International Journal of Agriculture and Biosciences 2025 14(1): 22-30.
https://doi.org/10.47278/journal.ijab/2024.199

RESEARCH ARTICLE eISSN: 2306-3599; pISSN: 2305-6622

Development of a Functional Drink based on the Yellow Variety Arracacha (*Arracacha xanthorrhiza*): Physicochemical, Techno-functional and Sensory Properties

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ABSTRACT

The objective of this research was to determine the physicochemical, techno-functional, and sensory characteristics of a functional arracacha drink made by solid-state fermentation with *Pleurotus ostreatus*. The physicochemical and techno-functional properties were evaluated in flours of different sizes, with and without solid-state fermentation, and in the final beverages. The drinks were sensory evaluated using Check All That Apply (CATA) and acceptability questions with 84 consumers. A completely random design was used for the fermentation process with the raw material at different particle sizes and a 2x3 factorial design for preparing the functional arracacha drink. The results indicated that the particle size (1.18 and 2mm) and the solid-state fermentation significantly influenced the physicochemical characteristics and technofunctional properties. Regarding the functional arracacha drink, neither the particle size (1.18mm and 2mm) nor the concentrations (50, 75, and 100%) had a significant effect on the pH, °Brix, and density. However, there was a significant effect on bioactive compounds, with the final 100% solid-state fermentation samples showing greater antioxidant capacity and polyphenol content. In the sensory evaluation, the arracacha functional drinks with the greatest acceptability were the solid-state fermentation samples of 1.18mm at 50% and 2mm at 75%, characterized by having attributes such as balanced, sweet, refreshing/fresh and pleasant flavor. In conclusion, a techno-functional drink was obtained using 75% arracacha solid state fermentation with a particle size of 2mm, with adequate physicochemical, techno-functional and sensory characteristics.

Keywords: Arracacha; Acceptability; Bioactive; Technofunctional; Sensory

Article History
Article # 24-696
Received: 07-Jul-24
Revised: 17-Aug-24
Accepted: 11-Sep-24
Online First: 09-Dec-24

INTRODUCTION

Currently, there is a growing demand for functional products due to concerns about food quality and the changing lifestyle of modern society (Gul et al., 2016). Functional foods are known to provide beneficial health effects, preventing various diseases such as anemia, diabetes, gout, cancer, and cardiovascular diseases. Additionally, they help combat skin wart issues, improve neurological function, promote good digestion, and serve as powerful antioxidants that strengthen the immune system (Aguilera et al., 2011).

The Andean region of Peru is home to a variety of underutilized root crops that offer great potential for diversifying the local diet and improving food security. Among these lesser-known roots are arracacha, ahipa, and achira, which have a wide range of culinary applications and economic advantages due to their adaptability and ease of propagation (Hermann & Heller, 1997). These Andean root crops, which are little known and consumed by the local population, have the potential to contribute to the development of functional foods with unique nutritional profiles and health benefits. Their wide range of culinary uses, economic accessibility, and adaptability to different growing conditions make them valuable resources for promoting dietary diversity and improving the health and well-being of Andean communities.

Cite this Article as: Medina-Pérez S, Pérez-Falcón LF, Rivera-Ashqui TA and Silva-Paz RJ, 2025. Development of a functional drink based on the yellow variety arracacha (*Arracacha xanthorrhiza*): physicochemical, techno-functional, and sensory properties. International Journal of Agriculture and Biosciences 14(1): 22-30. https://doi.org/10.47278/journal.ijab/2024.199

A Publication of Unique Scientific Publishers

These roots are primarily consumed in their natural state, without undergoing any processing. Additionally, there is limited information regarding the origin of these roots. Arracacha, in particular, holds significant importance for rural inhabitants, as its cultivation throughout the year generates job opportunities and economic income. This characteristic enables food processing companies to produce functional, innovative, competitive, and consumer-acceptable products (Leidi et al., 2018). Moreover, arracacha is easily digestible due to its small starch granules, which consist of both amylase and amylopectin. It boasts a high nutritional value, being rich in calcium, phosphorus, iron, niacin (vitamin B3), vitamin A, pyridoxine (B6), riboflavin (B2), ascorbic acid, proteins, fibers, and carbohydrates. These attributes confer upon arracacha a nutritional potential that surpasses that of other staple foods, such as potatoes and cassava (Castanha et al., 2018).

Research on the preparation of beverages using roots and solid-state fermentation (SSF) has yielded promising results. García & Pacheco-Delahaye (2010) created a powdered drink incorporating folic acid, which demonstrated favorable physicochemical and functional characteristics, including in vitro starch digestibility and shelf life. The formulation comprised 30.30% arracacha flour, 42.32% whole milk, 27.22% sugar, and 0.16% vanilla, resulting in high protein, mineral, and dietary fiber content. Similarly, Reyes-Moreno et al. (2014) developed a nutraceutical drink with antioxidant, antihypertensive, and antimutagenic properties from a blend of 60% extruded corn flour and 40% fermented beans, achieving a high antioxidant activity of 15,337μmol Trolox/100 g and significant inhibition of antihypertensive capacity at concentrations of 500 and 1000 μg/tube. Milán-Carrillo et al. (2017) produced a functional drink with high nutritional value and potential antihypertensive and antidiabetic effects from a 60:40 mixture of whole blue corn and black bean flours, fermented at 37°C for 90 h and 38°C for 100 h. A 200mL serving provided 34.2 and 23.4% of daily protein requirements for children aged 1 to 3 and 4 to 8 years, respectively, and 90-150% of the recommended daily intake of antioxidants. Martínez (2017) utilized lignocellulosic residue from bean hulls and barley grains to cultivate the edible fungus *Pleurotus ostreatus* under controlled conditions. Guerrero & Yépez (2018) produced a vodka-type alcoholic beverage from Andean roots (cassava and white carrot), optimizing the mixture of 50% cassava and 50% white carrot cooked for 40minutes to maximize soluble solids. Pérez (2019) investigated bioactive compounds from *Pleurotus* spp. using cocoa pod shell flour in SSF, enhancing secondary metabolite production, total polyphenol content, antioxidant activity, and reducing sugars. Lastly, Mor-Llombart (2021) assessed the SSF capacity of *Pleurotus ostreatus* in quinoa grain and flour, finding better results in quinoa grain regarding pH, acidity, water activity, biomass, and nutritional properties. Although the preparation and formulation of beverages have been extensively researched, the integration of native fruits and roots, such as arracacha, poses challenges in product development and innovation. This is largely due to the limited studies focused on exploring the potential of arracacha in this context. To address these challenges, the objective of the present study was to evaluate the physicochemical, techno-functional, and sensory characteristics of a functional beverage derived from arracacha.

