JOURNAL OF MEDICINAL FOOD
*J Med Food* 00 (0) 2015, 1–7

DOI: 10.1089/jmf.2014.0115

FULL COMMUNICATION

# Yacon-Based Product in the Modulation of Intestinal Constipation

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ABSTRACT This study aimed to assess the effects of a yacon-based product (YBP) on constipation in adults, including the elderly. Forty-eight individuals were recruited and divided into equal intervention groups named the test and control groups. The YBP (test) and the control (maltodextrin) were dissolved in commercial orange juice. The volunteers for the YBP/test group consumed, on a daily basis, orange juice containing 10 g fructooligosaccharide (FOS)/inulin per day. The control group consumed, on a daily basis, orange juice containing 25 g of maltodextrin. The study had a span of 30 days. We evaluated the participants' frequency of evacuation, consistency of the feces, constipation score, abdominal symptoms (flatulence, pain, and abdominal strain), and effects upon the microbiota, pH, lactate, and short-chain fatty acids (SCFAs) of the feces. The study showed an increased number of evacuations after the consumption of the YBP as well as an improvement in the consistency of the feces and a reduction in the constipation score. After 30 days of intervention, the group that consumed the YBP showed higher counts of *Bifidobacterium*, lower *Clostridium* and enterobacteria counts, and lower fecal pH. In relation to SCFAs, no significant change was found after the intervention. However, the lactate concentration was higher in the test group when compared to the post-treatment control group. The YBP was effective in improving constipation symptoms; not only was its functional characteristic in reducing constipation symptoms evident but it also demonstrated usefulness as a potential therapy.

**KEY WORDS:** • ***constipation*** • ***functional food*** • ***prebiotics*** • ***yacon***

## INTRODUCTION

Constipation is defined as a condition in which the number of evacuations per week is less than three, with the presence of hard and dry feces, which hinders the elimination process.[1] It is a very common ailment among children, adults, and the elderly, with its occurrence varying from 2% to 28%,[2] and it is more prevalent among women.[3] In the municipality of Viçosa (in Minas Gerais [MG], Brazil), a constipation prevalence of 31.4%[4] was found.

The insufficient ingestion of fibers is one of the main causes of constipation. Dietary insoluble fibers, such as brans, have been used as a way to treat constipation, with successful results.[5] However, soluble fibers, such as prebiotics, are also beneficial for treating the condition[6] because they promote the balance of healthy intestinal microbiota that ferment these prebiotic compounds into short-chain fatty acids (SCFAs), such as butyrate, which have a trophic effect over the intestinal epithelium.[7]

Prebiotics are nondigestible food components that benefit the host by selectively stimulating the proliferation and/or the activity of the desired bacterial population (bifidobacteria) in the colon, which results in the inhibition of pathogen growth, thus ensuring benefits to the health of the host.[8]

Common prebiotics are fructooligosaccharide (FOS) and inulin oligosaccharide compounds that naturally occur in many plants[9] and are formed by a specific bond ($\beta\,2 \rightarrow 1$), a glucose molecule and two to eight fructose molecules.[10] This bond is not broken by the digestive enzymes of the gastrointestinal tract; therefore, these compounds arrive in the colon intact and are fermented by the microbiota.

The yacon plant (*Smallanthus sonchifolius*) is one of the richest natural sources of FOS and inulin[11,12]; these nutrients compose around 10–14% of the plant's dry matter.

The yacon, originally cultivated in the Andes,[13] is a tuberous root belonging to the Asteraceae family. Its cultivation in Brazil started in the 1990s. Because it is a source of FOS and inulin, the root and its by-products can potentially be used as a source of prebiotics in the diet. The yacon has a

Manuscript received 17 July 2014. Revision accepted 2 December 2014.

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remarkably high water content, which can exceed more than 70% of its weight in fresh plants.[14] This characteristic makes the root highly perishable. The development of products that can reduce this perishability and increase yacon availability throughout the year is of great importance since the root is seasonal.

The consumption of moderate quantities of products made from the yacon root is related to a reduction in the levels of plasma glucose,[15,16] reduction of triglycerides,[17] increase in the absorption of calcium and magnesium,[18] and improvement of bowel regularity.[15,19]

This study aimed to assess the clinical effects of a yacon-based product (YBP) in constipated individuals by comparing the changes in their evacuation frequency, feces consistency, constipation score, abdominal symptoms, and the effects on the microbiota, pH, lactate, and SCFAs of the feces.

