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Yacon flour (*Smallanthus sonchifolius*) to a symbiotic yogurt

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Abstract

Adding functional ingredients to conventional products is an alternative to improve the population's access to quality nutrition. In this sense, this work was conducted to transform traditional yogurt into a symbiotic product, through the incorporation of probiotic lactic bacteria and yacon flour, a potato rich in prebiotic fiber, inulin, and fructooligosaccharides. Yacon flour was produced and evaluated for its composition and prebiotic potential. Two concentrations of yacon flour with probiotic *Bifidobacterium* were evaluated. The yogurts were manufactured industrially in a dairy factory. The final yogurts were evaluated for their physicochemical, microbiological, and sensory characteristics. The yacon flour produced stood out for its concentration of 56% prebiotic fibers and high efficiency in promoting the growth of four different probiotic microorganisms. The yogurts, with the addition of 5.5 or 8% yacon flour, met all the physical and chemical standards established by law. In the probiotic activity, the minimum concentration of probiotic bacteria required was maintained within the shelf life. And in the sensory evaluation, the symbiotic yogurts with (5.5 and 8%) yacon were well evaluated regarding flavor; however, the texture and color aspects were not approved by the tasters, requiring some more tests to improve these characteristics.

Keywords: functional food; fos; inulin; prebiotic; probiotic.

Practical Application: Enhancing yogurt with yacon flour boosts nutrition.

1 INTRODUCTION

In the search for a diet with greater health benefits, common products can be transformed or improved in terms of functional characteristics, by the addition of functional ingredients, such as prebiotic yogurts (Feitoza et al., 2017).

The traditional yogurt, despite being recognized as a processed product with high nutritional value and rich in proteins, calcium, phosphorus, vitamins, and carbohydrates, can be transformed into a functional product by adding specific ingredients (Leal et al., 2022). Functional yogurt has attracted greater commercial interest due to several factors that meet both consumer trends and the health and well-being needs of the population.

In the preparation of functional yogurt, the main ingredients used are probiotic microorganisms and/or prebiotic substances (fibers). Probiotics are defined as live organisms added to the diet that benefit the development of the intestinal colon microbiota (Zawistowska-Rojek & Tyski, 2018). The probiotics most commonly found in foods are *Lactobacillus acidophilus*, *Lactobacillus casei*, *Lactobacillus reuteri*, *Lactobacillus rhamnosus*, *Lactobacillus johnsonii*, *Lactobacillus plantarum*, *Bifidobacterium adolescentis, Bifidobacterium bifidum*, *Bifidobacterium breve*, *Bifidobacterium infantis*, *Bifidobacterium lactis*, and *Bifidobacterium longum* (Barajas-Álvarez et al. 2021). On the other hand, prebiotics are non-digestible carbohydrates that selectively stimulate the growth and/or activity of the species of beneficial colon bacteria (Peng et al. 2020), such as *Lactobacillus* and *Bifidobacterium* spp., in the intestinal tract (Terpou et al., 2019).

When yogurt contains both probiotic and prebiotic ingredients, the product is considered a symbiotic food. Symbiosis is characterized by the fact that the prebiotic compound selectively promotes the growth of probiotic microorganisms in the human body after consumption of the product (Devi et al., 2019). The main prebiotics are soluble fibers known as fructans, which include inulin, oligofructose, and fructooligosaccharides (FOS) (Melilli et al. 2024). Other prebiotics include galactooligosaccharides (GOS), lactulose, xylooligosaccharides (XOS), polydextrose, and human milk oligosaccharides (HMOs) (Melilli et al., 2024; Yoo et al., 2024).

Inulin is a polymer composed of 2 to 60 fructose molecules in β-(2–1) linkages, linked to a terminal glucose (Glu) molecule, α-(1–2) linkage. Inulin with a low degree of polymerization (DP) (< 10) is referred to as FOS, which are also known as oligofructose (Trujillo Toledo et al., 2019). The fibers, inulin and FOS, are

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naturally present in foods, such as Jerusalem artichoke, chicory, and yacon potato, with the latter being highlighted due to its numerous applications and derived products (Reis et al., 2021). Yacon (*Smallanthus sonchifolius* (Poepp.) H. Rob) is a plant native to the Andean region, widely consumed and produced in South America (Widowati et al., 2023). Its tuberous roots are known for their succulent texture and slightly sweet flavor, and are typically consumed naturally or as salads (Costa et al., 2024).

