*Yacon (*Smallanthus sonchifolius*): A Functional Food*

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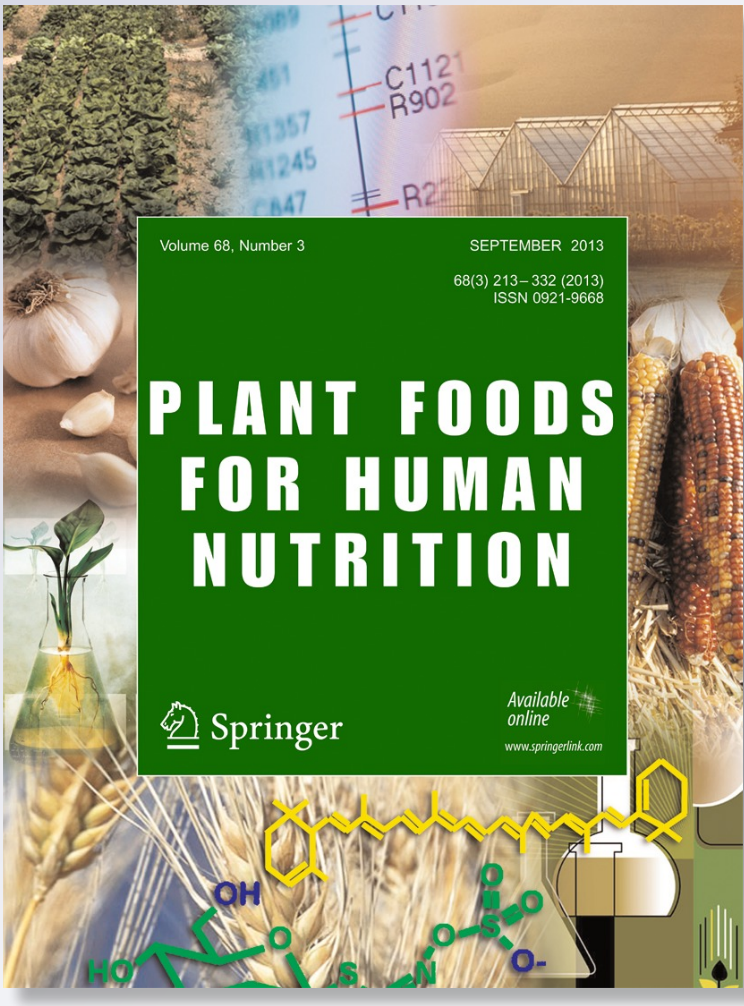

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ORIGINAL PAPER

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Abstract Yacon (*Smallanthus sonchifolius*) is an Andean tuberous root that is regarded as a functional food given that it contains fructooligosaccharides (FOS), inulin and phenolic compounds. The consumption of FOS and inulin improves the growth of *bifidobacteria* in the colon, enhances mineral absorption and gastrointestinal metabolism and plays a role in the regulation of serum cholesterol. Furthermore, the literature reports that the consumption of these prebiotics promotes a positive modulation of the immune system, improving resistance to infections and allergic reactions. Certain studies have demonstrated the potential of yacon as an alternative food source for those patients with conditions that require dietary changes. This review intends to describe the potential of yacon as a prebiotic and its cultivation and industrial processing for human consumption.

Keywords Fructans · Fructooligosaccharides · Phenolic compounds · Prebiotics · Yacon

Abbreviations

FOS	Fructooligosaccharides
NDOs	Non-digestible oligosaccharides
PAHO	Pan American Health Organisation
SCFA	Short-chain fatty acids

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Introduction

There is increasing interest in nutraceutical foods, which can be defined as foods that offer physiological benefits to the consumer beyond basic nutritional functions [1]. The consumption of prebiotics, such as fructooligosaccharides (FOS) and inulin, enhances certain physiological functions, promotes the immune response and increases resistance to pathogens [2].

Yacon is an Andean plant that is attracting global attention for its prebiotic advantages and benefits that are due to its high content of non-digestible oligosaccharides (NDOs), such as fructooligosaccharides and inulin, as well as phenolic compounds [3, 4] (Fig. 1). Therefore, yacon's tuberous roots have been used as natural sweeteners and syrups for digestive problems, particularly for balancing the intestinal microbiota. The traditional Andean population attributes anti-diabetic properties to the dry yacon leaves that are used in the preparation of teas as part of low calorie diets [5, 6].

In addition to prebiotics, yacon contains flavonoids, phenolic acids and tryptophan, which display antioxidant, anti-inflammatory, antimicrobial and anticancer activities. The phenolic compounds in yacon protect biomolecules, such as DNA, lipids and proteins, against damage caused by free radicals [7].

