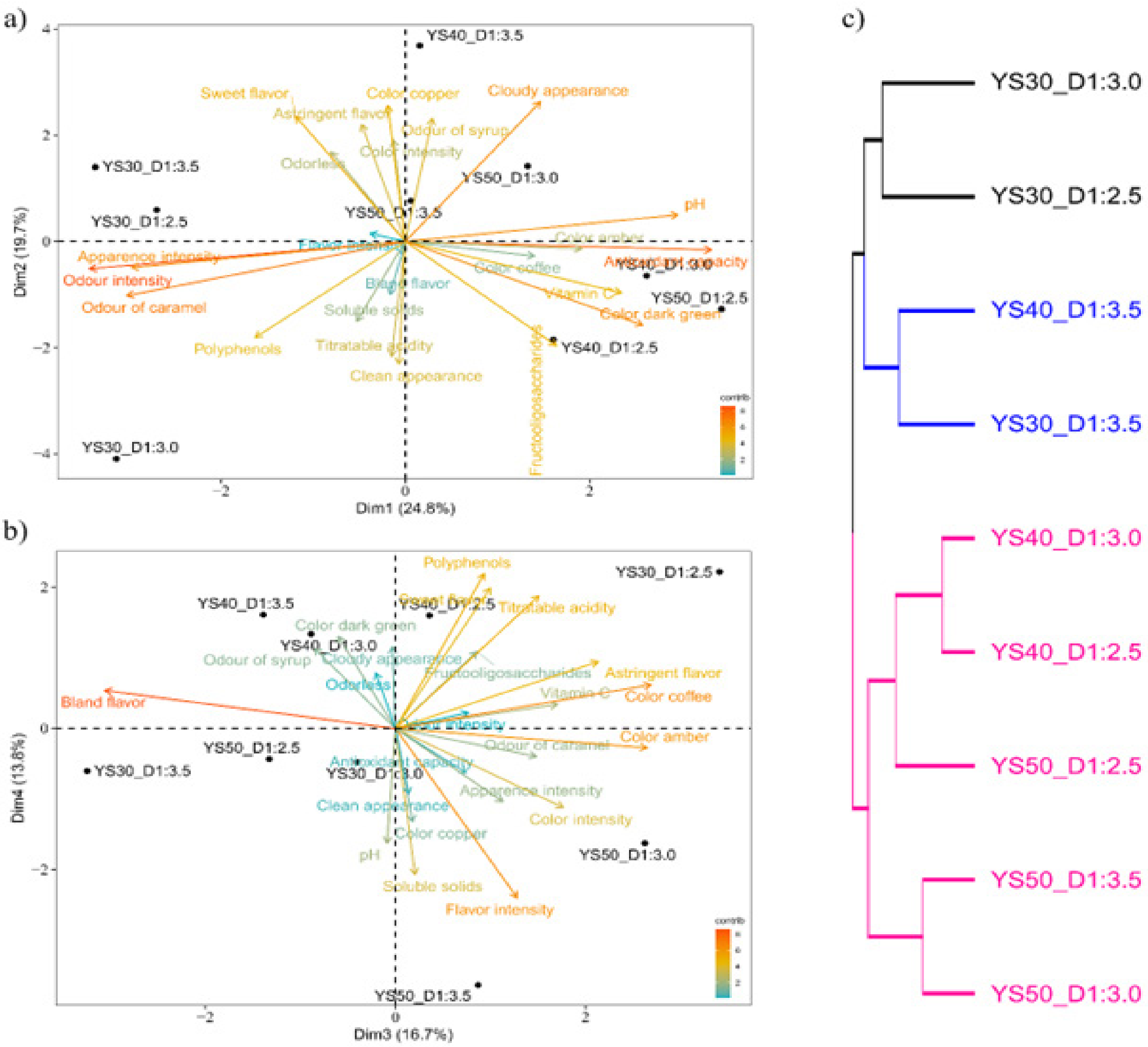

Figure 1. Biplot of Principal Component Analysis (PCA) to PC1 and PC2 (a), Biplot of Principal Component Analysis (PCA) to PC1 and PC2 (b), and Hierarchical Clustering of Principal Components (HCPC). In samples: YS30, YS40, and YS50 represent yacon syrup concentrations (YS) of 30, 40, and 50 Brix grade respectively. D1:2.5, D1:3.0, and D1:3.5 indicate pitahaya juice dilutions (DPJ) of 1:2.5, 1:3.0, and 1:3.5 (juice: water).

intensity and an odorless odour at a low intensity, finding a difference between the treatments. In terms of flavor, the beverage is sweet with a moderate to high intensity, finding a difference between the treatments, and in appearance, the beverage is slightly cloudy to cloudy with a moderate to high intensity, finding a difference between the treatments.