The presence of inulin and FOS in yacon provides beneficial properties that support its potential applications in the food industry (Gusso et al., 2015; Verediano et al., 2021). Yacon, in the form of syrup or flour, has been incorporated into different food products (Reis et al., 2021), with the potential to be an alternative in the production of healthy products (Mejía-Águila et al., 2021; Reis et al., 2021; Simanca-Sotelo et al., 2021). Its functional appeal, along with its low fat content and reduced caloric value, has attracted the interest of both industry and researchers (Gusso et al., 2015). Additionally, the use of yacon flour in cookies maintains the technological and sensory characteristics of the product, thus increasing the possibilities of using this ingredient in the baking industry (Simanca-Sotelo et al., 2021).

In this sense, yacon potato, mainly in the form of flour (for conservation and marketing reasons), has proven to be a good alternative ingredient in the preparation of functional foods. However, more information is needed regarding the influence of this compound on the technological and sensory aspects of the products produced. Thus, this study evaluated, in addition to the prebiotic potential of yacon flour, the technological and sensory potential of yacon flour incorporated into a probiotic yogurt, for the development of a symbiotic product.

1.1 Relevance of the work

This study aimed to transform traditional yogurt into a symbiotic product by adding probiotic bacteria and yacon flour (rich in prebiotic fibers). The yacon flour contained 56% prebiotic fibers and effectively promoted the growth of probiotics. The yogurts, with 5.5% or 8% yacon flour, met physicochemical standards and maintained the minimum probiotic concentration throughout shelf life. In sensory evaluation, the symbiotic yogurts were well accepted in terms of flavor, but texture and color required adjustments. The study demonstrates that adding functional ingredients can enhance the nutritional value of conventional products, though further optimizations are needed for greater consumer acceptance.

2 MATERIAL AND METHODS

2.1 Material

The yacon potatoes were purchased from a local distributor, and the other ingredients, such as milk, sucrose, lyophilized commercial culture for yogurt production (Y 472 E, Sacco®, Campinas, São Paulo, Brazil), traditional lactic ferment, and *Bifidobacterium* BB-12® (Chr. Hansen A/S, Horsholm, Denmark), were donated by a private dairy company (Valentim Laticínios, Domingos Martins – ES, Brazil).

The standards used for comparison were Glu, fructose, and sucrose produced by Synth. Other reagents of analytical standard grade used for chemical analyses were purchased from Sigma and Synth (Diadema, São Paulo). The culture media used were from the OXOID brand (São Paulo, São Paulo, Brazil).

2.2 Methodology

2.2.1 Yacon flour production

The yacon was washed under running water and then immersed in chlorinated water at 50 ppm for 10 min to remove dirt, and any unsuitable, rotten, darkened, or soiled parts were removed. The potatoes were sliced into 2.5-mm-thick rounds using a processor. After slicing, they were immersed in sodium bisulfite at a concentration of 0.5% for 5 min. The yacon slices were placed on perforated trays, and the weight of the material in each tray was recorded. The trays were placed in a fixed bed dryer with drying air at a temperature of 80°C, until the weight was constant. After drying, the dehydrated yacon (chips) was ground using a home blender (Hamilton Beach – São Paulo, Brazil) until flour was obtained. The granulometry of the flour obtained was not uniform, with the particles distributed in sieves of 6, 10, 20, 32, and 45 mesh.

The flour obtained was packaged in sealed polyethylene plastic bags and stored refrigerated at 4 to 6°C temperature.

2.2.2 Physicochemical analysis of yacon flour

The obtained yacon flour was analyzed for moisture, ash, protein, and lipid content. The analyses were performed in triplicate, following the methodologies of the Adolf Lutz Institute (Zenebon et al., 2008).