MATERIALS & METHODS

Raw Material and Particle Size Reduction Process

The arracacha (*Arracacia xanthorrhiza* Bancroft), yellow variety, Andean tuber, was used; the sample that was collected in a fresh state was 5 kg., in the months of may to october 2021, from the Abancay region, Apurímac (2378 meters above sea level). The fresh arracacha was washed, cut into cubes of approximately 1cm^3, and then dried in an oven (MEMERT, Germany) at 60°C for 24 h. Grinding and granulometry were carried out in a sieve-vibrator (RETSCH, Germany) and two particle sizes of 1.18 and 2.00mm in diameter were obtained, which were used for solid-state fermentation.

Solid State Fermentation Process (SSF) of Arracacha at different Particle Sizes

The particles 1.18 and 2.00mm in diameter, the sample was conditioned through the absorption capacity (conditioning of humidity), it consists of adding 10g of dry sample to a 100mL test tube, diluting it with distilled water and letting it rest for 24 hours to know how much water the substrate has absorbed. For the SSF process, 30g of each sample was placed in a 250mL Erlenmeyer flask in an autoclave at 121°C for 15min. After cooling to room temperature, a *Pleurotus ostreatus* strain was inoculated (3 circles of 1 cm diameter in Potato Dextrose Agar medium) and were taken to an incubator (INCUCELL, Czech Republic) for 25 days at 28±2°C for fermentation (Urben, 2017), then they were stored in plastic containers with lids at room temperature.

Preparation of the Functional Drink at different Concentrations

10g of fermented product was taken (arracacha diameters of 1.18 and 2.00mm) and placed in a test tube to dilute it with 100mL of table water, then it was liquefied for 1min at room temperature to finally filter the liquid with Whatman paper N° 1. From the extracted liquid, drinks were prepared with concentrations of 50, 75 and 100% of the SSF of 1.18 and 2.00mm. The samples were packaged in 1000mL glass bottles and pasteurized at 70°C for 10min in a water bath Maria (MEMMERT, Germany), then cooled to room temperature.

Physicochemical and Techno-functional Analysis

Proximal Chemical Analysis of Arracacha at different Diameter Sizes, SSF and Functional Drink

The arracacha raw material of different diameters and SSF, the moisture, protein, lipid, ash and total carbohydrate content was determined according to the methodology of Zenebon et al. (2008). The content of reducing sugars was determined using the dinitrosalicylic acid (DNS) method (Miller, 1959); for this purpose, the standard curve was carried out in concentrations of 0, 0.2, 0.4, 0.6, 0.8, and 1.0g/L of solutions of glucose, taking 1mL of these solutions in a test tube and then adding 1mL of DNS, heating it in a water bath (MEMMERT, Germany) until boiling for 5min, then cooling it for 10min and adding 5mL of distilled water, and the absorbance of 540nm was recorded in triplicate in the spectrophotometer (GENESYS 20 THERMO SPECTRONIC, United States). Likewise, 1mL of the sample in solution was taken in a test tube and 1mL of DNS was added, it was placed in a water bath until it boiled for 5minutes, then it was cooled and 5mL of distilled water was added, and then the spectrophotometer was read at 540 nm, this was done in triplicate; If the sample was concentrated, dilutions of 1/10 were made.

In addition, the pH in the raw material, SSF and the functional drink was quantified using the potentiometer (SI ANALITYCS, Germany) according to food analysis methods (Zenebon et al., 2008). The °Brix content was measured in the functional arracacha drink, for which the table refractometer equipment (ABBE SCHMIDT+HAENSCH, Germany) was used from 0-95%. Finally, the density was determined in the arracacha functional drink, the densimeter equipment (H-B INSTRUMENT COMPANY, United States) was used, 500mL of functional drink were measured in 500mL glass test tubes and placed inside the densimeter; once the liquid was stabilized, and the reading was taken. In all assays, assays were performed in triplicate.

Antioxidant Capacity

The antioxidant activity was determined with 2,2-Diphenyl-1-picrylhydrazyl (DPPH) from arracacha, SSF at 1.18 and 2.0mm in diameter and the functional drink in its different concentrations. DPPH has an intense purple color, which is reduced to form yellow diphenyl-picryl-hydrazine, bleaching due to the decrease in absorbance due to the reaction (Brand-Williams et al., 1995). To do this, they weighed 0.004g of the DPPH reagent in 100mL of absolute ethanol in a volumetric flask protected from light and mixed in a dark amber bottle. The preparation of the calibration curve was from a 1mg/L ascorbic acid solution, with dilutions in concentrations of 50, 30, 15, 10, 8, 4, 2 and 1µg/mL with absolute ethanol per triplicate. 2mL of the DPPH solution was added to 1mL of each previously prepared ethanol-ascorbic acid solution, which was allowed to stand in a dark environment for 30min, and the absorbance was read in the spectrophotometer (GENESYS 20 THERMO SPECTRONIC, United States) at 517 nm (Mensor et al., 2001). The percentage of antioxidant activity (%A.A.) was determined%A.A. = (100 – ((sample Abs – blank Abs) x 100/ control Abs)), where: sample Abs: 1mL of sample plus 2mL of DPPH, blank Abs: 3mL of absolute ethanol and control Abs: 1mL of absolute ethanol plus 2mL of DPPH. For the sample, 1mL of the sample solution was used (diluted in absolute ethanol) and 2mL of DPPH reagent was added, then the mixture was homogenized and after 30min, the measurements were at absorbance at 517 nm, in triplicate. The result obtained was inserted into the equation of the standard curve standard line to determine the concentrations that were multiplied by their corresponding dilutions; the concentration is expressed in antioxidant capacity equivalent to Vitamin C (CAEVC), which is a concept of antioxidant capacity based on the natural antioxidant (vitamin C), expressed in mg of ascorbic acid/100 g of sample (Kim et al., 2002).

Determination of Total Polyphenols

The quantification of the total polyphenols of the arracacha, SSF of 1.18 and 2.0mm in diameter and the functional drink in its different concentrations, was determined with the Folin Cioculteu reagent according to the modified methodology of Singleton and Rossi (1965); the total phenolic compounds react with the Folin Cioculteu reagent giving rise to a color that can be determined with the spectrophotometer. The calibration curve was prepared by dissolving gallic acid dissolved in absolute ethanol at concentrations of 1, 5, 12.5, 25, 50, 100, and 150mg/L; then, 0.5mL of Folin Cioculteu was added with the concentrations of gallic acid in triplicate, after 5min, 2.5mL of Folin was added and after 60min, 2mL of Na2CO3 was added in a low light environment and the absorbance was quantified in the spectrophotometer (GENESYS 20 THERMO SPECTRONIC, USA) at 760 nm. For the samples, 500µL of diluted extract and 2.5mL of Folin Cioculteu solution (10% v/v) were added, after 5min, 2mL of Na2CO3 (7.5% w/v) were added and stored in ambient air dark for 60min. The readings were carried out at 760nm in triplicate, the result was expressed in mg of gallic acid equivalent/100g.

