



## Original Article

## Yacon syrup: Beneficial effects on obesity and insulin resistance in humans

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## SUMMARY

**Background & aims:** Syrup obtained from yacon roots could be well positioned as a nutraceutical product due to its high fructooligosaccharides content. We examined the beneficial effects and tolerance of yacon syrup on human health.

**Methods:** Obese and slightly dyslipidemic pre-menopausal women were studied over a 120-day period in a double-blind placebo-controlled experiment. We used two doses of yacon syrup, 0.29 g and 0.14 g fructooligosaccharides/kg/day.

At the start and end of the study, anthropometric measurements, blood glucose, calcium, lipid and insulin concentrations and Homeostasis Model Assessment index were determined.

**Results:** The recommended daily consumption of yacon syrup with no undesirable gastrointestinal effects is 0.14 g fructooligosaccharides/kg.

Daily intake of yacon syrup produced a significant decrease in body weight, waist circumference and body mass index. Additionally, decrease in fasting serum insulin and Homeostasis Model Assessment index was observed. The consumption of yacon syrup increased defecation frequency and satiety sensation. Fasting glucose and serum lipids were not affected by syrup treatment and the only positive effect was found in serum LDL-cholesterol levels.

**Conclusions:** Yacon syrup is a good source of fructooligosaccharides and its long-term consumption produced beneficial health effects on obese pre-menopausal women with insulin resistance.

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## 1. Introduction

Overweight and obesity are major risk factors for the development of chronic diseases such as diabetes and coronary heart failure. A widely accepted notion is that insulin resistance and other alterations of the metabolic syndrome are a direct consequence of excessive abdominal visceral adipose tissue.<sup>1</sup> Additionally, other factors including inter-organ communication mediated by peptide hormones and inflammatory molecules are involved in the metabolic mechanisms of insulin resistance.<sup>2</sup>

It has been firmly established that non-diabetic people with metabolic syndrome are at very high risk for type 2 diabetes.<sup>3</sup> Both pathological conditions have shown a rapid progression worldwide, a phenomenon resulting from the epidemic proportions

reached by obesity. Thus, tackling obesity may go some way towards slowing down the progression to diabetes, reducing visceral fat, insulin resistance and metabolic syndrome. There is a pressing need to implement nutritional strategies to prevent or ameliorate these problems. However, much work remains to be done to elucidate the complex interaction between obesity and metabolic syndrome.

In addition to drug treatment, dietary interventions were shown to be an effective tool to prevent or treat insulin resistance and type 2 diabetes.<sup>4</sup> Besides contributing to desirable weight, dietary components appear to have an important role in the retardation of diabetes development. In general, the intake of a healthy diet rich in vegetables, fruits and grains appears to have protective effects.

Yacon (*Smallanthus sonchifolius* Poepp.&Endl.) H. Robinson is a native plant of the Andean region cultivated for its tubers, which are consumed mainly as “fruit”. In contrast with most edible roots, yacon stores its carbohydrates in the form of  $\beta$ -(2 → 1) fructooligosaccharides (FOS).<sup>5</sup>

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FOS are sugars found naturally in many types of plants but never in concentrations as high as in yacon roots.<sup>6</sup> FOS are able to resist the hydrolysis of enzymes in the upper part of the human gastrointestinal tract. For this reason, they have a low caloric value for humans.<sup>7</sup>

FOS have been shown to exert health benefits during digestion and can prevent and control constipation.<sup>8</sup> They have also been shown to reduce blood lipid and glucose levels in animals and in diabetic subjects.<sup>9,10</sup>

Yacon FOS are completely fermented in the colon by a group of beneficial bacteria that form part of the intestinal microflora. These bacteria (especially of the genus *Bifidus* and *Lactobacillus*) improve the gastrointestinal function.<sup>11</sup>

In a previous work we demonstrated that yacon roots administered as a diet supplement to normal rats produced no negative response, toxicity or adverse nutritional effects at two daily intake levels of 340 and 6800 mg FOS/body weight.<sup>12</sup> Moreover, yacon supplementation resulted in significantly reduced post-prandial serum triacylglycerol levels. These findings raise the interesting possibility of investigating the effects of yacon roots and of their derived products on human health.