2.2.3 Sugars and prebiotic fibers

Sample fractionation was determined by high-performance liquid chromatography (HPLC) with a BIO-RAD HPX 87P column (lead Pb stationary phase), using purified water as the mobile phase. The sample was diluted by adjusting the concentration to 1º brix and then placed in a water bath at 45°C with stirring for 30 min to extract the sugars present. After that, it was centrifuged at 12,000 rpm and then filtered through a Millipore polyvinyl decafluoride (PVDF) membrane with 0.22 m porosity and 13 mm diameter. The samples were then injected into a VARIAN liquid chromatograph, model PRÓ-STAR 410, with a refractive index detector and an automatic injector (AUTO SAMPLER 410), with a flow rate of 0.6 $mL.min^{-1}$ and a column temperature of 80°C, projecting a sequence of peaks that were compared with the pre-defined curves in the equipment. The fractionated and identified sugars were calculated ($mg.mL^{-1}$) by comparing their areas with those of their standards.

2.2.4 Potential prebiotic activity

Samples were tested for potential prebiotic activity using an in vitro method, based on the evaluation of optical density (OD) and growth curves of probiotic bacteria (Spréa et al., 2024). For this purpose, three *Lactobacillus* and one *Bifidobacterium* strains were used, namely *L. casei* NCTC 6375, *L. plantarum* DSM 12028, *L. acidophilus* LA-5 (Probio-Tec, Denmark), and *Bifidobacterium animalis spp. lactis* Bb12 (Probio-Tec, Denmark).

The samples and the positive controls, inulin and FOS, were diluted in deMan, Rogosa, and Sharpe (MRS) broth without Glu at a concentration of 2% (w/v) and were further pasteurized (72–75°C for 1 min), followed by centrifugation (3 min, 8000 × *g*).

To carry out the assay, probiotics were added to the samples or controls to achieve a concentration of probiotics of 5×10^5 colony-forming units per milliliter (CFU.mL^{-1}).

To maintain anaerobic conditions, 50 μL of sterilized liquid paraffin was added to each well. In addition, also as a positive control, the inoculum was added to MRS both containing 20 g.L^{-1} Glu. Finally, the samples or positive controls at 2% (w/v) in MRS broth without inoculum were used as blank controls. The microplate was incubated at 37°C for 48 h, with absorbance measurements at 620 nm registered every hour. After 48 h, the data were analyzed, and growth curves were generated.

2.2.5 Production of symbiotic yogurt

The yogurt production was carried out in a private dairy industry (Valentim Laticínios, Domingos Martins – ES, Brazil). Three formulations were produced with different concentrations of yacon flour as an ingredient of the symbiotic yogurt: formulation T1 control (0% yacon flour), formulation T2 (5.5% yacon flour), and formulation T3 (8.0% yacon flour). The minimum quantity of yacon flour used in the formulations (5.5%, w/v) was based on previous calculations in relation to the content of prebiotic fibers, in order to obtain a final product that was a source of fiber. In relation to the value of 8%, this represented the maximum amount of flour that could be dissolved in the yogurt without precipitation or formation of excessive lumps.

For yogurt production, standardized milk with 5% fat was added with 8.5% sugar and then heated to 83°C for 30 min in a special stainless steel yogurt pan. After heating, the mixture was cooled to 43°C, and culture for yogurt production (Sacco®) and *Bifidobacterium* cultures (Christian Hansen brand) were added according to the supplier's recommendations to initiate the fermentation process. The milk was then fermented for approximately 7 h at 43°C, until the yogurt reached a pH of 4.6–4.8. Yacon flour was then added, followed by beating and breaking the curd. The mixture was immediately packaged in 1 L polyethylene containers and stored in a cold chamber at 2–4°C until analysis.