## MATERIALS AND METHODS

### *Yacon-based product*

The product was processed according to the methodology proposed by Rodrigues,[16] which is going through patent request PI 1106621-0.

The chemical composition of the YBP was determined according to the AOAC methodology.[20] The following values were found in 100 g of product: 36.41 g carbohydrates, 0.08 g lipids, 0.20 g protein, 62.96 g humidity, 0.35 g ashes, and 19 g oligofructans (FOS and inulin).

### *Volunteers*

Adults, including elderly persons (from ages 20 to 75), with intestinal constipation were invited to take part in the study through fliers, Internet postings, and e-mail. The elderly were recruited by the Programa Municipal da Terceira Idade (PMTI) (Senior City Program) of the municipality of Viçosa/MG.

The Roma III Diagnostic Criteria[21] were used to confirm the diagnosis of constipation. The exclusion criteria were as follows: drug-induced constipation; presence of diseases/conditions that affect the intestinal flow, such as coeliac disease and lactose intolerance; laxative dependence; alcohol and drug use; intake of foods that contain prebiotics and probiotics (yogurts, beverages, supplements); or antibiotic usage in the last 3 months. The volunteers were informed of the objectives, as well as the terms of the study, and the consent form was presented to them; subsequently, their agreement in taking part in this study was requested.

### *Intervention*

Forty-eight volunteers (38 adults and 10 elders) took part in the study, 6 of whom were male and 42 female, with an average age of 39.77 ± 17.81 years; participants were divided in two equal intervention groups with 24 individuals each. The test group received 52 g of the YBP mixed with 448 mL of orange juice (Del Valle™), which contained a dose of 10 g of FOS/inulin. The control group received 25 g of maltodextrin mixed with 475 mL of orange juice (Del Valle). The quantity of maltodextrin was determined to provide the same amount of calories as the YBP. Twice a week the volunteers received their orange juice samples, totaling seven 500-mL bottles each. They were instructed to consume the juice in two daily portions, one in the morning and another in the evening (one bottle per day). The study had a span of 30 days.

### *Anthropometric assessment*

To characterize the studied population, an anthropometric assessment of the individuals was made before and after the intervention period. They were weighed while wearing light clothing on a digital electronic scale (Plenna™), with a capacity of 150 kg and 100-g precision. Their height was determined by using a millimetric vertical anthropometer, with a 2.0-m capacity and a 0.5-cm scale. The body–mass index (BMI), which correlates the weight (kg) and the square height (m),[22] was also calculated.

### *Evacuation categorization*

To categorize the evacuations, two assessment systems were used: the Bristol stool scale,[23] which assesses the consistency and the shape of the feces, and the Agachan score,[24] which aims at assessing the intensity of constipation. The Bristol stool scale is a medical scale used to classify the shape of the human feces in the following seven categories: 1, hard and separated lumps, similar to nuts; 2, sausage shaped, but lumpy; 3, like a sausage, but with cracks on its surface; 4, like a sausage, but with no cracks; 5, soft blobs with clear-cut edges; 6, fluffy pieces with ragged edges; and 7, watery. Category 4 is considered ideal. The volunteers used this scale to rate their bowel movements before and after the intervention period.

The Agachan score was also measured before and after the intervention. This score considers the following set of symptoms: evacuation frequency, pain while evacuating, difficulty and/or strain while evacuating, feeling of incomplete evacuation, abdominal pain, time needed to initiate the evacuation, type of assistance (no assistance, manual maneuvers, or use of laxatives), number of evacuation tries per day, and length of constipation. The lower the score is, the lower the constipation intensity. Values ranging from 0–10, 11–20, and 21–30 were classified as light, mild, and severe constipation,[3] respectively. The volunteers also registered the number of evacuations per week before and after the treatment.