Yacon syrup is a novel product obtained by concentrating the juice of yacon roots that contains approximately 40–50% FOS. Its physical and sensorial characteristics are similar to those of honey or sugar cane syrup.<sup>13</sup> Yacon syrup could be well positioned as a nutraceutical product due to its naturally high FOS content. The effects of the rich FOS-yacon syrup need to be exhaustively studied. Thus, the aim of the present work was to investigate the health benefits of the use of yacon syrup and its tolerance in patients with overweight and/or obesity and slight dyslipidemia through a randomized 120-day placebo-controlled intervention study.

## 2. Material and methods

### 2.1. Plant material

The *S. sonchifolius* (yacon) variety AMM5163 roots were obtained from the 2006 harvest of an experimental field at the International Potato Center, La Molina, Lima, Perú, the voucher specimen being deposited in the Center collection. The syrup was prepared in the International Potato Center processing plant.

### 2.2. Yacon syrup preparation and characteristics

The technology for producing yacon syrup is simple: juice is extracted from the root and concentrated until it reaches a level of 73°Brix.<sup>13</sup> The refractive index or degrees Brix was developed in the laboratory of the processing plant as a fast and simple method to estimate FOS content, enabling selection from among various yacon plots those with the highest FOS content.

The quality of the product in terms of FOS content is maintained using a particular evaporator design, with temperatures under 120 °C, at which point the sugars begin to break down into simple forms.<sup>13</sup>

Yacon syrup, as used in this study, has the following characteristics: concentration of soluble solids, 73 ± 1°Brix, density, 1.540 g/l, pH 5.4.

### 2.3. Chemical composition of syrup

The chemical composition of yacon syrup was determined at the International Analytical Servi Laboratories (Lima, Perú) using official methods of analysis of AOAC International (Association of Official Agricultural Chemistry, Maryland (US) 1997). The proteins were determined using the Kjeldahl method (970.22 AOAC); the

total lipid contents were determined by Soxhlet extraction method (AOAC 963.15); potassium and sodium were determined by atomic absorption spectrophotometry (American Association of Cereal Chemistry (AACC) method 40-71); ash was determined by incinerating at 500 °C in a muffle furnace for 6 h, the moisture was determined by AOAC 934.01 method.

Yacon syrup contained 2.16% (w/w) proteins, 0.14% (w/w) lipids and 67.04% (w/w) carbohydrates (25.65% free simple sugar, 41.39% FOS). FOS and free sugar concentrations in the syrup were estimated using a Fructan Assay Procedure AOAC Method 999.03, AACC Method 32.32 (Megazyme International Ireland Ltd.). FOS is considered as a soluble fiber, so that the FOS level in the syrup can also represent the level of fiber.

Potassium was the only micronutrient found at significant levels (936 mg/100 g) while sodium levels were low (84 mg/100 g). Total ash and moisture were 2.42 and 28.24% respectively.

For syrup that is bottled without preservatives and with an acidity of pH 5.4, shelf life can be quite long with or without refrigeration. Studies carried out at the International Potato Center showed that after twelve months of storage the syrup did not spoil and that the composition of its chemical carbohydrates (FOS, glucose, sucrose and fructose) did not change.<sup>13</sup>

### 2.4. Placebo syrup

This syrup was prepared with the following additives (w/v): tartaric acid 2.5%, carboxymethylcellulose 1.8%, saccharine 2.5% and glycerine 10%.

### 2.5. Subjects

Thirty-five out of a total of 55 women completed this study with good compliance.

The criteria for recruitment were: 31–49 years of age, no menopausal disorders, obesity with mild dyslipidemia and a history of constipation. Exclusion criteria were impaired liver or renal function, cardiovascular diseases, hypertension, diabetes mellitus or patients with severe hyperlipidemia. None of the participants had received laxatives, medication for weight loss or other pharmacotherapy during the 3 months prior to the study.

The nature and risks of the experimental procedures were fully explained to the subjects, after which their written informed consent was obtained. The study protocol was approved by the Medical Ethics Committee and Clinical Education – Investigation of the Hospital Angel C. Padilla, Tucumán, Argentina. In the province of Tucumán, Argentina, all research involving humans are under regulation of the Law of Research on Human Subjects No. 6580/94, which states that research requires the written consent of the subject or of his/her legal representative (art. 2, inc.c).

Each patient kept a diary in which they recorded time of syrup consumption, changes in usual eating, drinking or lifestyle behavior, frequency of defecation, possible discomfort related to gastrointestinal adverse effects (diarrhea, abdominal distension, flatulence, and nausea), satiety or hunger.