2.2.6 Physicochemical analysis of yogurt

Samples from the three yogurt formulations were analyzed for total dry extract (TDE), lipids, proteins, ash, pH, and titratable acidity, following the methodologies of the Adolf Lutz Institute (Zenebon et al., 2008). Carbohydrate content was determined by difference, according to Equation 1:

$$\text{Carbohydrate content} = (100 - [\%\ \text{moisture} + \%\ \text{ash} + \%\ \text{protein} + \%\ \text{fat}]) \quad (1)$$

2.2.7 Total lactic acid bacteria and bifidobacteria count

To quantify total lactic acid bacteria, MRS agar was used. Aliquots of 25 g of the samples were diluted in 225 mL of 0.1% peptone water, homogenized, and subjected to successive dilutions in 9 mL of the same diluent solution. Subsequently, the 10^{-6} to 10^{-8} dilutions were seeded using the pour plate method in MRS agar culture. The inverted plates were incubated at 37°C for 72 h in an anaerobic jar (Tharmaraj & Shah, 2003). Microorganisms of the genus *Bifidobacterium* were quantified in MRS-LP (Man, Rogosa, and Sharp with lithium chloride and sodium propionate) medium prepared by supplementing MRS with 0.05% cysteine, 0.3% lithium chloride, and 0.9% sodium propionate with incubation at 37 ± 1°C for 72 h in anaerobiosis (Van de Casteele et al., 2006).

The counting was performed on yogurts at 0, 7, 14, 21, and 28 days of refrigerated storage, and the results were expressed as CFU/g. Yogurt samples on the 28th day of storage (product validity) would be the reference period to guarantee the survival of probiotic bacteria at the ideal concentration.

2.2.8 Sensory analysis

The research project was submitted to the ethics committee for evaluation before being initiated and was approved on August 8, 2022, under number 57767622.1.0000.5072. All participants provided written informed consent prior to participation.

A total of 50 untrained tasters, yogurt consumers, of both sexes and aged between 18 and 43 years, including students and employees of the Instituto Federal do Espírito Santo (IFES), participated in the tests. The tests were carried out in the evening from 6 pm to 9 pm at the IFES Food Sensory Analysis Laboratory, which has individual booths for the tests.

The tasters were recruited based on their availability, interest, and frequency of yogurt consumption. Before the test was carried out, the consumers were warned about the possible occurrence of gastrointestinal discomfort or unpleasant taste due to ingestion of the product, and were assured they could withdraw from the research at any time. Therefore, all those who agreed to participate signed an informed consent form (ICF).

The tasters received the yogurt samples in 50 mL disposable plastic cups coded with a three-digit number of two treatments (T2 and T3). The sensory analysis was based on the simple stimulus method of the Adolf Lutz Institute (Zenebon et al., 2008), where the tasters evaluated attributes such as appearance, aroma, texture, flavor, overall impression, and purchase intention, all using a structured hedonic scale of five or nine points.

3 RESULTS AND DISCUSSION

3.1 Characterization of yacon flour

Considering that yacon should be added to yogurt in order to facilitate its incorporation into the product, the flour was prepared. The flour was then analyzed for its physicochemical characteristics and carbohydrate and fiber content, and the results found are presented in Table 1. The yacon flour presented, on average, 4.40% moisture, a value significantly lower than that found in the raw material from which it was obtained. Yacon root has a high moisture content, ranging from 70 to 90%, which makes it highly perishable (Alles et al., 2015). The low moisture content allows the product to be stored for long periods without significant organoleptic changes when kept under appropriate conditions (low relative humidity and low oxygen content).

Yacon roots consist mostly of water and carbohydrates. About 15–40% of the carbhydrates are free sugars, such as sucrose, fructose, and Glu (Alles et al., 2015). The proportion of monosaccharides varies significantly during the plant growth cycle and after harvest (Asami et al., 1989). Yacon flour contained 11.83% fructose and 4.47% Glu, in addition to 7.59% sucrose. Oligofructan fibers degrade into simple sugars as storage time increases, even contributing to the sweetness of the root (Zardini, 1991).

Regarding fiber content, the flour showed up 56% of FOS and inulin (Table 1). Products with a minimum of 2.5 g are considered a source of FOS or inulin with the potential to improve the human intestinal flora and be classified as functional foods (Silva et al., 2024).