FTIR Data Collection

For the different products (Arracacha sample of 1.18 and 2.0mm diameter with and without SSF), the FTIR spectra were obtained with a Nicolet IS10 FTIR Spectrometer (Thermo Scientific, Inc., USA) with Attenuated Total Reflectance (ATR) and the OMNI control software (Nicolet iS10 version, 2014). The spectral data were recorded using approximately 0.1-0.2g (Zapata et al., 2021) of the arracacha and SSF sample, also a drop (10-20µL) of the different concentrations of the drinks on top of the FTIR receptacle; three spectra were recorded for each sample at 4000-600 cm^{-1}.

Sensory Analysis: CATA and Acceptability

84 potential consumers of the product participated in the sensory evaluation. The participants were recruited from the Professional School of Agroindustrial Engineering of the Universidad Nacional Micaela Bastidas de Apurímac and were selected according to their interest in participating, through a non-probabilistic test for convenience. The group of participants was made up of students, teachers and administration staff. They were between 17 and 74 years old, and the male/female ratio (%) was 43/57 who gave their informed consent to participate voluntarily in this stage. Consumers were given an evaluation slip to take the CATA test (Check-All-That-Apply). This test consisted of selecting, from a list of 15 attributes, those considered appropriate to describe each of the six beverage formulations produced. Additionally, an acceptability question was included with a nine-point

hedonic scale (1 = I dislike it very much and 9 = I like it very much) (Jaeger et al., 2020a; Wichchukit & O'Mahony, 2015). The attributes presented to the participants were: Sweet, weak smell, strong orange, astringent, viscous, bitter, diluted, refreshing-fresh, Strong smell, Persistent smell, sour, orange, soft, balanced, pleasant taste and unpleasant taste (Jaeger et al. al., 2020b; Miraballes et al., 2018) All samples were coded using a code of three randomly selected Fig.s and were presented monadically. For the evaluation, the samples were presented at room temperature in plastic cups with 5mL of the drink (Lawless & Heymann, 2010).

Statistical Analysis

For the statistical determination of the nutritional characteristics (moisture, proteins, fat, reducing sugars, ash and pH), techno-functional properties (antioxidant capacity and total polyphenols) of the Arracacha at different diameters (1.18mm and 2mm) with and without SSF, a completely randomized design was used, considering four treatments (A: Arracacha at 1.18mm in diameter, B: Arracacha at 2.00mm in diameter, C: SSF at 1.18mm in diameter and D: SSF at 2.00mm in diameter). The one-way ANOVA statistic was analyzed, with α = 0.05 and a confidence level of 95%. In addition, it was checked if they are parametric data (normality and homogeneity of variance). Upon finding that there are significant differences, Tukey's multiple comparison of means was carried out to observe in which treatments there are significant differences.

In the case of functional drinks, the statistical evaluation of the physicochemical characteristics (°Brix, pH, density) at different concentrations of 50%, 75% and 100% of the SSF (1.18mm and 2mm) was made in a 2x3 factorial arrangement. °Brix and pH were evaluated with the Friedman statistic because they were non-parametric data because they did not meet the assumptions of normality and homogeneity of variance of the residuals; in the case of the techno-functional parameters, it was evaluated using ANOVA and the Tukey multiple comparison of means. In the CATA sensory evaluation (descriptive and acceptability), a correspondence analysis (CA) was carried out to obtain the sensory map of the drinks and attributes based on data obtained with a contingency table, which provides a representation of samples and variables used to describe them, Cochran's Q Test was applied to said table to identify significant differences between the attributes. The XLSTAT software version 2023 and R statistics version 4.4.1 were used.

RESULTS & DISCUSSION

Physicochemical Characteristics and Techno-functional Compounds of Arracacha at different Diameters with and without the Solid-state Fermentation Process (SSF)

Table 1 presents the physicochemical properties, antioxidant capacity, and total polyphenol content of arracacha with particle sizes of 1.18mm and 2mm, both with and without fermentation by Pleurotus ostreatus. The moisture content was 70.314% for 1.18mm and 67.342% for 2mm, consistent with Benalcázar (2011) and Barrera et al. (2004), who reported 71.030% and 74.10%, respectively. Rodríguez (2010) found moisture levels of 80.78% in Pichincha, indicating that the yellow variety used may account for the lower values observed. The protein content was 5.864% for 1.18mm and 5.409% for 2mm, exceeding Benalcázar’s (2011) report of 3.625%. Comparatively, yacón has 4.2 g/100g, while white arracacha shows 6.2 g/100g (Pacheco, 2019). The fat content was low, at 0.790% for 1.18mm and 0.401% for 2mm, influenced by particle size (Ramírez et al., 2021). The ash content was 4.207% for 1.18mm and 4.456% for 2mm, surpassing Benalcázar’s (2011) 3.193%. In comparison, mashua has 4.81%, while white arracacha and olluco present 5.18% and 5.93%, respectively (Barrera et al., 2004). The pH values were 6.257 and 6.240, differing from Benalcázar’s (2011) 6.877 for white arracacha from San José deminas. These results align with other Andean tubers, where yacón is 6.1, mashua 6.7, and olluco 6.5 (Pacheco, 2019). Overall, the physicochemical properties of arracacha highlight its nutritional value and potential for further research.

The reducing sugar content of arracacha was 80.543 g AR/100 g for the 1.18mm diameter and 79.315 g AR/100 g for the 2mm diameter, reflecting the high carbohydrate composition of roots and tubers, which makes them suitable as a carbon source for fermentation. These values are significantly higher than those reported by Huaccho (2016) for yellow pumpkin mashua (26.36 g glucose/100 g) and black mashua (26.03 g glucose/100 g), as well as Barrera et al. (2004), who noted 35.83% for mashua. The variation can be attributed to the yellow arracacha from Huanipaca used in this study, along with differences in chemical composition and measurement techniques. While Ramos & Arias (2010) reported a higher reducing sugar content of 84.97% for yacón from Cuñapata, the values from this study are comparable to yacón from the Pusa Pusa community (78.52%). The total carbohydrate content

Table 1: Quantification of the physicochemical and functional properties of Arracacha (Arr) and the solid state fermentation (SSF) process at different particle sizes

	Treatments			
Particle size (mm)	Arr 1.18	Arr 2.00	SSF 1.18	SSF 2.00
Moisture (%)	70.314 ±0.348^a	67.342 ±0.080^b	63.352 ±1.027^c	62.630 ±0.458^d
Proteins (%)	5.864±0.070^b	5.409±0.046^c	6.164±0.101^a	6.026±0.044^a
Fat (%)	0.790±0.126^a	0.401±0.079^b	0.263±0.043^c	0.248±0.023^c
Reducing sugars (g AR/100g sample)	270.200±1.108^a	242.611±0.588^b	179.494±1.183^c	171.325±0.812^d
Ash (%)	4.207±0.238^b	4.456±0.141^b	9.285±0.152^a	9.113±0.089^a
pH	6.257 ±0.006^a	6.247 ±0.032^a	6.050 ±0.036^b	6.000± 0.026^b
Total carbohydrates (%)	89.139±0.052^b	89.734±0.145^a	84.288±0.097^d	84.613±0.126^c
Antioxidant capacity (g EAA/100g sample)	0.326±0.011^b	0.364±0.010^a	0.248±0.016^c	0.300±0.009^b
Total polyphenols (mg EAG/100g sample)	83.199±1.511^b	73.640±1.017^c	97.405±1.288^a	94.945±1.187^a