### 2.6. Study design

Subjects were studied over a 120-day period in a double-blind placebo-controlled experiment.

The patients were randomly assigned to three groups. Group 1 received yacon syrup containing an intake level of 0.29 g FOS/kg body weight/day; group 2 received an intake level of 0.14 g FOS/kg body weight/day, and group 3 included patients who received the placebo syrup.

The subjects were instructed to consume the syrup 1 h before meals. The intake of 0.14 or 0.29 g FOS/kg body weight of the syrup or of the placebo was spread over the day as a half-dose after breakfast and another after dinner.

During the experimental period, the subjects maintained a healthful slightly hypocaloric diet (carbohydrates 50%, fat 30%, protein 15% of total energy intake, and 10 g dietary fibre/day, as calculated using the Argentine table of food composition). All patients excluded food products containing large amounts of FOS such as onions and leeks from their diet. They were instructed to maintain their habitual lifestyle behavior with moderate physical activity (45 min walks twice a week). None of the subjects used medication throughout the study.

### 2.7. Anthropometric parameters

Anthropometric parameters were obtained by trained personnel. Body weight was measured with a digital scale balance when the subjects were fasting, had an empty bladder, were minimally clothed and with no shoes. Height and waist circumference were measured with a tape measure under the same conditions. Height was measured while the subjects were standing up. Waist circumference was measured at the smallest circumference of the waist, from measurements made at the level of the umbilicus with the subject standing up. The body mass index (BMI) was calculated as weight (kg)/height<sup>2</sup> (m<sup>2</sup>) or by means of BMI normogram.<sup>14</sup>

### 2.8. Blood sampling and analysis

At the beginning of the study and on day 120, the blood samples were taken from the antecubital vein after overnight fasting (12 h). In order to prevent the effect of the luteal phase, the blood samples were collected at day 7 of the menstrual cycle.

Samples were transferred to sterilized centrifuge tubes and allowed to clot at room temperature. Immediately afterwards they were centrifuged for 10 min at 3000g for serum separation.

#### 2.8.1. Glucose and insulin levels

Glucose levels were measured by the glucose-oxidase method<sup>15</sup> using an automated analyzer Hitachi 902 (Roche).

Serum insulin was determined with an electrochemiluminescence immunoassay<sup>16</sup> using a system COBAS 6000 analyzer (Roche).

#### 2.8.2. Lipids and lipoproteins levels

Enzymatic processes were used to determine serum levels of triacylglycerols<sup>17</sup> (glycerolphosphate-oxidase-PAP method) and cholesterol<sup>18</sup> (esterase-oxidase-peroxidase method) with an autoanalyzer Hitachi 902 (Roche).

HDL cholesterol was determined after precipitation of LDL lipoproteins with polyanions (dextran sulphate-Mg<sup>2+</sup>)<sup>19</sup> using the same autoanalyzer. LDL-cholesterol concentrations were calculated using the Friedewald equation.<sup>20</sup>

#### 2.8.3. Calcium levels

Serum calcium was determined by a photometric (*o*-cresoftalein) method using a Hitachi 902 (Roche) analyzer.

#### 2.8.4. HOMA-IR

Homeostasis model assessment for insulin resistance values, which indicate insulin sensitivity, was calculated as the product of fasting blood glucose (mmol/l) multiplied by insulin concentration ( $\mu$ U/ml) and divided by 22.5.<sup>21</sup>

### 2.9. Statistics

All data were expressed as the mean  $\pm$  Standard error (SE). Significant differences were analyzed with paired Student's *t* test between pre-treatment and 120-day experimental period values. Statistical significance was set at  $p < 0.05$ .

All calculations were performed using the Statistical Package for Social Sciences 12.0 (SPSS) program.

## 3. Results

A total of 55 obese women were selected to participate in a double-blind, placebo-controlled study during a 120-day period.

As shown in Table 1, baseline characteristics did not differ between the 2 intervention groups under study.

In the diet supplementation studies, daily intake levels of yacon syrup were calculated with respect to the amount of FOS. The addition of 20 g FOS/70 kg body weight/day (0.29 g FOS/kg body weight/day) led to significant gastrointestinal adverse effects reported by the patients such as diarrhea, severe abdominal distention, flatulence and nausea. The subjects considered the flatulence severe and unacceptable and no adaptation in symptoms occurred over time. Therefore, this group was excluded from the present study. In contrast, the group treated with yacon syrup at a level intake of 10 g FOS/70 kg body weight/day (0.14 g FOS/kg body weight/day) went through the whole experimental period with no difficulties.