Yacon flour was tested for its prebiotic potential on four probiotic strains at a concentration of 2% (w/v) (Figure 1). Inulin and FOS, recognized prebiotics, along with Glu, were used as positive controls. Figure 2 displays the growth curves of these strains, with measurements taken by spectrophotometry at an OD of 620 nm. In every case, the biomass concentration began to rise within the first 8 h of incubation. As anticipated, Glu proved to be the most effective carbon source for both *Bifidobacteria* and *Lactobacillus* strains, showing the highest maximum growth rates across all strains, followed by inulin, a well-known plant-derived prebiotic.

For all probiotic microorganisms, yacon flour served as an effective carbon source, comparable to the positive control, achieving ODs above 2.0, demonstrating its efficient prebiotic potential. Furthermore, the growth curves indicate that yacon exhibited maximum growth similar to the positive control inulin for *L. casei, L. plantarum,* and *B. animalis*.

In all tested probiotic microorganisms, yacon flour showed superior OD results compared to FOS, with stationary phases closely resembling those of inulin. Moreover, it is important to note that the biomass increase due to the proliferation of microorganisms occurred more rapidly than with the positive controls such as inulin, FOS, and Glu, for *L. casei*, *L. acidophilus,* and *Bifidobacterium bacterium*, with the exponential growth phase occurring between 6 and 8 h in all observed cases. Additionally, yacon flour promoted exponential growth, with OD values ranging from 2.0 to 2.5, being similar for *L. plantarum* and superior for *L. casei*, *L. acidophilus* LA-5, and *B. bifidum* BB-12 compared to both positive controls. This led to higher OD values observed between 8 and 12 h. These findings suggest that yacon flour may be a valuable source of prebiotics, being able to promote the

Table 1. Physicochemical analysis of yacon flour growth of beneficial bacteria in the gut.

Yacon flour	Mean ± standard deviation
Moisture	4.40 ± 1.45%
Ash	3.87 ± 0.19%
Lipids	0.55 ± 0.09%
Sugars	
Fructose	11.83 ± 2.59%
Glucose	4.47 ± 1.62%
Sucrose	7.59 ± 1.30%
Prebiotic fibers	
Fructooligosaccharides	38.05 ± 1.14%
Inulin	18.43 ± 1.45%

Values are mean ± standard deviation of three separate replicates.

The obtained results align well with previous studies that also reported the prebiotic potential of yacon flour. Sousa et al. (2015) verified that yacon flour possessed prebiotic potential due to their capacity of promoting the growth of four probiotic strains when used at a concentration of 1% (w/v), compared to a conventional carbon source, namely Glu at 2% (w/v). The authors further noted that yacon flour at 1% (w/v) was able to support a similar level of growth to that promoted by Glu at 2% (w/v).

In the study conducted by Pedreschi et al. (2003), *L. plantarum*, *L. acidophilus,* and *B. bifidum* were cultivated under anaerobic conditions, to simulate the intestinal environment, in commercial FOS (Neosugar and Nutraflora) and in yacon extract. FOS fermentation was evaluated by measuring microbial growth (changes in OD), pH, or acidification of the medium and by determining the amount of FOS consumed. The culture medium with both strains of *Lactobacillus* and *B. bifidum* showed an increase in OD after 24 and 48 h, respectively, indicating microbial growth and suggesting the use of FOS as a carbon source. In general, the increase in OD for each type of probiotic was very similar for both commercial FOS and yacon extract. The pH variation observed in the media was also similar for both groups. These results suggest that yacon extract has potential as a prebiotic and can be used by probiotic *Bifidobacterium* and *Lactobacillus* species (Alles et al., 2015). In our study, the biomass increase due to the proliferation of microorganisms generally occurred more rapidly than reported by Pedreschi et al. (2003), with the exponential growth phase occurring between 6 and 8 h in all observed cases. This may be linked to the DP and composition of FOS (Pedreschi et al., 2003).

3.2 Physicochemical composition of yogurt

The values of the physicochemical composition of the yogurts added with yacon flour and the control yogurt, as well as pH and acidity values, are shown in Table 2.