### *Abdominal symptoms*

At the end of the study, the patients registered their perceptions of abdominal pain, abdominal strain, and flatulence according to four classifications: 0, no symptoms; 1, bearable symptoms; 2, uncomfortable symptoms; and 3, symptoms that impaired daily activities.[3]

### *Microbiota quantification and pH analysis*

For the stool collection, the participants were instructed to evacuate into a clean and dry container and to transfer a part of the fresh feces to the polypropylene collection flask with a screw lid and a capacity of 80 mL. The feces were stored in the collection containers at −80°C. This collection was performed before and after the clinical intervention. The stool samples were weighed in sterile polyethylene plastic bags. After the proper dilutions were made, plating was carried out in depth for each group to be analyzed. For the assessment of the different microbial groups, the following culture media were used: MRS agar (Difco, Detroit, MI, USA) for *Lactobacillus*,[25] modified MRS (Difco) for *Bifidobacterium*; RCM (Difco) for *Clostridium*,[26] MacConkey agar (Difco) for enterobacteria, and the Wilkins Chalgren medium (Difco) for total anaerobes.

All samples were incubated at 37°C/72 h in an anaerobic chamber (Anaerobac work station; Bug Box, Leeds, United Kingdom). The microbiological count was expressed in $Log_{10}UFC\ g^{-1}$.

The pH measurement was carried out in the first dilution for the analysis of the microbiota by using a pH meter (Bel Engineering W3B, Monza, Italy).

### *Lactate and SCFA quantification*

The lactate and SCFA analyses of the feces were conducted in duplicate, in accordance with that proposed by Smirick-Ktjardes *et al.*[27] For the extraction, 500 $\mu$L of 25% metaphosphoric acid was added to the samples, mixed in a vortex, and kept resting for 30 min at room temperature. After this stage, the tubes were centrifuged at 13,500 *g* for 30 min at 4°C; the supernate was centrifuged again at 13,500 *g* for 20 min and frozen at −20°C.

The analyses of the lactic, acetic, propionic, and butyric acids were conducted in a gas chromatography system (CGMS–QP 5000; Shimadzu, Tokyo, Japan). The aforementioned acids were separated and identified in a Nukol capillary column ($30 \times 0.25 \times 0.01$ mm). For the chromatographic separation, 1 mL of the sample was injected with the aid of a 10-mL syringe (Hamilton™) in a Splitless system on SIM (Selective Ion Monitoring) mode. Helium gas was used as a carrier, with linear velocity programed to 38.5 cm/sec. The temperatures of the injector and the detector were 200°C and 220°C, respectively. The programming of the column with the initial temperature at 80°C (for 5 min), raising 12°C/min up to 180°C, and finishing at 25°C/min up to 220°C (for 20 min) accounted for a total of 34.13 min of analysis. The mass was scanned from 40 to 400 *m/z*. The flow of the mobile phase in the column was 1.1 mL/min. From the stock solutions of acetic, lactic, butyric, and propionic acids, dilutions were made to obtain standard solutions. Each solution was injected in the chromatography system to obtain the curves, correlating the peak area with the concentration of acid in the solution. The volume of 1 mL of each sample was injected with the aid of a 10-mL syringe in a Splitless system, and each of the acids present were identified and quantified by comparison with the retention times and fatty acid concentrations in the standard solutions. The calculations were made by the microcomputer attached to the gas chromatography system equipped with the software GC Solution.

### *Ethics committee*

This study was approved by the Comitê de Ética em Pesquisa com Seres Humanos (Ethics Committee for Human Researches) of the ''Universidade Federal de Viçosa'' (UFV) (Federal University of Viçosa), following the judgment standards of the Declaration of Helsinki.

### *Statistical analyses*

To assess the distribution of variables, the Kolmogorov–Smirnov test was conducted. From the results of the test, parametric or nonparametric tests were chosen.[28] To compare the variables of the two groups before and after the intervention, a paired *t*-test was conducted for the variables with normal distribution.

For the variables that did not follow a normal distribution, the Wilcoxon test was performed. For the comparison of independent groups, Student's *t*-test was chosen for the variables with normal distribution, and the Mann–Whitney test for variables that did not show a normal distribution. The level of rejection of the null hypothesis was 5%.

For the analyses, we chose the SAS software (Statistical Analysis System; SAS Institute, Inc., Cary, NC, USA), version 9.20, licensed to UFV.

## RESULTS

### *Volunteers*

The data for age, weight, height, and BMI before and after clinical intervention are shown in Table 1.

For these variables, there was no statistically significant difference before and after the intervention period in both groups.

### *Evacuation categorization*

Patients in both groups showed similar values for the Bristol scale, Agachan score, and number of evacuations before the intervention period. After 30 days of treatment, there was a significant increase in the Bristol scale and number of bowel movements ($P < .001$) in the group that consumed the juice with YBP.