The long-term consumption of yacon syrup led to a very significant decrease in body weight, with an important reduction in waist circumference (Table 2). BMI, a measure of the total amount of body fat, also showed a remarkable decrease in the treated group. These effects were not observed in the control group (placebo).

A subjective effect with respect to satiety was reported by all women who received yacon syrup supplementation. In spite of this finding, nutrient intake remained constant during the experimental period in both treated and placebo groups. Carbohydrate, protein and fat contributed 50, 15 and 31% of the total energy intake. The mean energy intake of the subjects in the present study was 25–30 kcal/kg body weight/day, which is in agreement with a slightly hypocaloric diet.

Altered bowel function, particularly constipation, is a common feature in the women participating in this study. As shown in Table 2, the frequency of defecation was low. Supplementation of yacon syrup increased the defecation frequency during the experimental period by 3.5-fold as compared to the placebo group.

Before yacon syrup treatment, fasting serum glucose levels showed no differences between the groups (Table 3). During the

**Table 1**  
Pre-treatment characteristics of patients scheduled to participate in this study.

	Yacon syrup (n = 40)	Placebo (n = 15)
Age, years	41 $\pm$ 7	40 $\pm$ 9
Body weight, kg	89.2 $\pm$ 11.4	90.7 $\pm$ 10.3
Height, m	1.64 $\pm$ 0.15	1.62 $\pm$ 0.08
BMI, kg/m <sup>2</sup>	34 $\pm$ 2	33 $\pm$ 3
Fasting serum glucose, mmol/l	4.68 $\pm$ 0.66	5.06 $\pm$ 0.55
Fasting serum insulin, $\mu$ U/ml	12.6 $\pm$ 1.7	13.7 $\pm$ 1.3
HOMA-IR <sup>a</sup>	6.30 $\pm$ 1.10	5.35 $\pm$ 0.09
Waist circumference, cm	105.1 $\pm$ 8.3	102.4 $\pm$ 3.1
Systolic pressure, mm Hg	130 $\pm$ 10	120 $\pm$ 10
Diastolic pressure, mm Hg	80 $\pm$ 7	80 $\pm$ 10
Frequencies of defecation, time/day	0.28 $\pm$ 0.08	0.30 $\pm$ 0.10

Values are means  $\pm$  SD. The groups not differ for any variable,  $p > 0.05$ .

<sup>a</sup> Insulin sensitivity was estimated using HOMA-IR values.<sup>21</sup>

**Table 2**

Clinical data of subject before and after 120 days of yacon syrup or placebo treatment.

	Yacon syrup (0.14 g FOS/body weight/day)		Placebo	
	Pre-treatment	120 days	Pre-treatment	120 days
Body weight, kg	91.2 ± 8.4	76.2 ± 6.1 <sup>a</sup>	90.7 ± 10.3	92.3 ± 10.1
BMI, kg/m <sup>2</sup>	34 ± 2	28 ± 3 <sup>a</sup>	33 ± 3	32 ± 4
Waist circumference, cm	105.1 ± 5.0	95.2 ± 4.8 <sup>a</sup>	101.4 ± 3.1	101.9 ± 2.4
Frequencies of defecation, time/day	0.28 ± 0.08	0.99 ± 0.05 <sup>a</sup>	0.30 ± 0.10	0.30 ± 0.10

Data are means ± SD.

<sup>a</sup> Significant difference as analyzed with paired Student's *t* test between pre-treatment and experimental period values, *p* < 0.05.

intervention period, no effect on glucose level was found, showing a normo-glycemic status. In contrast, an important effect was observed in fasting insulin and HOMA-IR values, a useful tool for insulin sensitivity measurement. As shown in Table 3, all women have abnormal baseline HOMA-IR values (cut off <2.70) and elevated fasting insulin levels. After 120 days of yacon syrup treatment, both parameters decreased significantly compared to pre-treatment values. There were no changes in the placebo group.

Serum lipids and lipoproteins levels before and after 120 days of syrup treatment are shown in Table 4. There were no significant changes in either total cholesterol or triacylglycerol levels. However, at the intake level assayed, yacon syrup consumption led to a significant decrease in LDL-cholesterol levels compared to pre-treatment ones while values remained unchanged in the placebo group. In addition, HDL-cholesterol values were not affected by the treatment.