Several studies show an increase in the efficiency of the immune system as a result of the intake of nutraceuticals, especially fructans. It has been shown that regular consumption of these compounds increases resistance to infection by intracellular pathogens and leads to a reduction in allergies in the digestive tract. An increase in *bifidobacteria* in the intestinal microbiota appears to be correlated with fructans consumption [8].

Yacon has great potential to become a profitable product for small-scale farming using organic cultivation [3]. In producer countries, there is a wide variety of products derived from yacon roots, such as flour, dehydrated products, slices or "chips", tea (dried leaves), juices, purees and sweeteners in the form of syrup with a high FOS content [9].

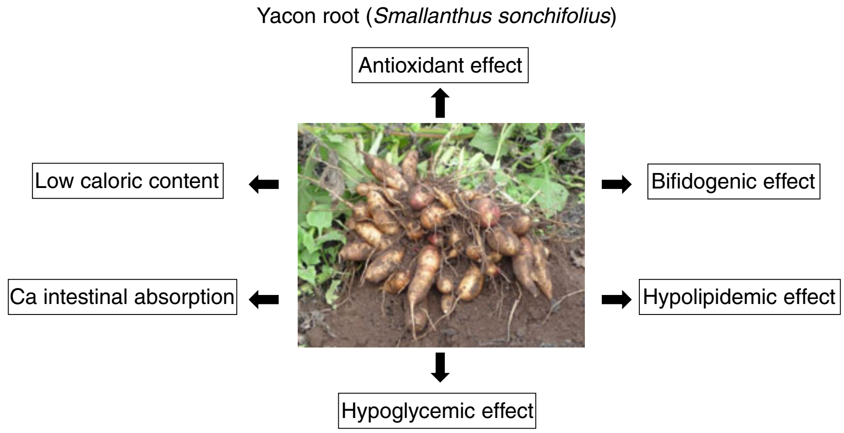

Fig. 1 The functional properties of the yacon plant

Due to the high demand for quality food, the inclusion of yacon as a source of fructan-type prebiotics in the production of different foods for human use represents a great opportunity for both innovation and adding value in the functional food industry. Therefore, this review summarizes the current knowledge on yacon's functional characteristics and the effects of regular yacon consumption on human and animal physiology.

Cultivation and Composition of Yacon Plant

Yacon is a crop found in the Andes, which includes a widespread area from Venezuela to north-western Argentina [10]. Yacon is cultivated between 900 and 3,500 m above sea level in Peru, between 600 and 2,500 m above sea level in Bolivia and Ecuador, and between 600 and 800 m above sea level in Argentina [9, 11].

Yacon has been part of the Andean diet since pre-Columbian times. In the last decade of the 20th century, the cultivation of yacon spread to several countries outside of the Andean region, such as western New Zealand, Europe, the USA and Japan, due to the medicinal properties of its roots and leaves [9, 11]. The Czech Republic has been a pioneer in yacon cultivation in Europe [12]. In Brazil, yacon is becoming an important crop, especially in the State of São Paulo [13]. In the early 1990s, a Brazilian farmer born in Japan introduced this species to the Capão Bonito/São Paulo region, where the tubers of 60–80 g are planted in beds 1 m wide by 0.4 m high and spaced 1.4 m between rows and 0.9 m between plants [13].

According to Zardini [10], the name yacon is derived from the Quechua term "yaku", which means water. However, yacon is also known in other regions by other names, including (1) Arboloco, (2) Aricoma, (3) Jícama/chícama, (4) Yíquima, (5) Jiquimilla and (6) Llacon. In English, it is known as "yacon strawberry" and in French, the name is "poire de terre".

Yacon was initially classified as *Polymnia* (*Compositae, Heliantheae*), but further studies placed the species that grow in Central and South America in the genus *Smallanthus* [9]. The yacon used in the diet of the indigenous tribes that inhabit the high mountains of the Andean region belongs to the species *Smallanthus sonchifolius*, from the family Asteraceae [11].

Yacon is sold in markets and fairs in the Andean region [9]. In Peru, Bolivia, Ecuador and Argentina, it is generally eaten at religious festivals, such as Corpus Christi and All Souls' Day. Yacon is generally consumed peeled and fresh, like a fruit and in fruit salad with bananas, oranges and papayas. Yacon can also be baked in the oven or consumed in the form of a refreshing beverage by extracting its juice.

The roots of yacon can weigh between 200 and 500 g each and can reach up to 2 kg. Each plant produces bunches of 5–20 units, giving an average of 5 kg/plant (Fig. 2). The freshly harvested roots are insipid, but after approximately 3–5 days of sun exposure, they become juicy and sweet. The taste of sweet yacon has been described as similar to that of a fresh apple or watermelon [14].

The chemical composition of yacon produced in the Andean region is presented in Table 1. Fresh yacon roots have a content of 69–83 % moisture, 0.4 to 2.2 % protein, and 20 % sugars [9].