Regarding the Agachan score, there was a decrease ($P < .001$) in values for the test group, indicating a change in the classification of moderate to mild constipation (Table 2). For the control group, there were no statistical differences between the pre- and postintervention periods.

### *Abdominal symptoms*

Only two volunteers from the test group reported abdominal pain, classifying it as tolerable. Tolerable symptoms of flatulence were reported by 13 volunteers. Regarding abdominal distension, three volunteers reported tolerable symptoms. All volunteers reported that these annoyances occurred only during the first week of the intervention. The volunteers in the control group reported no such discomfort during treatment.

Table 1. Clinical Characteristics of the 48 Constipated Volunteers Before and After Intervention for 30 Days, Viçosa/MG, 2013

| | *Test group* | | | *Control group* | | |
|---|---|---|---|---|---|---|
| | *Before* | *After* | | *Before* | *After* | |
| *Variables* | *Average ± DP* | *Average ± DP* | P-*value* | *Average ± DP* | *Average ± DP* | P-*value* |
| Age (years) | 39.83 ± 18.51 | 39.83 ± 18.51 | 1.00 | 39.71 ± 17.62 | 39.71 ± 17.62 | 1.00 |
| Weight (kg) | 63.53 ± 11.34 | 63.48 ± 10.89 | .52 | 63.33 ± 8.92 | 63.28 ± 8.74 | .74 |
| Height (m) | 1.64 ± 0.06 | 1.64 ± 0.06 | 1.00 | 1.67 ± 0.06 | 1.67 ± 0.06 | 1.00 |
| BMI | 23.56 ± 3.03 | 23.56 ± 2.95 | .57 | 22.85 ± 3.22 | 22.83 ± 3.19 | .80 |

DP, standard deviation; *t*-test paired $P \geq .05$.
BMI, body–mass index.

*Microbiota quantification*

In the test group, the count of *Bifidobacterium* increased ($P < .05$), and *Clostridium* and Enterobacteriaceae counts decreased ($P < .05$) after 30 days of intervention. For the control group, there was only a decrease ($P < .05$) of *Lactobacillus*, with no difference among the other bacterial groups studied (Fig. 1).

*pH, lactate, and SCFAs*

The fecal pH of the test group showed a decrease ($P < .05$) after treatment with the YBP. For the control group, there was no statistically significant difference in fecal pH. Between the two groups, there was no significant difference before the intervention ($P = .428$). However, after the intervention, the pH of the test group was significantly lower ($P = .001$) compared with the control group (Table 3). Regarding organic acids, there was no statistically significant difference between the two study groups before or after the intervention, but after the intervention, the test group had higher lactate values than the control group ($P = .02$).

Table 2. Bristol Scale, Agachan Score, and Number of Bowel Movements Before and After Treatment in Both Groups

| | *Test group* (n = 24) | *Control group* (n = 24) |
|---|---|---|
| | *Average ± DP* | *Average ± DP* |
| Bristol scale | | |
| Before | 2.29 ± 0.90 | 2.33 ± 0.82 |
| After | 3.50 ± 0.78 | 2.29 ± 0.78 |
| *P* | < .001[a] | .84[a] |
| Agachan | | |
| Before | 12.71 ± 3.26 | 12.83 ± 3.65 |
| After | 5.96 ± 2.8 | 12.54 ± 3.04 |
| *P* | < .001[b] | .33[a] |
| Evacuation number | | |
| Before | 2.04 ± 0.95 | 1.92 ± 0.78 |
| After | 6.08 ± 1.69 | 2.00 ± 0.59 |
| *P* | < .001[b] | .54[a] |

[a]Wilcoxon test; [b]Paired *t*-test, $P < .05$.