In the 120-day treated group, a significant positive effect was found in blood calcium concentration (increasing trend compared to initial blood calcium level, 2.59 ± 0.01 vs 2.21 ± 0.02 mmol/l, *p* < 0.05). This effect was not observed in the placebo group (*p* > 0.05).

#### 4. Discussion

To the best of our knowledge, this is the first study that demonstrates the beneficial effects of yacon syrup on human health at an intake level that caused no undesirable side effects.

Yacon syrup is a novel product which contains approximately 41% FOS obtained by concentrating the juice of the tuberous storage roots of yacon.<sup>13</sup> With a characteristic chemical composition, this syrup is different from other products such as honey, cane sugar and maple syrup, and can be considered as a hypocaloric product. FOS are considered as a soluble fiber, so that the rich FOS-yacon syrup can also represent a product with high levels of soluble fiber.

The concept of nutraceutical food started in Europe with reference to any food with beneficial effects on the health of the consumers. On the basis of our findings, yacon syrup would be a good candidate for this list of products.

The aim of the present study was to determine the positive effects of yacon syrup administered to pre-menopausal obese women. Our results show that a daily intake level of 0.29 g FOS/kg body weight causes undesirable gastrointestinal side effects such as abdominal distension and/or flatulence. These findings are in

agreement with other studies in which oligofructose consumption has shown dose-related increases in mild flatulence and discomfort.<sup>22</sup> However, we also noticed that a daily consumption of 0.14 g FOS/kg body weight could be tolerated with no adverse effects.

In a previous work in which we evaluated the sub-chronic toxicity of yacon tubers in rats we found no toxic effects at doses of 340 and 6800 mg FOS/kg body weight/day.<sup>12</sup> In a recent study using dried yacon root in combination with silymarin (2.4 g + 0.8 g/day, respectively), no adverse effects were found in patients suffering from the metabolic syndrome.<sup>23</sup> The present study was carried out using a daily intake level of FOS lower than those in the above study and with no other drugs, and provides strong support for the conclusion that the recommended daily consumption of yacon syrup without great risk of side effects is 0.14 g FOS/kg body weight.

Epidemiological studies demonstrated that the prevalence of diabetes rises with increased BMI. It has been shown that among equally overweight or obese individuals, those characterized by an increase in abdominal fat (as assessed by waist circumference) are at increased risk of type 2 diabetes and cardiovascular diseases.<sup>24</sup> A moderate weight loss in abdominally obese patients is associated with a preferential mobilization of visceral adipose tissue, which in turn leads to substantial improvements in the metabolic risk profile.

Obesity tends to occur frequently in women at the perimenopausal period owing to changes in lipid and glucose metabolism accompanied by ovary hypoactivity.<sup>25</sup> Our study included pre-menopausal obese women as estimated for BMI values with a large waist circumference. One of our major findings was that long-term use (120 days) of rich FOS-yacon syrup led to a significant decrease in body weight with an important reduction in waist circumference. Weight regulation is a complex system of multiple overlying feedback mechanisms and for many patients weight loss is a difficult goal to achieve. The present medical treatment of obesity aims at decreasing appetite, altering calorie absorption and increasing thermogenesis.<sup>26</sup> All the Food and Drug Administration (FDA) approved weight loss medications that affect appetite such as sibutramine, phentermine and diethylpropion are believed to act on the central nervous system. However, for some patients, the risks and adverse effects of this pharmacotherapy may outweigh the benefits.

Yacon roots and the syrup made by concentrating root juice are natural products rich in FOS. It has been shown that dietary FOS are able to modulate the production of gastrointestinal peptides such

**Table 3**

Fasting serum glucose, insulin and HOMA-IR values before and after 120 days of yacon syrup or placebo treatment.

	Yacon syrup (0.14 g FOS/body weight/day)		Placebo	
	Pre-treatment	120 days	Pre-treatment	120 days
Serum glucose, mmol/l	4.68 ± 0.66	4.18 ± 0.50	5.06 ± 0.55	4.84 ± 0.66
Serum insulin, μUI/ml	12.6 ± 1.7	7.3 ± 2.4 <sup>a</sup>	13.7 ± 1.3	14.2 ± 1.5
HOMA-IR	6.30 ± 1.10	2.07 ± 0.91 <sup>a</sup>	5.35 ± 0.09	5.66 ± 1.01

Data are means ± SD.