The oligosaccharides from yacon have repeated units of β-1.2-D-frutofuranosil with a terminal sucrose. The major FOSs in yacon are kestose, nystose and 1-fructofuranosyl nystose, similar to those found in Jerusalem artichoke tubers (*Helianthus tuberosus*) [15, 16].

The sugar levels in yacon roots may vary depending on factors such as location, farming, the growing season, harvest time and the post-harvest temperature (Table 2). In Brazil, yacon root carbohydrates are composed of 34–55 % FOS, 7–9 % glucose, 13–14 % fructose and 10–13 % sucrose [15, 17]. However, in Peru, researchers have found yacon roots with carbohydrates consisting of 40–70 % FOS, 5–15 % sucrose, 5–15 % fructose and less than 5 % glucose (dry basis) [5, 11].

Yacon contains low-polymerization β-oligosaccharide, inulin, small amounts of vitamins and minerals and no

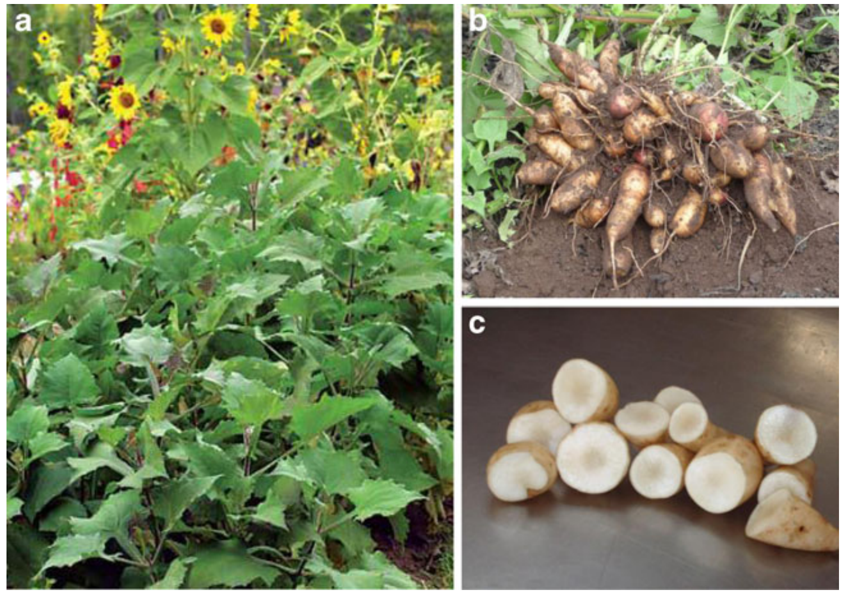

Fig. 2 Yacon plants. **a** Vegetative and reproductive organs; **b** Yacon roots; **c** Slices of yacon root (Sources: **a** http://www.motherearthnews.com/multimedia/image-gallery.aspx?id=74438&seq=1; **b** http://yacon.wordpress.com/about/; **c** G.T. [17])

starch. The most abundant minerals in yacon are calcium and potassium. In addition, yacon juice is rich in free essential amino acids [18]. The tuberous yacon root is rich in bioactive substances, such as phenolic compounds, ester derivatives, methyl esters, and glycosides. These compounds occur naturally in both the leaves and the roots.

Yacon juice contains 850 ppm of polyphenolic compounds, such as chlorogenic acid, which is considered to be yacon's primary antioxidant, in addition to tryptophan and caffeic acid derivatives [19]. The phenolic acids appear to be responsible for some of yacon's biological activities, including its anti-hyperglycaemic and cytoprotective effects, as well as waste disposal (Table 3). Yacon roots are rarely used in cooking due to the browning reaction that takes place very rapidly once the tissue is damaged. Yacon root rapidly darkens in storage even at low temperatures. This browning reaction appears to be related to yacon's phenolic content, especially the levels of caffeic and chlorogenic acids and endogenous polyphenol oxidase activity [20].

Yacon leaves have several phenolic compounds that enable epiphytic bacterial growth with very specific metabolic properties, inhibiting the attack of pathogens [12]. Total phenol levels in young yacon leaves are lower than in leaves collected at the time of tuber harvest [4].

Polyphenols found in yacon leaves and bark produce an acrid and astringent flavour, as well as impart a typical odor. Polyphenols are also substrates for the enzymatic browning of damaged tissues in yacon root, giving it a greenish or black color due to a condensation reaction of polyphenol compounds with amino acids and the enzymatic polymerization of polyphenols. The phenolic and flavonoid compounds, however, can modulate lipid peroxidation involved in atherogenesis, thrombosis and carcinogenesis through antioxidant activity against superoxide O_2 ions [12].