These results show the potential use of pitahaya sweetened with yacon for the production of beverages and thus achieve functional products as new options for the market.

Recent studies reported by Lim et al. (2025) indicate that functional beverages are the most active, largest, and fastest-growing sector of the functional food industry, being a product that allows the incorporation of various ingredients and bioactive compounds. Similarly, dragon fruit extract can also be used to prepare fermented beverages and natural carbonated probiotic drinks (Kumari et al. 2025). In another study, Miglioranza et al. (2024) used extracts from the red pulp and the pitahaya peel to produce fermented products such as kombucha.

Multivatiate analysis

In the PCA (Figura 1a y 1b), it was observed that the YS30_D1:3.0 formulation presented higher values in odor, titratable acidity, and clear appearance polyphenols. Meanwhile, YS30_D1:2.5 had a stronger odor, presenting a caramel odor with a score of 8, these formulations also presented close values of total polyphenol compounds, and intensity in appearance with an average score of 6.8 represented with the orange vector and showed no statistical difference between the SS component, as well as in the sensory characteristics of flavor with a low score of 4 represented by the sky-blue color, finally, these formulations formed the same group (figure 1c) due to the previously highlighted characteristics.

It can be observed that the formulations YS40_D1:3.5; YS30_D1:3.5 also formed another group (blue), presenting similar values of color, odor, and appearance, the intensity of the odor presents a score of 7.5 with a syrup odour and a score of 6.5 in the copper color represented, regarding the BCs for these two formulations, very similar values of total polyphenol compounds, Vitamin C, antioxidant activity, as well as pH, TA, and SS were detected, there was no difference between this grouping.

A third group (Figure 1a, 1b y 1c) was formed by the formulations YS40_D1:3.0; YS40_D1:2.5; YS50_D1:2.5; YS50_D1:3.5 and YS50_D1:3.0 who were characterized by presenting a brown, copper, and amber color with scores from 6 to 7 and dark green color with lower scores from 3 to 5, and closer values of vitamin C and antioxidant activity, there was no difference between the physicochemical characteristics pH, TA, and SS, Figure 1.

Finally, the attributes that allowed the panelists to detect differences between the samples were color, odor, and appearance represented with the red vector, while the flavor did not allow differences in the samples represented by the orange vector.

Figure 2 presents a correlation network, showing a positive correlation between Vitamin C vs FOS (r=0.72) and vs Antioxidant Capacity (r=0.8). On the other hand, pH vs titratable acidity showed a positive correlation of 0.76. A high correlation is also observed between amber color vs coffee color of 0.94, as well as between the intensity of odour vs coffee color with a high correlation of 0.9. The astringent flavor had a moderate positive correlation with sweet flavor, and the sweet flavor had a negative correlation with the flavor.

The synergistic effect between acidity and total SS in fruits, enhances their acceptability among consumers.