<sup>a</sup> Significant difference as analyzed with paired Student's *t* test between pre-treatment and experimental period values, *p* < 0.05.

**Table 4**  
Fasting serum lipids and lipoproteins levels before and after 120 days of yacon syrup or placebo treatment.

	Yacon syrup (0.14 g FOS/body weight/day)		Placebo	
	Pre-treatment	120 days	Pre-treatment	120 days
Total Cholesterol, mmol/l	5.28 ± 0.80	5.17 ± 0.97	5.33 ± 1.11	5.20 ± 1.07
LDL-cholesterol, mmol/l	3.54 ± 0.71	2.52 ± 0.26 <sup>a</sup>	3.64 ± 0.63	3.43 ± 0.71
HDL cholesterol, mmol/l	1.20 ± 0.16	1.48 ± 0.33	1.14 ± 0.35	1.30 ± 0.30
Triacylglycerols, mmol/l	2.02 ± 1.10	2.10 ± 0.97	2.28 ± 0.97	2.19 ± 0.78

Data are means ± SD.

<sup>a</sup> Significant difference as analyzed with paired Student's *t* test between pre-treatment and experimental period values, *p* < 0.05.

as Glucagon-like protein 1 (GLP-1), Glucose-dependent insulinotropic peptide (GIP) and ghrelin.<sup>27</sup> These peptides cause the suppression of glucagon secretion, delay gastric emptying and regulate food intake. The present study showed a positive effect of yacon syrup on weight loss in initially abdominal obese patients with a remarkable mobilization of visceral adipose tissue. This finding could be attributed to the high content of FOS in the product administered, probably through the above mechanism.

In addition, syrup supplementation was able to enhance satiety sensation. This subjective effect could be related to the delay in gastric emptying, an indirect action of FOS. This fact would contribute to weight loss.

Our study demonstrated that the administration of yacon syrup for 120 days to constipated women significantly improved defecation frequency. It is known that FOS, soluble non-digestible carbohydrates, effectively increase stool bulk.<sup>8</sup> FOS have been classified as prebiotics since they are fermented by the microflora in the large intestine, leading to a modulation in the composition of the natural ecosystem. Pedreschi et al.<sup>11</sup> demonstrated "in vivo" that yacon FOS have the potential to be fermented by *Bifidobacteria* and *Lactobacilli* species so that yacon roots are a novel source of prebiotics. Since yacon syrup is a rich source of FOS of low degree of polymerization, we think that the improvement in bowel habitat in the patients included in this study could be associated with the utilization of FOS by bacteria in the colon that produce short-chain fatty acids, which improve gut function.

Although there is a study in the literature that suggests that the administration of yacon roots in combination with silymarin would probably improve the laboratory markers of the metabolic syndrome, e.g. glycemia, triacylglycerolemia,<sup>23</sup> to the best of our knowledge this is the first study that demonstrates the ability of a 120-day treatment with yacon syrup alone to improve both HOMA-IR index and insulin plasma levels in obese women. These positive effects may involve one or more compounds present in yacon syrup. In addition to FOS, yacon roots are a promising source of phenolic compounds showing antioxidative activity.<sup>28,29</sup> It is known that high levels of free radicals and a decrease in antioxidant defense mechanisms can lead to development of insulin resistance and diabetes complications.<sup>30</sup> Although no phenolic compound level determinations have been carried out, we think that these compounds might contribute, at least partly, to the improvement of insulin resistance.

Many studies have reported the close relationship between insulin resistance and/or hyperinsulinemia and abdominal adipose tissue accumulation,<sup>24</sup> insulin resistance being a pre-diabetes condition. Our results suggest that a dose of yacon syrup of 0.14 g FOS/kg body weight/day is a safe and effective means of reducing risk factors for the development of co-morbidities associated with type 2 diabetes.

In our study, the fasting blood glucose levels in syrup-supplemented women did not differ from those in the placebo group throughout the experimental period. This finding is in agreement with our previous work, indicating lack of hypoglycemic activity in normal rats supplemented with yacon root flour.<sup>12</sup> Luo et al.<sup>31</sup>

showed that 20 g FOS/day supplied to healthy subjects had no detectable effects on either fasting plasma glucose or insulin-stimulated glucose metabolism. We think that our results would be related to the high amount of FOS and the low content of other carbohydrates such as fructose, glucose and sucrose in yacon syrup. These characteristics will be of particular value for the incorporation of this natural product into the diet of diabetic patients.