Table 1 Chemical composition of yacon root

Components %	Moscatto et al. [40]	Lobo et al. [13]	Ribeiro [43]	Choque Delgado et al. [17]
Moisture	7.49±0.17	ND	8.09±1.74	8.02±0.08
Protein	6.48±0.15	2.64±0.07	4.50±1.26	2.45±0.09
Lipids	0.31±0.01	0.61±0.02	0.67±0.19	0.87±0.10
Ash	3.56±0.02	3.85±0.06	2.88±0.13	2.53±0.14
Insoluble fibre	ND	7.85±0.17	11.79±0.36	3.46±0.12
Carbohydrate[a]	82.16	ND	ND	86.13
Calcium (mg/g)	ND	0.83±0.01	0.22±0.40	ND
Magnesium (mg/g)	ND	0.62±0.09	0.40±0.00	ND

Dry basis

ND Not determined

[a] Estimated by the difference

Table 2 Carbohydrate composition of yacon root

Carbohydrate %	Moscatto et al. [40]	Lobo et al. [13]	Habib et al. [25]	Choque Delgado et al. [17]
Fructose	4.13	13.51	26.00	14.10
Glucose	1.96	8.97	10.01	7.30
Sucrose	3.25	13.42	10.00	10.5
FOS/fructans	ND	55.33	52.00	34.31
1-kestose (GF2)	8.19	ND	ND	13.99
Nystose (GF3)	5.36	ND	ND	13.72
Fructofuranosyl-nistose (GF4)	4.03	ND	ND	6.59

FOS Fructooligosaccharides, *ND* Not determined

The Functional Effects of Yacon

Yacon administered as a dietary supplement is well tolerated and produces no negative response, toxicity or adverse nutritional effects [17]. In addition, yacon's low glucose content and high concentrations of fructooligosaccharides allow the study of possible effects in patients with metabolic diseases, such as diabetes and metabolic syndrome [21]. In this regard, yacon has been proven to reduce levels of glucose in normal and diabetic rats with hyperglycemia [22].

Table 3 Findings on yacon phenolic acids in animal models

Yacon source	Research, subject randomized, dose and duration	Design and measures	Main findings	Author, year and disease
Yacon tea	Rats (Sprague–Dawley)	Body parameters: plasma glucose, plasma insulin levels, body weight.	Yacon water extract produces an increase in plasma insulin concentration.	Aybar et al. [22]
	Dose: 2 % oral yacon leave tea *ad libitum* instead of water for 30 days.	Renal parameters: kidney weight, kidney-to-body weight ratio, creatinine clearance, urinary albumin excretion.	Decrease in plasma glucose levels in normal rats. Diabetic manifestations were reduced as revealed by clinical parameters.	Diabetes.
Crude extracts from yacon leaves	Rats (Wistar)	Plasmatic glucose and creatinine and enzymatic activity of AST, ALT and ALP.	The hydro-ethanolic extract of yacon significantly reduces the levels of glucose in diabetic rats.	Baroni et al. [44]
	Dose: oral extracts (400 mg/kg) or water for 3, 7, 10, and 14 days.	Consumption of food, water, urine volume, body weight of the animals.		Diabetes.
Leaf organic extracts and enhydrin	Rats (Wistar)	The fasting and post-prandial blood glucose and serum insulin levels.	Effective glycemic control in diabetic animals.	Genta et al. [31]
	Dose: methanol, butanol and chloroform extracts (50, 10 and 20 mg/kg body weight) by eight weeks.	Hypoglycemic activity (OGTT). Dose optimization of each extract.	Increased plasma insulin level. Caffeic, chlorogenic and dicaffeoylquinic acids were significant components. Enhydrin was effective in reducing post-prandial glucose.	Diabetes.
Tea extracts and ent-kaurenoic acid	Mice (albino)	Hypoglycemic activity	100 mg/kg BW yacon leaf tea extract is effective in lowering blood glucose levels of normoglycaemic mice.	Raga et al. [45]
	Dose: yacon leaf tea extract (200, 100 and 50 mg/kg body weight) during 1–2 h	Blood glucose level (OGTT)		Diabetes.
Extracts from yacon leaves	Rats (Wistar)	Fractions were tested in superoxide radical scavenging assays, as an inhibition of lipoperoxidation of subcellular membranes.	Lipoperoxidation was inhibited of rat liver subcellular membranes.	Valentová et al. [6]
	Fractions: DPPH and xanthine/XOD		Rat hepatocytes were protected against oxidative injury.	Oxidation activity

OGTT Oral glucose tolerance test, *DPPH* 1,1-diphenyl-2- picrylhydrazyl, *BW* Body weight

Because of its inulin and FOS contents, yacon has shown important prebiotic characteristics. It resists digestion in the upper digestive tract and is hydrolyzed and fermented by colonic bacteria, such as *lactobacillus* and *bifidobacteria* [23]. It has been shown that the association between prebiotics and probiotics has beneficial consequences for the intestinal tract [5, 15]. *Bifidobacteria* inhibit the growth of putrefactive bacteria in the colon and promote the absorption of $Ca2^{+}$ and $PO4^{-}$ ions as well B vitamin synthesis. These bacteria can also stimulate the immune system [16]. In this regard, the consumption of yacon root leads to an increase in short-chain fatty acids (SCFA) that protect against colon cancer [24].