EAA: Equivalent in Ascorbic Acid, AA: Gallic Acid. The values obtained are expressed as mean±standard deviation (SD). The values that show the same letter vertically, on the same line, do not present significant differences (P>0.05) and otherwise, there is a significant difference (P<0.05).

was 89.139% for the 1.18mm diameter and 89.734% for the 2mm diameter, consistent with the high starch content typically found in roots and tubers, and similar to the 87.0 g/100 g reported for white arracacha (Pacheco, 2019) and 88.19% for oca (Barrera et al., 2004). The amylose content in native starches is reported to be 18.1% for arracacha and 21.8% for cassava (Dos Santos et al., 2018; Moraes et al., 2014), while purple arracacha (39%) and yellow arracacha (35.8%) have high amylose levels, although lower than corn starch due to the smaller starch granule size in arracacha (around 20 µm) compared to corn (around 30 µm) (Castanha et al., 2018).

In terms of antioxidant capacity, significant differences were observed between the values of non-fermented and fermented samples, except for the unfermented 1.18mm sample and the fermented 2.00mm sample, which showed no differences. However, there was a slight decrease in antioxidant capacity in the fermented sample compared to the non-fermented one. Regarding total polyphenols, no significant differences were found between the 1.18mm and 2mm particle sizes of the fermented arracacha, while other comparisons revealed significant differences, with the highest total polyphenol content in the fermented samples. The antioxidant capacity was 0.326g EAA/100g for the 1.18mm diameter and 0.364g EAA/100g for the 2mm diameter, values comparable to the antioxidant capacity equivalent to vitamin C (VCEAC-DPPH) reported by Almeida et al. (2011), Kuskoski et al. (2005), Arnao et al. (2012), and Muñoz et al. (2007), which included murici (0.295g VCEAC/100g), pineapple (0.411g AAE/100g), yacón root aqueous extract (0.497g AAE/100g), and star fruit (0.559g AAE/100g). Additionally, Muñoz et al. (2023) reported antioxidant content by the DPPH method for various Andean roots and tubers: yacón (127.45µM TE), red olluco (109.08µM TE), yellow olluco (38.62µM TE), mashua (172.01µM TE), arracacha (68.73µM TE), and oca (145.21µM TE). The variation in these data is attributed to the presence of compounds such as vanillic acid, caffeic acid, cinnamic acid, and malvidin, which significantly contribute to antioxidant activity.

The total polyphenol content for the 1.18mm diameter was 83.199 mg EAG/100 g, while for the 2mm diameter it was 73.640 mg EAG/100 g. These values are comparable to those reported by Almeida et al. (2011) for tamarind (83.8mg GAE/100g) and Kuskoski et al. (2005) for guava (83.0mg GAE/100g) and graviola (84.3mg GAE/100g), but higher than Muñoz's et al. (2007) report of 67.64mg GAE/100g for yacón. However, Pacheco (2019) found higher values in white arracacha (196.3mg GAE/100g) and olluco (260.1mg GAE/100g), indicating that differences may stem from the specific varieties and origins of the tubers. Doylet and Rodríguez (2018) reported that the phenolic content of mashua ranges from 128 to 146 mg GEA/100 g, with variations likely due to the presence of flavonoids, phenolic acids, and tannins, which can be influenced by tuber maturity and drying conditions. Additionally, Muñoz et al. (2023) noted the polyphenol content in various Andean roots and tubers: yacón (29.65mg GAE/100g), red olluco (21.51mg GAE/100g), yellow olluco (17.46mg GAE/100g), mashua (27.22mg GAE/100g), and arracacha (24.77mg GAE/100g), attributed to the presence of four phenolic compounds: chlorogenic acid, caffeic acid, coumaric acid, and protocatechuic acid.

Fig. 1 displays the FTIR curve values of arracacha with diameters of 1.18mm and 2mm, both with and without solid-state fermentation (SSF), revealing wave numbers (cm^{-1}) corresponding to nitrite functional groups (602.64, 599.23, 598.85 in the 630-560 range), saturated aliphatic functional groups (606.17 in the 605-635 range), nitro and nitroso compounds (1366.05, 1366.03, 1369.74, 1370.36 in the 1390-1360 range), 1-hydroxyanthraquinones (1633.35, 1634.82, 1633.78, 1633.92 in the 1640-1620 range), alkynes and triple bond groups (3300.54 in the 3340-3300 range), and saturated aliphatic amide functional groups (3296.06, 3270.56, 3270.19 in the 3370-3270 range), with each group characterizing the chemical properties of the compounds (De Almeida Barbosa, 2013; Mondragón, 2020). FTIR spectra exhibit behavior similar to native starch spectra reported for yellow mashua, yellow oca, pink oca, and yellow olluco (Velásquez-Barreto et al., 2019), with typical starch peaks at 1155, 1080, 1021, and 930 cm^{-1} attributed to C-O bonds, a peak at 1638 cm^{-1} likely indicating bound water in starch molecules (Hui et al., 2009), bands at 1047 and 1022 cm^{-1} relating to the degree of crystallinity in starch granules, and a band at 995 cm^{-1} sensitive to water-starch interactions (Hoyos-Leyva et al., 2017), with higher absorbance ratios in the 1047 cm^{-1} /1022 cm^{-1} and 995 cm^{-1} /1022 cm^{-1} regions observed in starches from yellow oca, pink oca, and yellow olluco compared to yellow mashua starches, suggesting more ordered double helical structures within the crystalline sheets of starch granules (Warren et al., 2016).

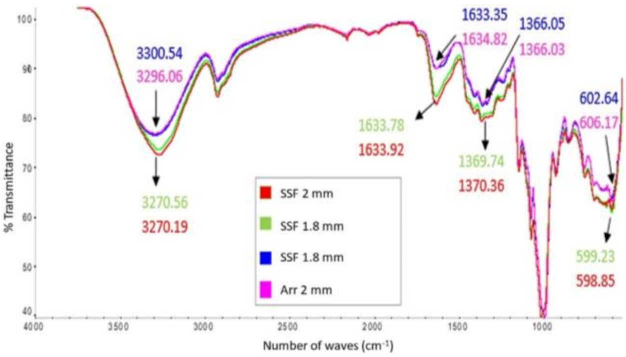

Fig. 1: FTIR curves of the sample Arr (Arracacha) and the SSF (Solid State Fermentation) of different diameters 1.18 and 2.00mm

Physicochemical Characteristics and Technofunctional Compounds of the Arracacha Functional Drink

Table 2 presents °Brix, pH and density of the arracacha functional drink in the concentrations of 50, 75 and 100% analyzed using the Friedman and Kruskal-Wallis statistics as they are non-parametric. For °Brix, the drink turned out to be statistically different for the treatments, recording an effect of particle size on total solids. In the pH, significant differences were found, where it was determined that factors in particle sizes and concentration affect the pH of the functional drink. With respect to density, a significant effect of the concentration of the drink affects its density was evident. For the antioxidant capacity and total polyphenols of the functional drink, the analysis of