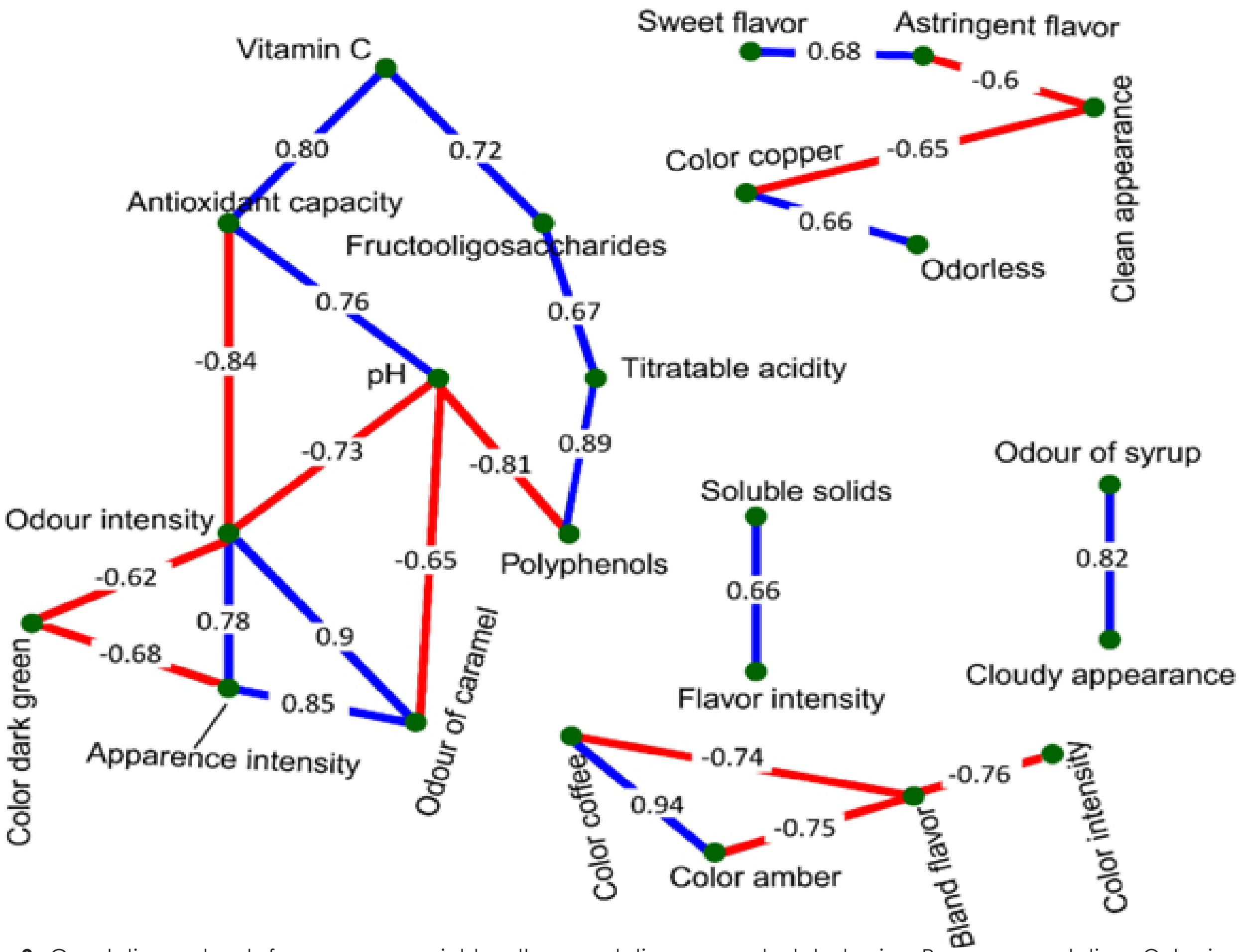

Figure 2. Correlation network for response variables, the correlation was calculated using Pearson correlation. Only significant correlations are presented.

Conclusion

The results demonstrate that the beverage formulated based on diluted *Hylocereus ocamponis* pitahaya juice at juice:water levels of 1:2.5, 1:3.0, and 1:3.5, and sweetened with yacon syrup (*Smallanthus sonchifolius*) at concentration levels of 30, 40, and 50 °Brix contains bioactive compounds (Vitamina C, polifenoles totales, capacidad antioxidante y fructooligosacáridos). The treatment with YS at 50°Brix and DPJ of 1:2.5 presented the highest value for Vitamin C, Antioxidant activity, and FOS. The treatment with YS at 30°Brix and DJP of 1:2.5 had the highest content of PTC. Regarding sensory characteristics, the treatment that presented the best color, odour, flavor, and appearance according to the panelists was YS50_D1:2.5 (YS 50°Brix y DPJ 1:2.5), a beverage that showed no significant difference ($p \leq 0,05$) with the treatment YS30_D1:2.5, which had the highest content in bioactive compounds and with the physicochemical characteristics of 4.19 ± 0.02 pH, SS of13.45 ± 0.48 |Brix, and TA of 0.375 ± 0.015%.

The technological parameters of the beverage were pasteurization at 90°C/10 min, packaging and sealing at 85°C, and cooling at room temperature.

Conflict of interests

The authors declare no conflict of interest associated with this study.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.