Certain investigations have shown that yacon promotes several important aspects of health. An experiment using a diabetic rodent model showed that FOS consumption could improve insulin release and/or insulin-like activity [25]. The authors commented that the regular intake of yacon flour exerts lipid-lowering effects through the activation of the lipoprotein lipase enzyme and a slight increase in fasting plasma insulin levels [25]. Some authors state that the saccharides present in yacon, particularly β-(2→1) fructooligosaccharides, could modulate the metabolic syndrome that occurs in type 2 diabetes and dyslipidemia, which are considered to be risk factors for atherosclerosis [4].

Polyphenolic compounds could alter glucose metabolism and anti-hyperglycemic activity, acting as anti-diabetic agents [26]. This effect on glucose metabolism may be mediated by the insulin-like effect or by improvement in antioxidant status [27]. In this regard, phenolic extracts of yacon leaves were able to reduce glucose production in rat hepatocytes by increasing glucokinase mRNA expression [28].

As natural antioxidants, polyphenol compounds are of great importance to human health, particularly in protecting cell membranes against damage from oxygen radicals. Moreover, these compounds may play a role in cardiovascular disease and cancer [20, 29]. Ethanolic extract of yacon leaves was proven to exert antioxidant activity and cytoprotective effects against tert-butyl hydroperoxide in a model of oxidative damage in rat hepatocytes [7]. Trials in humans have also reported the antioxidant activity of the phenolic compounds present in yacon leaves, acting to prevent chronic diseases, such as atherosclerosis, a disease that involves free radicals in its development [12].

Studies of yacon syrup revealed that its consumption over a long period produced beneficial effects on premenopausal obese women with dyslipidemia and insulin resistance [30]. The daily consumption of yacon syrup produced a significant reduction in body weight, waist circumference and body mass index. A reduction in fasting serum insulin and the homeostasis index was also observed. Furthermore, ingestion of yacon syrup increased the frequency of defecation and satiety [30].

A recent study evaluated the hypoglycaemic activity of phenolic compounds in organic extracts from yacon leaves in Wistar rats. The results indicated that enhydrin, the main sesquiterpene lactone from yacon leaves, caffeic acids, chlorogenic acids and three dicaffeoylquinic acids (CAF, 3-CQ; 3.4-DCQ, 3.5 and 4.5-DCQ -DCQ) are related to its hypoglycemic effect given that these compounds reduced levels of blood glucose in diabetic animals [31]. Two newly identified sesquiterpene lactones and 11 known melampolides were isolated from yacon leaves. These compounds have been shown to inhibit the production of nitric oxide (NO) in LPS-treated macrophages [32].

Low pH and the production of SCFA due to the consumption of prebiotics result in hypertrophy of the mucosal cells, enlargement of the intestinal surface and enhanced solubility of mineral ions [33]. Yacon consumption for relatively short periods also resulted in increased intestinal absorption of minerals and bone mass, favoring the biomechanical properties of bone in rats [13]. The enlargement of the cecal wall observed after yacon consumption appears to contribute to the increased mineral absorption in those animals. In fact, some studies show that daily consumption of a combination of short- and long-chain inulin-type fructans significantly increases calcium absorption and bone mineralization during pubertal growth. The effects of these dietary factors on calcium absorption appear to be modulated by genetic factors, including genetic polymorphism of a specific D-vitamin receptor [34]. It has been observed that the consumption of inulin-type fructans also reduces osteoporosis progression by increasing the bioavailability of calcium, with a significant increase in bone density and bone mineral mass [33].

Studies performed by Pinto and colleagues [35] showed that yacon also produces antimicrobial compounds, which could explain the fact that pesticides are not necessary for yacon cultivation. These authors reported the inhibition of aflatoxin production when aqueous and ethanol yacon extracts were added to *Aspergillius flavus* cultures [35]. Recently, Joung and colleagues [36] showed that the n-hexane fraction of yacon leaf extract has antimicrobial activity against six different strains of methicillin-resistant *Staphylococcus aureus* (MRSA) in the presence of 4,000 lux with a minimal inhibitory concentrations (MICs) assay (15.6 g/ml). No activity was detected when the tests were performed in the absence of light.

Although rare, the literature shows two cases of adverse effects after yacon consumption. The first case involved the development of anaphylactic reactions by a 55-year-old woman due to consumption of yacon root [37], and the second report involved the development of renal lesions in rats following prolonged consumption of yacon leaf extracts [38]. Thus, clinical trials are still needed to determine the safety of yacon as a dietary supplement in specific situations.