Table 2: Physicochemical and technofunctional properties of Arracacha beverages

Formulations	Drink sample		°Brix*	pH*	Density (g/mL)*	Antioxidant capacity (g EAA/100g sample) **	Polyphenols Total (mg EAG/100g sample) **
	Particle size (TP)	Concentration (C)					
F1	SSF 1.18mm	50%	0.843±0.208[d]	6.980±0.006[a]	1.061±0.001[c]	142.919±0.978[e]	24.359±0.402[c]
F2		75%	1.004±0.006[cd]	6.740±0.006[c]	1.090±0.001[a]	151.387±2.587[d]	32.008±0.965[a]
F3		100%	1.658±0.126[b]	6.540±0.006[d]	1.011±0.001[d]	170.508±2.587[c]	32.701±1.008[a]
F4	SSF 2.00mm	50%	1.011±0.010[cd]	6.930±0.006[b]	1.075±0.005[b]	151.387±2.587[d]	18.215±0.611[d]
F5		75%	1.121±0.003[cd]	6.330±0.006[e]	1.091±0.001[a]	179.612±1.694[b]	23.505±0.241[c]
F6		100%	2.007±0.015[a]	6.120±0.006[f]	1.011±0.001[d]	203.321±1.694[a]	27.339±0.679[b]
Particle size (TP)			<0.05	<0.05	<0.05	<0.05	<0.05
Concentration (C)			0.013	<0.05	0.704	<0.05	<0.05
TP*C			0.620	<0.05	0.649	<0.05	0.657

SSF: Solid State Fermentation, EAA: Equivalent in Ascorbic Acid, AA: Gallic Acid. The values obtained are expressed as mean±SD. The values that show the same letter vertically, on the same line, do not present significant differences (P>0.05) and otherwise, there is a significant difference (P<0.05). *Using the Friedman method (Non-parametric), **AxB factorial design (Parametric).

Table 3: Cochran's Q test for each attribute of the drink sample

Attributes	p-values	SSF 1.18mm			SSF 2mm		
		50%	75%	100%	50%	75%	100%
Treatments		F1	F2	F3	F4	F5	F6
Sweet	0.430	0.107 (a)	0.048 (a)	0.083 (a)	0.083 (a)	0.131 (a)	0.107 (a)
Weak odor	0.247	0.500 (a)	0.417 (a)	0.369 (a)	0.405 (a)	0.405 (a)	0.393 (a)
Strong orange	0.000	0.083 (ab)	0.119 (ab)	0.190 (b)	0.024 (a)	0.024 (a)	0.119 (ab)
Astringent	0.197	0.071 (a)	0.119 (a)	0.083 (a)	0.167 (a)	0.083 (a)	0.119 (a)
Viscous	0.397	0.048 (a)	0.036 (a)	0.048 (a)	0.036 (a)	0.048 (a)	0.083 (a)
Bitter	0.025	0.143 (a)	0.214 (ab)	0.321 (b)	0.155 (a)	0.190 (ab)	0.202 (ab)
Diluted	0.517	0.250 (a)	0.274 (a)	0.214 (a)	0.250 (a)	0.321 (a)	0.262 (a)
Refreshing/ Fresh	0.123	0.274 (a)	0.179 (a)	0.143 (a)	0.274 (a)	0.226 (a)	0.202 (a)
Strong smell	0.035	0.083 (a)	0.131 (a)	0.226 (a)	0.190 (a)	0.107 (a)	0.131 (a)
Persistent odor	0.580	0.143 (a)	0.155 (a)	0.107 (a)	0.107 (a)	0.083 (a)	0.119 (a)
Acid	0.015	0.036 (ab)	0.048 (ab)	0.107 (b)	0.012 (a)	0.012 (a)	0.048 (ab)
Soft orange	0.013	0.298 (ab)	0.298 (ab)	0.250 (a)	0.429 (b)	0.393 (ab)	0.298 (ab)
Balanced	0.004	0.095 (a)	0.262 (b)	0.143 (ab)	0.238 (ab)	0.250 (ab)	0.262 (b)
Palatability	0.093	0.274 (a)	0.226 (a)	0.202 (a)	0.238 (a)	0.357 (a)	0.321 (a)
Unpleasant taste	0.734	0.214 (a)	0.190 (a)	0.202 (a)	0.238 (a)	0.167 (a)	0.167 (a)

SSF: Solid State Fermentation

variance was applied as we had parametric data. In the antioxidant capacity, it was observed that there is no statistical difference in the particle size of 1.18mm and the concentration of 75% with respect to the particle size of 2mm and the concentration of 50%. Furthermore, the one that obtained the highest antioxidant capacity was the 100% concentrated drink with a particle size of 2mm. With respect to the total polyphenol content of the fermented arracacha, in the 1.18mm particle size and in the concentrations of 75 and 100% they reached higher values of total polyphenols and there is no significant difference, there is also no significant difference for the particle size of 1.18mm and 2mm with their concentrations 50 and 75%, respectively; although in the other treatments there is a statistically significant difference.

CATA Sensory Evaluation (Descriptive and Acceptability) for the Arracacha Functional Drink

Table 3 presents the results of the Cochram Q test obtained through the CATA questions. Of the 15 attributes evaluated, 10 attributes did not present significant differences (Sweet, Weak Odor, Astringent, Viscous, Dilute, Refreshing/Fresh, Strong Odor, Persistent Odor, Pleasant Taste and Unpleasant Taste). However, 5 attributes were significantly different between the samples (Strong Orange, Bitter, Acid Orange, Mild and Balanced). The CATA (Check-All-That-Apply) methodology allows consumers to sensory describe products simply and quickly, relating the attributes that influence their acceptability.

Sample F3 presented a lower frequency in the descriptors strong orange, bitter, acid, although more frequently in attribute soft orange. Samples F4 and F5 were most frequently described as strong orange and acidic. Sample F1 was described as having a balanced flavor. Several studies have applied this method to characterize drinks and foods: San-Martín (2019) applied CATA together with the ideal profile method with 90 evaluators for a smoothie of pineapple juice, apple pulp and carrot juice. The most preferred attributes were: natural flavor, refreshing, slightly sweet, uniform consistency, fluid appearance, apple flavor, sweet and slightly acidic. Consumers indicated that an ideal smoothie should have lots of pineapple flavor and be refreshing, with greater intensity. Other desired attributes were: pineapple smell, slightly sweet, apple flavor, little carrot smell and flavor. Based on this, they recommended a formulation with 30% pineapple juice, 40% apple pulp and 30% carrot juice. Pilco (2021) used CATA with 28 attributes to evaluate a quinoa and kiwicha-based drink by untrained Peruvian and Finnish panelists. Panelists from both countries did not find significant differences in 7 attributes related to color and odor, such as green, lead, fresh herbs, dry herbs, grass, gelatinous and sticky. León (2019) applied CATA with 24 attributes to evaluate 7 vegetable drinks, including a control sample formulated from sprouted and malted cañihua variety Cupi. Cochran's Q test showed significant differences (P<0.05) for 14 of the 24 color, odor and texture attributes between the drinks.