It was observed that there was no significant difference ($p >$ .05) in the titratable acidity values between the three treatments, and the values found were within the range established by the legislation of 0.6 to 1.5 g of lactic acid/100 g (Brasil, 2007). Additionally, no statistical difference was observed between the pH values found. Although there is no standard required by current legislation, monitoring the evolution of pH during yogurt production is very important. Values below 4.0 at the end of the fermentation stage may favor the exudation of whey during storage of the product, which is a defect in fermented milk and should be avoided.

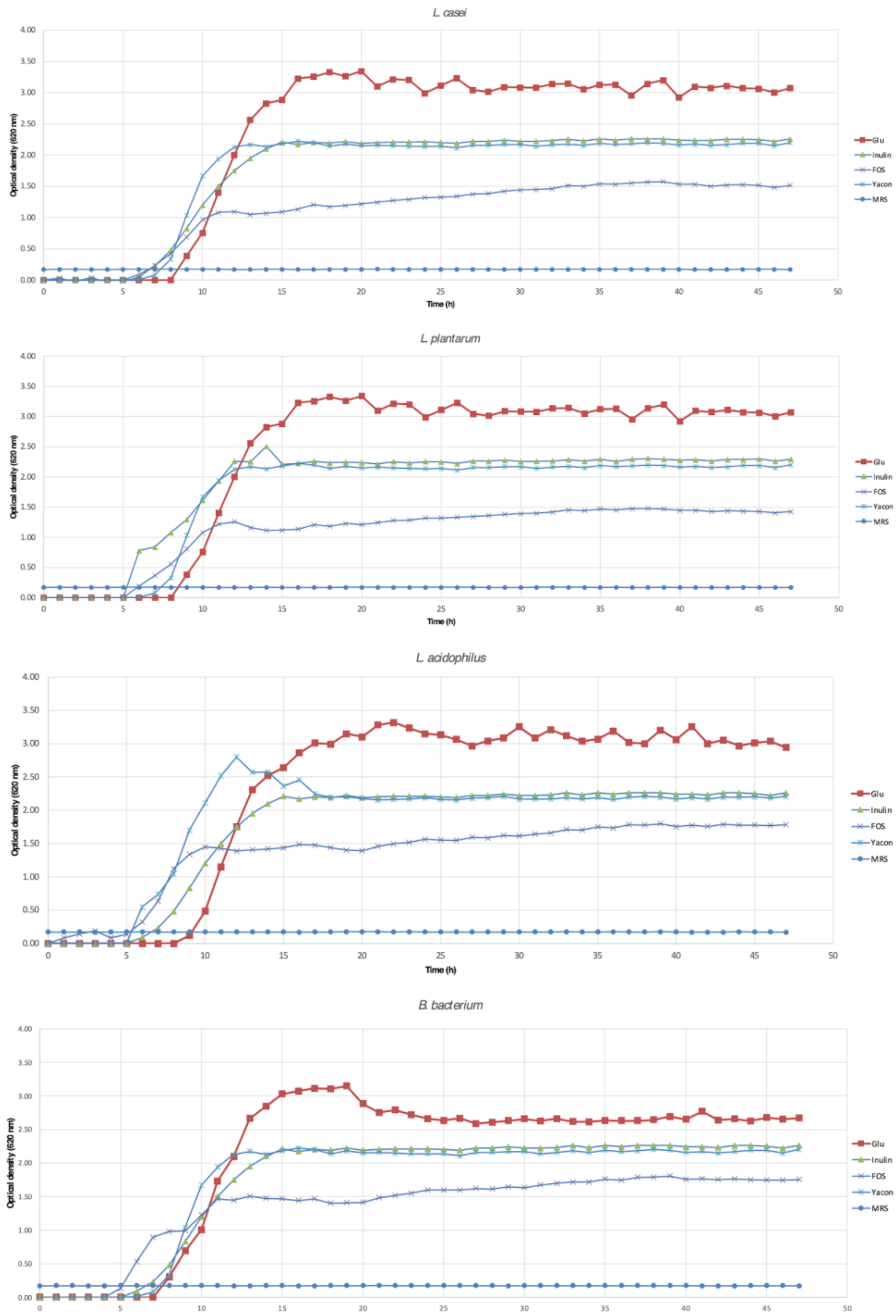

Figure 1. Growth curves of *Bifidobacterium* and *Lactobacillus* probiotic strains obtained in the prebiotic activity assay.