## DISCUSSION

The present study showed positive results regarding the modulation of constipation by the YBP during the 30 days of intervention. There was an increased number of bowel movements, improvement in the shape of the feces, and a decrease in the intensity of constipation (as measured by the

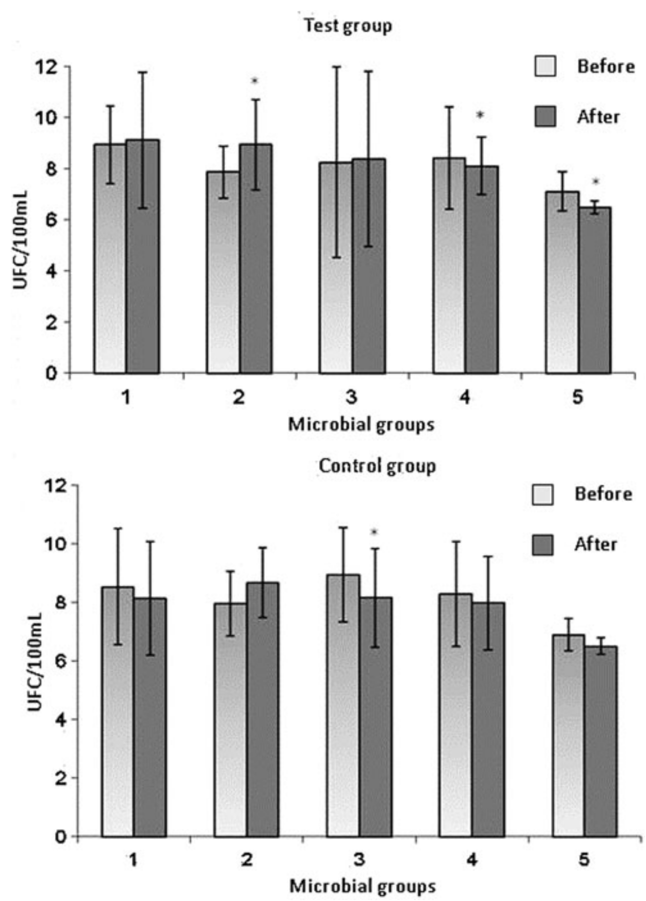


**FIG. 1.** Count of the different microbial groups present in the feces of the 48 volunteers from both intervention groups before and after treatment for 30 days. 1, Total anaerobes, 2, *Bifidobacterium,* 3, *Lactobacillus*, 4, *Clostridium,* 5, *Enterobacteria*. *Paired *t*-test, $P < .05$.

TABLE 3. pH, ACETATE, BUTYRATE, PROPIONATE, AND LACTATE FOUND IN THE FECES OF 48 VOLUNTEERS OF THE TWO INTERVENTION GROUPS BEFORE AND AFTER TREATMENT FOR 30 DAYS

| | *Test group* | | | *Control group* | | |
|---|---|---|---|---|---|---|
| | *Before* | *After* | | *Before* | *After* | |
| *Variables* | *Average ± DP* | | P | *Average ± DP* | | P |
| pH | 6.98 ± 0.74 | 6.56 ± 0.53 | .006[a] | 7.15 ± 0.72 | 7.17 ± 0.67 | .157[a] |
| Acetate | 64.74 ± 24.59 | 61.83 ± 34.11 | .570[b] | 63.00 ± 33.00 | 60.68 ± 29.10 | .112[b] |
| Butyrate | 25.25 ± 15.77 | 25.84 ± 15.29 | .576[b] | 17.65 ± 4.15 | 18.33 ± 3.43 | .207[b] |
| Lactate | 4.50 ± 3.010 | 4.86 ± 3.05 | .133[b] | 3.27 ± 0.96 | 3.05 ± 1.48 | .555[b] |
| Propionate | 27.67 ± 23.31 | 26.06 ± 18.68 | .202[b] | 31.87 ± 19.80 | 31.77 ± 22.57 | .676[b] |

Acid values mM. DP, standard deviation.
[a]Paired *t*-test.
[b]Wilcoxon test.

Agachan score) in volunteers who consumed sources of prebiotic in comparison with the control group. Maltodextrin was used as a placebo, for it is an easily digested and absorbed carbohydrate and is not fermented by the bacteria in the colon, thus not interfering with the microbial ecology of the gastrointestinal tract.[3] Unlike other studies that evaluated doses of FOS and inulin in the modulation of constipation, the volunteers in this study had symptoms of abdominal discomfort, such as flatulence and bloating, during the first week of intervention. This effect is probably related to the marked increase of desirable bacteria in the colon, due to the consumption of the YBP and its fermentation products, such as gas, for example; once the microbiota in the colon was balanced, these metabolites also were balanced and did not cause the undesirable effects after the second week of intervention. In a study conducted by Genta *et al.*,[15] the authors found an increased frequency of bowel movements in 55 women who consumed yacon syrup for 120 days; the dose administered in that study was of 0.14 g FOS per kg of body weight. A similar result was found in a study of constipated elderly individuals using the same dose and period of this intervention.[29]