Fig. 2 shows the sensory map of the different arracacha samples, where 74.96% of the total variability of the data is explained. Fig. 2(a) shows the formation of four groups: The first group formed by samples F2 and F6 described as having a strong odor and unpleasant taste. The second group made up of F4 and F5 characterized by

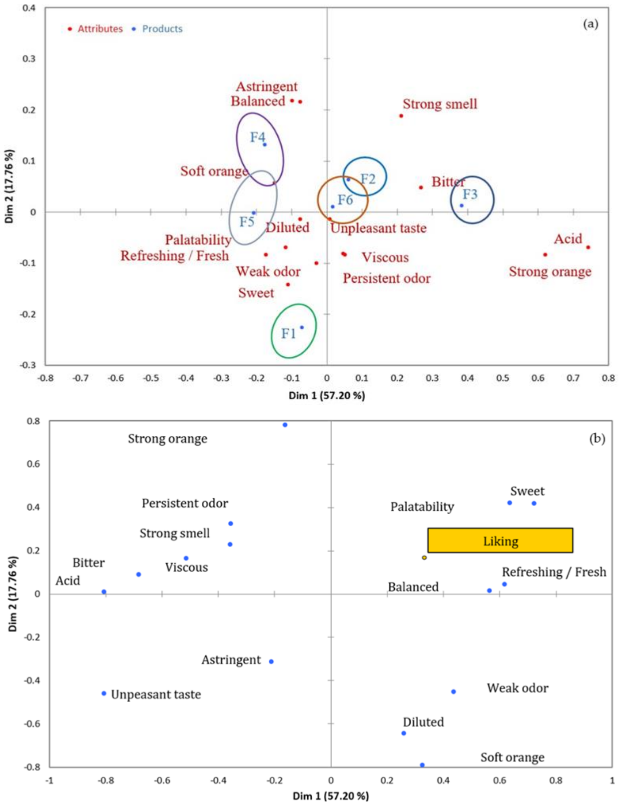

Fig. 2: Sensory analysis maps using tasting questions (a) and acceptability (b) of the different arracacha drinks.

being astringent, balanced and soft orange. The third group formed by F1 described as being sweet, with a weak smell and the fourth group by F3 characterized by being bitter. Regarding Fig. 2(b), acceptability is related to the attributes of sweet, pleasant flavor, balanced and refreshing/fresh. These attributes were used to describe samples F4 and F5, therefore they indicate that these drinks have greater acceptability. Various studies have applied the CATA method to relate the sensory description of products with their acceptability by consumers (Cardinal et al., 2015). San-Martín (2019) found that the acceptability of a smoothie based on pineapple juice, apple pulp, and carrot juice was positively related to attributes such as refreshing flavor, apple smell and flavor, little carrot smell and flavor, natural flavor, uniform consistency, slightly acidic and fluid appearance. Consumers selected a formulation with 30% pineapple juice, 40% apple pulp and 30% carrot juice. Pilco (2021) evaluated the acceptability of drinks based on quinoa and kiwicha, finding that the drink with 100% enzymatically treated kiwicha had greater acceptance than malted drinks. The most accepted attributes were homogeneous, almost colorless, caramel, grain flavor, white and soy. On the other hand, León (2019) reported that the control drink, the vegetable drink with 72-h malting and the 96-h cañihua drink were the most accepted. These products were characterized by having a white and brown color, a flavor of Andean grains, vanilla, soy, fresh herbs and chocolate, with a liquid, soft and homogeneous texture. In general, vegetable drinks with malted cañihua had greater acceptability than sprouted drinks.

Conclusion

The study identified the physicochemical, techno-functional, and sensory characteristics of a functional beverage made from arracacha. Arracacha particles with a diameter of 1.18mm, both with and without Solid State Fermentation (SSF), showed superior physicochemical and bioactive values compared to 2mm particles, which had higher total carbohydrate content and antioxidant capacity. FTIR spectra revealed similar patterns for samples without SSF, while distinct spectra were noted for SSF samples, highlighting predominant carbohydrate functional groups. The most acceptable sensory characteristics were found in the SSF samples at 1.18mm (50% concentration) and 2mm (75% concentration), noted for their balanced, sweet, refreshing, and pleasant flavor according to the CATA method.

Despite these promising findings, the study has limitations. The limited number of samples and the focus on specific particle sizes may restrict the generalizability of the results. Future research should explore a broader range of particle sizes and fermentation conditions, as well as the long-term stability and health benefits of the functional beverage. Additionally, further studies could investigate the economic feasibility of large-scale production and market acceptance of arracacha-based beverages.

Conflict of Interest: The authors declare there is no conflict of interest.

Informed Consent Statement: All participants received information about the study and gave voluntary verbal consent to participate. Approval was obtained from the Human Ethics Committee of the Peruvian Union University (N° 021-2021-IA).

Funding: This study did not receive any specific funding from grants or non-profit organizations.

Data Availability Statement: The primary data is accessible with the corresponding author and can be shared upon reasonable request.

Author Contributions: This study was a collaborative effort among all authors. Medina-Pérez and Pérez-Falcón contributed to the study design and data analysis. Medina-Pérez conducted the laboratory experiments. Rivera-Ashqui and Silva-Paz analyzed the data, interpreted the results, and drafted the manuscript. All authors reviewed and approved the final manuscript.

REFERENCES

Aguilera, C.M., Barberá, J.M., Díaz, L.E., Duarte de Prato, A., Galvez, J., Hernández, A.G., Gómez, S., Gonzales-Gross, M., Granado, F., Guarner, F., Marcos, A., Martínez, O., Nova, E., Olmedilla, B., Pujol-Amat, P., Ramos, E., Romeo, J., Tobal, F.M., Warnberg, J., & Zarzuelo, A., (2011). *Alimentos funcionales: Aproximación a una nueva alimentación.* Madrid: Instituto de Nutrición y Transtornos Alimentarios.

Almeida, M.M.B., de Sousa, P.H.M., Arriaga, Â.M.C., do Prado, G.M., Magalhães, C.E. de C., Maia, G.A., & De Lemos, T.L.G., (2011). Bioactive compounds and antioxidant activity of fresh exotic fruits from northeastern Brazil. *Food Research International, 44*(7), 2155-2159. https://doi.org/10.1016/j.foodres.2011.03.051

Arnao, I., Suárez, S., Cisneros, R., & Trabucco, J. (2012). Evaluación de la capacidad antioxidante de los extractos acuosos de la raíz y las hojas de *Smallanthus sonchifolius* (yacón). *Revista de la Sociedad Química del Perú*, *78*(2), 120-125.