The Technical Regulation for the Identity and Quality of Fermented Milks (Brasil, 2007) does not include physicochemical requirements such as TDE and carbohydrates. The TDE levels in this study were higher than those reported by Pizetta (2013) for yogurt with yacon flour (20.55%), while the yogurt without yacon flour had a TDE of 18.44%, slightly higher than the values found in the present study. Conversely, the carbohydrate levels obtained in this study were lower than those reported by Pizetta (2013), who obtained a content of 12.95% for yogurt with yacon flour and 11.29% for the control yogurt.

The TDE, lipid, and carbohydrate values showed differences between the samples with yacon and the control. Yogurts added with 5.5 and 8% yacon presented significantly higher TDE, lipid,

Figure 2. Sample of natural yogurt (T1) and yogurt added with 5.5% yacon flour (T2).

Table 2. Physicochemical characterization, pH, and titratable acidity values of yogurt samples

Composition	T1 – control	T2	T3
TDE (%)	16.68 ± 0.43^b	21.69 ± 0.42^a	21.36 ± 0.07^a
Protein (%)	2.90 ± 0.05^a	2.73 ± 0.07^b	3.02 ± 0.05^{ab}
Lipids (%)	4.53 ± 0.71^b	5.91 ± 0.01^a	5.75 ± 0.35^a
Sugars (%)*	8.53^b	12.24^a	12.25^a
pH	4.28 ± 0.08^a	4.25 ± 0.01^a	4.26 ± 0.02^a
Titratable acidity (g lactic acid 100 g^{-1})	1.10 ± 0.07^a	1.06 ± 0.01^a	1.11 ± 0.02^a

TDE: total dry extract; T: Treatment.
*Estimated by the difference between TDE and the sum of proteins and lipids. Values are mean±standard deviations of three separate replicates. Means followed by the same letter in the row do not differ statistically at 5% probability.

and carbohydrate contents compared to the control yogurt ($p < .05$). This fact can be justified by the greater presence of solids in this yogurt due to the addition of yacon flour.

The lipid contents of the yogurt with 5.5 and 8% yacon and the control yogurt in this study complied with the legislation according to the Technical Regulation for the Identity and Quality of Fermented Milks (Brasil, 2007), which establishes that a whole yogurt must have 3.0 to 5.9 g of fat/100 g of yogurt.

Only the yogurt with 5.5% yacon flour differed in the protein content ($p < .05$) as compared to the control yogurt. However, all yogurts complied with the protein content established by the legislation (Brasil, 2007), which determines that a whole yogurt must have at least 2.9 g of milk proteins/100 g of yogurt.

3.3 Total lactic acid bacteria and bifidobacteria enumeration in yogurt

The values of the total viable lactic acid bacterial count for the yogurt samples on the 28th day of storage are presented in Table 3.

Despite the significant difference between treatments ($p < .05$), the addition of yacon flour still allowed the total lactic bacterial count to remain above 10^7 CFU/g throughout the analyzed period for all treatments. This result is compatible with current legislation, which recommends a total lactic bacterial count of at least 10^7 CFUs per gram of the product (CFU/g) for yogurts.

The viability of the probiotic culture of *Bifidobacterium* sp. over the 28-day storage period, evaluated using the MRS-LP medium, showed values of 1.32×10^7 CFU/g to T1, 8.45×10^7 CFU/g to T2, and 9.79×10^7 CFU/g to T3, meeting the minimum count of 10^6 CFU of bifidobacteria/g of product, with significant difference ($p < .05$) between the treatments (T2 = T3; T1 < T2; and T1 < T3, by Tukey's test). In the study by Silva et al. (2024), the viable cell counts of the probiotic microorganism *Bifidobacterium* sp. remained between 4.93×10^6 and 2.12×10^6 for yogurts with 0.5% lactic cultures, 1.21×10^7 and 2.62×10^7 for yogurts with 1.0% lactic cultures, and 1.53×10^7 and 7.57×10^7 for yogurt with 1.5% lactic cultures after 28 days of storage.