Yacon Root Processing

There is great potential for commercial products that are generated from yacon. In this sense, the National Research Council ranked yacon as a promising raw material based on its high fructans content [10]. Due to its high concentration of fructose, yacon root is a fruitful source for the development of natural sweeteners and syrups for people with digestive problems. Yacon leaves are consumed in teas for patients with diabetes or those who suffer from digestive and kidney diseases [22].

Certain studies have shown that incorporating inulin and fructans into various foods, especially baked goods, makes them acceptable to consumers because of its sensory characteristics. Yacon syrup has already been incorporated into several product formulations that are considered to be "light", easy to chew and have a porous texture [39]. Likewise, products using inulin are known for their sensory characteristics, such as a neutral and mild flavour that increases palatability, stability and acceptability [40].

There are already some industrial products derived from yacon on the market, such as flour, candy, sliced chips, teas, nutritional drinks and purees. "Chancaca" is a concentrated sweetener with a high sugar content that Andean natives prepare by boiling the root juice until crystallization, resulting in solid blocks of a dark brown color [9]. Fructose from yacon has a sweetening power 30–70 % greater than that of sucrose, in addition to being a non-caloric sweetener [13, 17]. Lastly, the presence of inulin in the yacon tubers is of great interest to the industrialization of inulinase produced by microorganisms [41].

Other research has shown that vacuum drying would be an appropriate way to increasing yacon's shelf life, improving the appearance and preserving the characteristics of the root. This process is relevant to adding value to the product and would increase the product's demand [42].

Conclusions

According to Pan American Health Organisation (PAHO), the human health depends on both hereditary and environmental factors, including lifestyle and access to adequate food. In this respect, functional foods are gaining more supporters due to the benefits associated with their consumption. Yacon, a natural resource from the Andes, has great potential as a functional food due to its high content of fructooligosaccharides and inulin, which promote the development of the colonic microbiota. In addition to the roots, yacon leaves are also exploited because of their phenolic compounds, which have antioxidant properties that protect cell membranes against damage caused by oxygen radicals and consequently, cardiovascular disease and cancer. Yacon's regular use may benefit patients with digestive and kidney diseases, as well as those with diabetes and metabolic syndrome. The high levels of FOS and phenolic compounds represent a potentially profitable niche for yacon in small-scale farming systems, which are characterized by ecological practices and local processing, thereby contributing to sustainable development of the region. An alternative product may be sweet syrups and natural sweeteners for people with digestive problems and obesity, reaching a broader group of beneficiaries. Currently, several clinical studies are being conducted to evaluate the conditions necessary for the safe use of yacon as a dietary supplement in groups other than the populations that have traditionally used this plant in their diet.

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Conflict of Interest The authors declare no conflict of interest.

References

1. Agência Nacional de Vigilância Sanitária (ANVISA) (2005) Alimentos. Comissões e Grupos de Trabalho. Comissão Tecnocientífica de Assessoramento em Alimentos Funcionais e Novos Alimentos. Alimentos com Alegações de Propriedades Funcionais e ou de Saúde, Novos Alimentos/Ingredientes, Substâncias Bioativas e Probióticos. Brasil. http://www.anvisa.gov.br/alimentos/comissões/tecno.htm. Accessed 1 February 2012
2. Vos AP, van Esch BC, Stahl B, M'Rabet L, Folkerts G, Nijkamp FP, Garssen J (2007) Dietary supplementation with specific oligosaccharide mixtures decreases parameters of allergic asthma in mice. Int Immunopharmacol 7(Suppl 12):1582–1587
3. Graefe S, Hermann M, Manrique I, Golombek S, Buerkert A (2004) Effects of post-harvest treatment on the carbohydrate composition of yacon roots in the Peruvian Andes. Field Crop Res 86:157–165
4. Valentová K, Lebeda A, Dolezalová I, Jirovský D, Simonovska B, Vovk I, Kosina P, Gasmanová N, Dziechciarková M, Ulrichová J (2006) The biological and chemical variability of yacon. J Agric Food Chem 54:1347–1352
5. Pedreschi R, Campos D, Noratto G, Chirinos R, Cisneros-Zevallos L (2003) Andean yacon root *(Smallanthus sonchifolius Poepp. Endl*) frutooligosaccharides as a potential source of prebiotics. J Agric Food Chem 51:5278–5284
6. Valentová K, Cvak L, Muck A, Ulrichova J, Simanek V (2003) Antioxidant activity of extracts from the leaves *of Smallanthus sonchifolius*. Eur J Nutr 42:61–66
7. Simonovska B, Vovk I, Andrensek S, Valentová K, Ulrichová J (2003) Investigation of phenolic acids in yacon (*Smallanthus sonchifolius*) leaves and tubers. J Chromatogr A 1016:89–98
8. Watzl B, Girrbach S, Roller M (2005) Inulin, oligofructose and immunomodulation. Br J Nutr 93(Suppl 1):S49–S55
9. National Research Council (NRC) (1989) Lost crops of the Incas: little-known plants of the Andes with promise for worldwide Cultivation. National Academy Press, Washington, DC
10. Zardini E (1991) Ethnobotanical notes on yacon, *Polymnia sonchifolia* (*asteraceae*). Econ Bot 45(Suppl 1):72–85