Barrera, V., Brito, B., Caicedo, C., Córdova, J., Espín, S., Espinoza, P., Estrella, J., Heredia, G., Merino, F., Monteros, A., Muñoz, L., Nieto, M., Tapia, C., Valverde, F., & Villacrés, E. (2004). *Raíces y tubérculos andinos: alternativas para la conservación y uso sostenible en el Ecuador.* Quito: INIAP.

Benalcázar, B. M. (2011). *Determinación de las características físicas y químicas de la Zanahoria Blanca (arracacia xanthorrhiza bancroft) proveniente de la Zona de San José deminas Provincia de Pichincha* [Tesis para título profesional, Universidad Técnica del Norte].

Brand-Williams, W., Cuvelier, M. E., & Berset, C. L. W. T. (1995). Use of a free radical method to evaluate antioxidant activity. *LWT-Food science and Technology*, *28*(1), 25-30. https://doi.org/10.1016/S0023-6438(95)80008-5

Cardinal, P., Zamora, M. C., Chambers IV, E., Carbonell Barrachina, Á., & Hough, G. (2015). Convenience sampling for acceptability and CATA measurements may provide inaccurate results: A case study with fruit-flavored powdered beverages tested in Argentina, Spain and USA. *Journal of Sensory Studies*, *30*(4), 295-304. https://doi.org/10.1111/joss.12158

Castanha, N., Villar, J., da Matta Junior, M. D., Dos Anjos, C. B. P., & Augusto, P. E. D. (2018). Structure and properties of starches from Arracacha (Arracacia xanthorrhiza) roots. *International journal of biological macromolecules*, *117*, 1029-1038. https://doi.org/10.1016/j.ijbiomac.2018.06.015

De Almeida Barbosa, L.C. (2013). *Espectroscopia no infravermelho na caracterizacao de compostos organicos.* (Primeira. edição). Viçosa: UFV.

Dos Santos, T. P. R., Franco, C. M. L., Demiate, I. M., Li, X. H., Garcia, E. L., Jane, J. lin, & Leonel, M. (2018). Spray-drying and extrusion processes: Effects on morphology and physicochemical characteristics of starches isolated from Peruvian carrot and cassava. *International Journal of Biological Macromolecules*, 118, 1346–1353. https://doi.org/10.1016/j.ijbiomac.2018.06.070

Doylet, R., & Rodríguez, L. (2018). Estudio comparativo de la composición química y carácter reductor de dos variedades de *Tropaeolum tuberosum* (Ruíz y Pavón, Kuntze) Mashua. [Trabajo de grado, Universidad de Guayaquil].

García, A., & Pacheco-Delahaye, E. (2010). Evaluación de de una bebida láctea instantánea a base de harina de arracacha (*Arracacia xanthorrhiza*) con la adición de ácido fólico. *Revista Chilena de Nutrición*, 37(4), 480-492. https://doi.org/10.4067/s0717-75182010000400009

Guerrero, E. I., & Yépez, A. C. (2018). Elaboración de una bebida alcohólica destilada a partir de yuca *(Manihot esculenta)* y zanahoria blanca *(Arracacia xanthorrhiza)* [Tesis de pregrado, Universidad San Francisco de Quito].

Gul, K., Singh, A. K., & Jabeen, R. (2016). Nutraceuticals and functional foods: the foods for the future world. *Critical Reviews in Food Science and Nutrition*, 56(16), 2617-2627. https://doi.org/10.1080/10408398.2014.903384

Hermann, M., & Heller, J. (1997). *Andean roots and tubers: ahipa, arracacha, maca and yacon, Andean roots and tubers: Ahipa, arracacha, maca and yacon. Promoting the conservation and use of underutilized and neglected crops.* Vol. 21. Rome: International Plant Genetic Resources Institute.

Hoyos-Leyva, J. D., Bello-Pérez, L. A., Alvarez-Ramirez, J., & Agama-Acevedo, E. (2017). Structural characterization of aroid starches by means of chromatographic techniques. *Food Hydrocolloids*, *69*, 97-102. https://doi.org/10.1016/j.foodhyd.2017.01.034

Huaccho, C., (2016). *Capacidad antioxidante, compuestos fenólicos, carotenoides y antocianinas de 84 cultivares de mashua (Tropaeolum tuberosum Ruiz y Pavón)* [Tesis de maestria, Universidad Nacional Agraria La Molina].

Hui, R., Qi-He, C., Ming-liang, F., Qiong, X., & Guo-qing, H. (2009). Preparation and properties of octenyl succinic anhydride modified potato starch. *Food Chemistry,* 114(1), 81-86. https://doi.org/10.1016/j.foodchem.2008.09.019

Jaeger, S. R., Beresford, M. K., Lo, K. R., Hunter, D. C., Chheang, S. L., & Ares, G. (2020a). What does it mean to check-all-that-apply? Four case studies with beverages. *Food Quality and Preference*, 80, 103794. https://doi.org/10.1016/j.foodqual.2019.103794

Jaeger, S. R., Chheang, S. L., Jin, D., Roigard, C. M., & Ares, G. (2020b). Check-all-that-apply (CATA) questions: Sensory term citation frequency reflects rated term intensity and applicability. *Food Quality and Preference*, *86*, 103986. https://doi.org/10.1016/j.foodqual.2020.103986

Kim, D. O., Lee, K. W., Lee, H. J., & Lee, C. Y. (2002). Vitamin C equivalent antioxidant capacity (VCEAC) of phenolic phytochemicals. *Journal of Agricultural and Food Chemistry*, 50(13), 3713-3717. https://doi.org/10.1021/jf020071c

Kuskoski, E. M., Asuero, A. G., Troncoso, A. M., Mancini-Filho, J., & Fett, R. (2005). Aplicación de diversos métodos químicos para determinar actividad antioxidante en pulpa de frutos. *Food Science and Technology*, 25, 726-732. https://doi.org/10.1590/S0101-20612005000400016

Lawless, H. T., & Heymann, H. (2010). *Sensory evaluation of food: principles and practices*. (Second edition). London: Springer Science & Business Media.

Leidi, E. O., Altamirano, A. M., Mercado, G., Rodriguez, J. P., Ramos, A., Alandia, G., & Jacobsen, S. E. (2018). Andean roots and tubers crops as sources of functional foods. *Journal of Functional Foods*, *51*, 86-93. https://doi.org/10.1016/j.jff.2018.10.007

León, D. (2019*). Formulación de una bebida vegetal a partir de germinado y malteado de cañihua (Chenopodium pallidicaule Aellen) variedad Cupi* [Tesis para título profesional, Universidad Peruana Unión].

Martínez, A. M. (2017). *Aprovechamiento de los residuos de la Cáscara de haba (Vicia faba) mediante el cultivo del hongo Pleurotus ostreatus* [Tesis de pregrado, Escuela Superior Politécnica de Chimborazo].