In the present study, we investigated the effect of long-term (120 days) yacon syrup administration on the fasting blood lipid profile of obese women. All the women included in this study had mild dyslipidemia. Syrup use at a dose of 0.14 g FOS/kg body weight/day was unable to reduce serum total cholesterol, HDL-cholesterol or triacylglycerols levels. The only positive effect was a reduction in LDL-cholesterol levels. Although convincing lipid-lowering effects have been observed in animals, high doses of FOS had to be used<sup>12,32</sup> at intake levels clearly not feasible for humans.

Our findings are in agreement with studies in which fructooligosaccharides were incapable of reducing serum lipid concentrations in subjects with normal blood lipids, but had moderate effect on hyperlipidemic and uncontrolled diabetic patients.<sup>10</sup> In the present study, we considered the choice of subjects (obese, mild dyslipidemic pre-menopausal women) and the duration of the experimental period (120 days) as important factors which could determine the outcome of the experiment. Moreover, this study used a relatively low dose of FOS contained in the syrup, the maximum intake level with no adverse gastrointestinal side effects. However, we think that in these experimental conditions, the modest LDL-cholesterol-lowering action of yacon syrup with no other effect on serum lipids already suggests a beneficial effect on these patients.

It is often believed that women are less suitable patients than men for the study of the dietary effects on serum lipids because of the confusing effects of the menstrual cycle or of the use of oral contraceptives. However, none of the participants in our study had used hormonal medication and the blood samples were collected at the end of the treatment period at day 7 of the menstrual cycle, in which no progesterone action is evident. We think that this study design was appropriate for the detection of relevant changes in the main outcome variables without hormonal interference.

The present results showed only a slight increase in calcium blood level after yacon syrup treatment. The concentration of calcium in blood is maintained within narrow limits, through the rapid coordinated responses of the parathyroid hormone and calcitonin secretions. This fact makes the calcium blood determination a not absolutely accurate test to determine calcium concentrations, mainly at bone level. Riedt et al.<sup>33</sup> suggested that overweight pre-menopausal women did not lose bone with moderate weight loss when they consumed and/or absorbed sufficient amounts of calcium. Lobo et al.<sup>34</sup> demonstrated in rats a stimulatory effect of yacon root FOS on calcium intestinal absorption and balance resulting in higher bone calcium content. Although no bone mineral density measurements were carried out, we speculated that the same mechanisms would be involved in our experimental group. Since the most definitive role for calcium in

women is bone health, further studies are required to determine the effect of yacon syrup consumption on adequate calcium absorption and balance in these patients.

The major products of FOS metabolism in the intestine are short-chain fatty acids (SCFA). The data presented in this study demonstrate that yacon syrup is an excellent source of FOS with favorable health effects on pre-menopausal obese women and that these effects would be probably modulated via SCFA produced during FOS fermentation in the colon.<sup>35</sup> Much has been investigated concerning SCFA production in the gut and the different metabolic significance of the individual acids. It is known that butyrate serves as fuel for the mucosa, whereas acetate and propionate enter the portal blood and may influence systemic carbohydrates and lipids' metabolism.<sup>36,10</sup> Therefore, the pattern of fermentation of syrup-containing FOS might be important when predicting their metabolic effects.

Other possibilities included gut hormones secreted in response to FOS fermentation in the cecum such as GLP-1, GIP and ghrelin.<sup>27</sup> These peptides are released by the endocrine cells of the intestine and enhance post-prandial insulin secretion.<sup>37</sup> In addition, GLP-1 suppresses glucagon secretion, delays gastric emptying and inhibits food intake or appetite. In a previous work, we showed that yacon root supplements in rats led to a significant enlargement in the cecum that would produce an increase in GLP-1 secretion.<sup>12</sup> All these data lead us to suggest the hypothesis that yacon syrup-containing FOS could play a role in the management of obesity, metabolic syndrome and diabetes through their capacity to promote secretion of GLP-1.

In summary, the yacon syrup is a natural product rich in FOS that could be well positioned as a nutraceutical product since the present results demonstrate its beneficial effects on human health.

### Conflict of interest

There are no conflict of interests.

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