11. Manrique I, Párraga A, Hermann M (2005) Yacon syrup: principles and processing. Series: Conservación y uso de la biodiversidad de raíces y tubérculos andinos: Una década de investigación para el desarrollo (1993–2003). No. 8B. International Potato Center, Universidad Nacional Daniel Alcides Carrión, Erbacher Foundation, Swiss Agency for Development and Cooperation. Lima, Peru
12. Valentová K, Sersen F, Ulrichová J (2005) Radical scavenging and anti-lipoperoxidative activities of *Smallanthus sonchifolius* leaf extracts. J Agric Food Chem 53:5577–5582
13. Lobo AR, Colli C, Alvares EP, Filisetti TM (2007) Effects of fructans-containing yacon (*Smallanthus sonchifolius Poepp & Endl.*) flour on cecum mucosal morphometry, calcium and magnesium balance, and bone calcium retention in growing rats. Br J Nutr 97:776–785
14. Manrique I, Hermann M, Bernet T (2004) Yacon - fact sheet. Lima, Peru: International Potato Center (CIP). http://www.cipotato.org/artc/cipcrops/factsheetyacon.pdf. Accessed 29 July, 2012
15. Roberfroid M, Gibson GR, Hoyles L, McCartney AL, Rastall R, Rowland I, Wolvers D, Watzl B, Szajewska H, Stahl B, Guarner F, Respondek F, Whelan K, Coxam V, Davicco MJ, Léotoing L, Wittrant Y, Delzenne NM, Cani PD, Neyrinck AM, Meheust A (2010) Prebiotic effects: metabolic and health benefits. Br J Nutr 104(Suppl 2):S1–S63
16. Choque Delgado GT, Tamashiro WMSC, Pastore G (2010) Immunomodulatory effects of fructans. Food Res Int 43:1231–1236
17. Choque Delgado GT, Thomé R, Gabriel DL, Tamashiro WMSC, Pastore G (2012) Yacon (*Smallanthus sonchifolius*)-derived fructooligosaccharides improves the immune parameters in the mouse. Nutr Res 32:884–892
18. Kapuler A, Gurusiddiah S (1994) The twenty protein aminoacids free in the juices of our common vegetables and herbs. J Home Consum Hortic 1:3–18
19. Takenaka M, Yan X, Ono H, Yoshida M, Nagata T, Nakanishi T (2003) Caffeic acid derivates in the roots of yacon (*Smallanthus sonchifolius*). J Agric Chem 51:793–796
20. Neves V, da Silva A (2007) Polyphenol oxidase from Yacon roots (*Smallanthus sonchiflolius*). J Agric Chem 55(Suppl 6):2424–2430
21. Genta SB, Cabrera WM, Grau A, Sánchez SS (2005) Subcronic 4-month oral toxicity study of dried *Smallanthus sonchifolius* (yacon) roots as a diet supplement in rats. Food Chem Toxicol 43:1657–1665
22. Aybar MJ, Sánchez Riera AN, Grau A, Sánchez SS (2001) Hyploglycemic effect of the water of *Smallantus sonchifolius* (Yacon) leaves in normal and diabetic rats. J Ethnopharmacol 74:125–132
23. Bibas Bonet ME, Meson O, De Moreno De Leblanc A, Dogi CA, Chaves S, Kortsarz A, Grau A, Perdigón G (2010) Prebiotic effect of yacon (*Smallanthus sonchifolius*) on intestinal mucosa using a mouse model. Food Agric Immunol 21(Suppl 2):175–189
24. de Moura NA, Caetano BF, Sivieri K, Urbano LH, Cabello C, Rodrigues MA, Barbisan LF (2012) Protective effects of yacon (*Smallanthus sonchifolius*) intake on experimental colon carcinogenesis. Food Chem Toxicol 50:2902–2910
25. Habib NC, Honoré SM, Genta SB, Sánchez SS (2011) Hypolipidemic effect of *Smallanthus sonchifolius* (yacon) roots on diabetic rats: biochemical approach. Chem Biol Interact 194(Suppl 1):31–39
26. Büyükbalci A, El SN (2008) Determination of *in vitro* antidiabetic effects, antioxidant activities and phenol contents of some herbal teas. Plant Foods Hum Nutr 63:27–33
27. Chemler JA, Lock LT, Koffas MA, Tzanakakis ES (2007) Standardized biosynthesis of flavan-3-ols with effects on pancreatic beta-cell insulin secretion. Appl Microbiol Biotechnol 77(Suppl 4):797–807
28. Valentová K, Truong NT, Moncion A, de Waziers I, Ulrichová J (2007) Induction of glucokinase mRNA by dietary phenolic compounds in rat liver cells *in vitro*. J Agric Food Chem 55(Suppl 19):7726–7731