Mensor, L. L., Menezes, F. S., Leitão, G. G., Reis, A. S., Santos, T. C. D., Coube, C. S., & Leitão, S. G. (2001). Screening of Brazilian plant extracts for antioxidant activity by the use of DPPH free radical method. *Phytotherapy Research,* 15(2), 127-130. https://doi.org/10.1002/ptr.687

Milán-Carrillo, J., Gutiérrez-Dorado, R., Cuevas-Rodríguez, E. O., Sánchez-Magaña, L. M., Rochín-Medina, J. J., & Reyes-Moreno, C. (2017). Bebida funcional con potencial antidiabético y antihipertensivo elaborada con maíz azul y frijol negro bioprocesados. *Revista Fitotecnia Mexicana*, 40(4), 451-459. https://doi.org/10.35196/rfm.2017.4.451-459

Miller, G.L., (1959). Use of Dinitrosalicylic Acid Reagent for Determination of Reducing Sugar. *Analytical Chemistry,* 31, 426–428. https://doi.org/10.1021/ac60147a030

Miraballes, M., Hodos, N., & Gámbaro, A. (2018). Application of a pivot profile variant using CATA questions in the development of a whey-based fermented beverage. *Beverages,* 4(1), 11. https://doi.org/10.3390/beverages4010011

Mondragón, P. (2020). *Principios y aplicaciones de la espectroscopia de infrarrojo en el análisis de alimentos y bebidas*. (Primera edición.). Jalisco: Centro de Investigación y Asistencia en Tecnología y Diseño del Estado de Jalisco A. C.

Moraes, J., Branzani, R. S., & Franco, C. M. L. (2014). Behavior of Peruvian carrot (Arracacia xanthorrhiza) and cassava (Manihot esculenta) starches subjected to heat-moisture treatment. *Starch/Staerke*, 66(7–8), 645–654. https://doi.org/10.1002/star.201300207

Mor-Llombart, P. (2021). *Evaluación del impacto del proceso de fermentación en estado sólido con Pleurotus ostreatus en las propiedades de la quinoa* [Tesis de Doctorado, Universitat Politècnica de València].

Muñoz, A. M., Jimenez-Champi, D., Contreras-López, E., Fernández-Jerí, Y., Best, I., Aguilar, L., & Ramos-Escudero, F. (2023). Valorization of extracts of Andean roots and tubers and its byproducts: bioactive components and antioxidant activity in vitro. *Food Research*, *7*(4), 55–63. https://doi.org/10.26656/fr.2017.7(4).002

Muñoz, A. M., Ramos-Escudero, D. F., Alvarado-Ortiz Ureta, C., & Castañeda Castañeda, B. (2007). Evaluación de la capacidad antioxidante y contenido de compuestos fenólicos en recursos vegetales promisorios. *Revista de la Sociedad Química del Perú*, 73(3), 142-149.

Pacheco, M. T. (2019). *Obtención y caracterización de compuestos bioactivos procedentes de tubérculos andinos y de subproductos de la industria agroalimentaria* [Tesis de doctoraldo, Universidad Autónoma de Madrid].

Pérez, L.F. (2019). *Obtaining bioactive compounds produced by Pleurotus sp. in solid state fermentation of cocoa pod husk (Theobroma cacao)* [Tese de Doutorado, Universidade Federal do Paraná].

Pilco, S. (2015). *Elaboración de una bebida a base de granos andinos: Quinua (Chenopodium quinoa) y Kiwicha (Amaranthus caudatus)* [Tesis de Doctorado, Universidad Nacional Agraria La Molina].

Ramírez, R., Aponte, A., Benavides, Y., & Ortiz, Y. (2021). Evaluación químico bromatológica de las variedades Yurac Llajum, Gello Llajum y Yurac Checche de *Smallanthus sonchifolius* (Poepp & Endl). H. Robinson (Yacón) procedente de Puno. *Ciencia e Investigación*, 13(2), 73-77. https://doi.org/https://doi.org/10.15446/acag.v70n4.784412021

Ramos, R., & Arroyo, G. A. (2010). Evaluación químico bromatológica de las variedades Yurac Llajum, Gello Llajum y Yurac Checche de Smallanthus Sonchifolius (Poepp & Endl). H. Robinson (Yacón) procedente de Puno. *Ciencia e Investigación*, 13(2), 73-77. https://doi.org/10.15381/ci.v13i2.3229

Reyes-Moreno, C., Milán-Carrillo, J., Valdez-Ortiz, A., Delgado-Vargas, F., Martín, L., Sánchez-Magaña, J. J. R. M., & Gutiérrez-Dorado, R. (2014). Bebida con potencial nutracéutico elaborada con maíz QPM extrudido y frijol fermentado. *Revista Iberoamericana de Ciencias*, 1(3), 61-77.

Rodríguez, S. (2010). *Caracterización física, química y nutricional de la zanahoria del ecotipo blanca (Arracacia xanthorrhiza esculenta) cultivadas en suelos edafoclimáticos arcillo-calizos, aireados en las provincias Pichincha y Tungurahua del Ecuador* [Tesis de pregrado, Universidad Tecnológica del Ecuador].

San-Martín, F. C. (2019). *Comportamiento reológico, propiedades fisicoquímicas y atributos sensoriales de un batido de funcional a base de manzana, piña y zanahoria* [Tesis de pregrado, Universidad Nacional de Trujillo].

Singleton, V. L., & Rossi, J. A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American journal of Enology and Viticulture*, 16(3), 144-158.

Urben, A.F. (2017). *Produção de cogumelos por meio de tecnologia chinesa modificada: biotecnologia e aplicações na agricultura e na saúde*. (Terceira ed.). Brasilia: Empresa Brasileira de Pesquisa Agropecuária.

Velásquez-Barreto, F. F., Bello-Pérez, L. A., Yee-Madeira, H., & Velezmoro Sánchez, C. E. (2019). Esterification and characterization of starch from Andean tubers. *Starch-Stärke*, *71*(1-2), 1800101. https://doi.org/10.1002/star.201800101

Warren, F. J., Gidley, M. J., & Flanagan, B. M. (2016). Infrared spectroscopy as a tool to characterise starch ordered structure—a joint FTIR–ATR, NMR, XRD and DSC study. *Carbohydrate Polymers*, 139, 35-42. https://doi.org/10.1016/j.carbpol.2015.11.066

Wichchukit, S., & O'Mahony, M. (2015). The 9-point hedonic scale and hedonic ranking in food science: some reappraisals and alternatives. *Journal of the Science of Food and Agriculture*, 95(11), 2167-2178. https://doi.org/10.1002/jsfa.6993

Zapata, F., López-Fernández, A., Ortega-Ojeda, F., Quintanilla, G., García-Ruiz, C., & Montalvo, G. (2021). Introducing ATR-FTIR spectroscopy through analysis of acetaminophen drugs: Practical lessons for interdisciplinary and progressive learning for undergraduate students. *Journal of Chemical Education*, 98(8), 2675-2686. https://doi.org/10.1021/acs.jchemed.0c01231

Zenebon, O., Pascuet, N., & Tiglea, P. (2008). *Métodos físico-químicos para análise de alimentos*. (IV edição). São Paulo: Instituto Adolfo Lutz.