Table 3. Viable lactic acid bacterial count in deMan, Rogosa, and Sharpe medium.

Samples	CFU/g count after 28 days
T1 (control)	8.9×10^9 CFU/g^a
T2	5.2×10^7 CFU/g^c
T3	3.0×10^8 CFU/g^b

T: Treatment.
Values are means ± standard deviations of three separate replicates. Means followed by the same letter in the row do not differ statistically at 5% probability.

3.4 Sensory analysis

The average results obtained in the analysis of the acceptance of the appearance, aroma, texture, flavor, and overall impression of the yogurt samples, as well as the indication of purchase intention, are presented in Table 4.

There was no significant difference ($p > .05$) between the yogurts in relation to any attribute, possibly because the different concentrations of yacon flour used were insufficient to promote a sensory difference. The attributes of "appearance" and "texture" obtained the lowest averages, with the scores being between "indifferent" and "slightly liked," probably due to the grainy characteristic of the flour causing a lower acceptance of this product (Figure 2).

In the assessment of acceptability of the "aroma" and "overall impression" of yogurts added with yacon flour, the average scores were between "I liked it slightly" and "I liked it fairly." For flavor, the averages were between "I liked it slightly" and "I liked it very much."

In the assessment of purchase intention, the yogurt added with yacon flour obtained an average between "I would probably buy it" and "maybe yes/maybe no." In the study by Pizetta (2013), the yogurt added with yacon flour obtained a higher average than in this study but remained between "maybe yes, maybe I wouldn't buy it" and "I would probably buy it" on the scale used.

The average scores for the aroma, flavor, texture, and overall impression attributes in this study were higher than those found by Vasconcelos et al. (2012) in a study with light yogurt with added yacon flour involving 92 individuals. In their study, the average scores ranged from 5.3 and 5.7 for aroma, 3.7 and 4.4 for flavor, 3.8 and 4.8 for texture, and 3.9 and 4.5 for overall impression, corresponding to yogurts with 3.86 to 1.58% yacon flour, respectively. In the study by Pizetta (2013), the averages for the aroma and flavor attributes were higher than those found in this study. The averages were obtained between the hedonic terms "I liked it a little" and "I liked it" on the scale used, based on the evaluation of 55 individuals.

Table 4. Average results of the acceptance analysis (hedonic scale) and purchase intention of yogurt with yacon flour added (n = 50).

Attributes	Yogurt with 5.5% yacon flour – T2	Yogurt with 8.0% yacon flour – T3
Appearance*	6.00[a]	5.88[a]
Aroma*	6.42[a]	6.14[a]
Texture*	5.74[a]	5.24[a]
Flavor*	7.16[a]	6.72[a]
Overall impression*	6.70[a]	6.38[a]
Purchase intent**	2.66[a]	3.08[a]

T: Treatment.
*Ratings range from 1 to 9 (I really disliked it to I really liked it);
**Ratings range from 1 to 5 (I would definitely buy it to I definitely would not buy it);
Means followed by the same letter in the row do not differ statistically at 5% probability.

The sensory analysis indicated that some aspects of the formulation should be improved to increase product acceptance, such as appearance and texture. The yogurt had a grainy/sandy texture and a color change from white to light brown.

4 CONCLUSIONS

Since the primary goal of the production of a symbiotic yogurt was successfully achieved, namely achieving the minimum number of viable probiotic microorganisms required by the legislation over the 28-day shelf life, further research should focus on evaluating alternative treatments and methods of incorporating the flour into the yogurt to improve its sensory aspects.

Yacon is a unique and nutritious food, but its short shelf life limits its usability. Therefore, the use of yacon flour is an appropriate solution to maintain its properties and benefits over a longer period. Yacon flour stands out as a valuable ingredient for the food industry, offering significant health benefits, particularly for gut health improvements, and significant opportunities to use it in the development of functional foods. To ensure that these benefits may reach consumers, additional studies must be carried out in order to further improve the technological and sensory characteristics of these flours.

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