Regarding the anthropometric parameters, no significant difference was found in the intervention period. This result is similar to other studies that evaluated the effects of FOS on metabolic syndrome[17] and constipation.[30]

Constipation causes changes in the balance of intestinal microflora, namely, a decrease in beneficial bacteria and a parallel increase of potentially pathogenic microorganisms and fungi.[31] Studies of prebiotics, both in animal and human models, have demonstrated the ability of these compounds to normalize the microbiota and stimulate intestinal motility.[3,15,32] The bifidogenic effect of FOS on healthy adults has been demonstrated in clinical trials,[6,33,34] but few studies have evaluated the effect of FOS on constipation. In the present study, there was a significant increase in the population of bifidobacteria and a decrease in the *Clostridium* and Enterobacteriaceae counts in the test group, demonstrating a positive effect on the modulation of the microbiota balance after YBP consumption.

Some species of the *Clostridium* and Enterobacteriaceae genera are associated with the emergence of some intestinal complications such as diarrhea, colitis,[35] necrotizing enterocolitis,[36] and gastroenteritis.[37] Therefore, the reduction in bacterial counts of both *Clostridium* and enterobacteria after YBP ingestion indicates a potential benefit for gut health. Clinical benefits were observed in 10 elderly individuals of both sexes diagnosed with constipation who had consumed 10 g of FOS for 30 days. The authors found an increase in the bacterial count of the *Bifidobacterium* genus and decreased clostridia counts in the group that received supplementation. However, no increased frequency of bowel movements[38] was reported.

The bifidogenic effect of FOS and inulin observed in this study is similar to the findings of other authors who carried out *in vitro*[39] or *in vivo* studies by using oligofructose,[40,41] galactooligosaccharides,[42,43] FOS, and inulin[37,44] as sources of indigestible carbohydrates. An increase in the production of SCFAs by means of the fermentation of prebiotics results in a decrease in the pH of the colon, which may be one of the mechanisms that explains the decreased population of potentially pathogenic bacteria.[40] However, Gibson *et al.*[41] showed that this acidity may not be the only mechanism of inhibiting pathogens. The authors demonstrated through experiments on the fermentation of nondigestible carbohydrates that even at neutral pH levels, bacteria of the *Clostridium* genus were inhibited when cocultured with *Bifidobacterium infantis*. The authors concluded that this positive effect of maintaining a balanced microbiota may be explained by the presence of inhibitory substances such as bacteriocins, which are produced by bifidobacteria.

In this study, the group receiving the YBP showed lower fecal pH after the intervention and when compared to the control group, indicating that the higher acidity may have acted positively in increasing the population of bifidobacteria and decreasing the population of Clostridia and enterobacteria.

Regarding lactate and SCFAs, no increase was found in their production after the ingestion of the YBP, which corroborates the findings of other studies.[30,37] Some authors[30,45] have argued that the increased production of SCFAs also leads to a greater use of these acids by enterocytes and by bacteria in the colon, thus reflecting a lower value found in the stool. An increase in the concentration of lactate was found for the test group after the consumption of prebiotics and when compared to the control group. This effect may be related to the increase of bifidobacteria in the test group, which are the main producers of this organic acid. The increased lactate concentration also reflects the results found for pH.

Yacon, being a source of prebiotic compounds, may be considered a food with a functionality claim. Functional foods should be consumed to reduce the risk of developing chronic diseases and conditions, thus acting preventively. In this study, the effect of a YBP was evaluated as a therapeutic treatment for constipation, but it can also be used to prevent the onset of the condition.

The consumption of the YBP was effective in increasing the number of bowel movements, improving stool consistency, and decreasing chronic constipation. Moreover, it showed a bifidogenic effect and was effective in decreasing the count of genera of unwanted bacteria during the 30 days of intervention. Because of its versatility, the YBP can be incorporated into various types of food, contributing to the development of products with a functionality claim based on a high content of FOS and inulin. The YBP, when compared to prebiotic ingredients available in the Brazilian market (usually imported), can be considered a low-cost easily accessible food.

## AUTHOR DISCLOSURE STATEMENT

No competing financial interests exist.

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