29. Pérez-Jiménez J, Serrano J, Tabernero M, Arranz S, Díaz-Rubio ME, García-Diz L, Goñi I, Saura-Calixto F (2009) Bioavailability of phenolic antioxidants associated with dietary fiber: plasma antioxidant capacity after acute and long-term intake in humans. Plant Foods Hum Nutr 64:102–107
30. Genta S, Cabrera W, Habib N, Pons J, Carillo IM, Grau A, Sánchez S (2009) Yacon syrup: beneficial effects on obesity and insulin resistance in humans. Clin Nutr 28:182–187
31. Genta SB, Cabrera WM, Mercado MI, Grau A, Catalán CA, Sánchez SS (2010) Hypoglycemic activity of leaf organic extracts from *Smallanthus sonchifolius*: constituents of the most active fractions. Chem Biol Interact 185:143–152
32. Hong SS, Lee SA, Han XH, Lee MH, Hwang JS, Park JS, Oh KW, Han K, Lee MK, Lee H, Kim W, Lee D, Hwang BY (2008) Melampolides from the leaves of *Smallanthus sonchifolius* and their inhibitory activity of LPS-induced nitric oxide production. Chem Pharm Bull 56(Suppl 2):199–202
33. Roberfroid M, Cump J, Devogelaer JP (2002) Dietary chicory inulin increases whole-body bone mineral density in growing male rats. J Nutr 132:3599–3602
34. Abrams SA, Griffin IJ, Hawthorne KM, Liang L, Gunn SK, Darlington G, Ellis KJ (2005) A combination of prebiotic short- and long-chain inulin-type fructans enhances calcium absorption and bone mineralization in young adolescents. Am J Clin Nutr 82:471–476
35. Pinto M, Gonçalez E, Rossi M, Felício J, Medina C, Fernandes M, Simoni IC (2001) Activity of the aqueous extract from *Polymnia sonchifolia* leaves on growth and production of aflatoxin B1 by *Aspergillus flavus*. Braz J Microbiol 32:127–129
36. Joung H, Kwon DY, Choi JG, Shin DY, Chun SS, Yu YB, Shin DW (2010) Antibacterial and synergistic effects of *Smallanthus sonchifolius* leaf extracts against methicillin-resistant *Staphylococcus aureus* under light intensity. J Nat Med 64:212–215
37. Yun EY, Kim HS, Kim YE, Kang MK, Ma JE, Lee GD, Cho YJ, Kim HC, Lee JD, Hwang YS, Jeong YY (2010) A case of anaphylaxis after the ingestion of yacon. Allergy Asthma Immunol Res 2:149–152
38. de Oliveira RB, de Paula DA, Rocha BA, Franco JJ, Gobbo-Neto L, Uyemura SA, dos Santos WF, Da Costa FB (2011) Renal toxicity caused by oral use of medicinal plants: the yacon example. J Ethnopharmacol 133:434–441
39. Maldonado S, Singh J (2008) Efecto de gelificantes en la formulación de dulce de yacón. Ciênc Tecnol Aliment 28(Suppl 2):429–434
40. Moscatto JA, Borsato D, Bona E, de Oliveira AS, de Oliveira MCH (2006) The optimization of the formulation for a chocolate cake containing inulin and yacon meal. Int J Food Sci Tech 41:181–188
41. Cazetta ML, Martins PMM, Monti R, Contiero J (2005) Yacon (*Polymnia sonchifolia*) extract as a substrate to produce inulinase by *Kluyveromyces marxianus* var. *bulgaricus*. J Food Eng 66:301–305
42. Reis FR, Lenzi MK, Masson ML (2012) Effect of vacuum drying conditions on the quality of yacon (*Smallanthus sonchifolius*) slices: process optimization towards color quality. J Food Process Preserv 36:67–73
43. Ribeiro JA (2008) Estudos químicos e bioquímicos do yacon (*Smallanthus sonchifolius*) in natura e processado e influência do seu consumo sobre níveis glicêmicos e lipídeos fecais de ratos. Juciane de Abreu Ribeiro.-Lavras: UFLA
44. Baroni S, Suzuki-Kemmelmeieret F, Caparroz-Assef SM, Nakamura RC, Bersani-Amado CA (2008) Effect of crude extracts of leaves of *Smallanthus sonchifolius* (yacon) on glycemia in diabetic rats. Braz J Pharm Sci 44(Suppl 3):521–530
45. Raga DD, Alimboyoguen AB, del Fierro RS, Ragasa CY (2010) Hypoglycaemic effects of tea extracts and ent-kaurenoic acid from *Smallanthus sonchifolius*. Nat Prod Res 24(18):1771–1782