NUTRIVISA

ORIGINAL ARTICLE

https://doi.org/10.52521/nutrivisa.v11i1.14314

Yacon syrup supplementation improves cholesterol and body composition in overweight and obese women: a double-blind randomized clinical trial

A suplementação de xarope de yacon melhora o colesterol e a composição corporal em mulheres com sobrepeso e obesidade: um ensaio clínico randomizado duplo-cego

Marília Magalhães CABRAL[1] Antônio Augusto Ferreira CARIOCA[1] Gabriel Martins de Araújo SOUSA[4] Paula Alexandre de FREITAS[1] Jamile Carvalho TAHIM Thiago Santos GARCES[3] Thereza Maria Magalhães MOREIRA[3] Saulo Chaves MAGALHÃES[2] Andrelina Noronha Coelho de SOUZA[2] Ariclecio Cunha de OLIVEIRA[1,2] Maria Luisa Pereira de MELO[1] Keciany Alves de OLIVEIRA[1,2]*

[1]Postgraduate Program in Nutrition and Health, State University of Ceara-UECE, Fortaleza-CE, Brazil

[2]Postgraduate Program in Physiological Sciences, State University of Ceara-UECE, Fortaleza-CE, Brazil

3Postgraduate Program in Public Health, State University of Ceara-UECE, Fortaleza-CE, Brazil

4Graduation in Nutrition, State University of Ceara-UECE, Fortaleza-CE, Brazil

*Corresponding author: keciany.oliveira@uece.br

ABSTRACT

Obesity is a multifactorial chronic disease with high prevalence among women in Brazil. It can cause changes in glycemic, lipid and anthropometric profiles, bringing about adjacent diseases. Yacon syrup contains prebiotics that have been shown to have a positive effect on obesity originated diseases. Our study evaluated the effect of long-term use of yacon syrup on lipid, glycemic, anthropometric profiles and oxidative damage markers in overweight or obese women assisted in an university extension project. In this randomized, double-blind clinical trial, 15 adult women were allocated into yacon group (n=10) and control group (n=5). They consumed 12 mL of yacon syrup (5.3 g of fructooligosaccharides) and 12 mL of maltodextrin syrup (placebo) for 30 days, after breakfast, and followed an individualized food plan. Blood samples were collected and an anthropometric assessment was performed before (D1) and after (D2) the 30 days of intervention.There was no significant change in fasting blood glucose in any of the evaluated groups (P<0,05). There was a decrease in the amount of body fat, cholesterol and 8-isoprostane after 30 days of yacon syrup supplementation (P<0,05). Chronic yacon syrup had no effect on the glycemic profile, but decreased total cholesterol, body fat and 8-isoprostane levels in overweight or obese women.Keywords: Smallanthus sonchifolius; yacon; obesity; women; oxidative stress.

RESUMO

A obesidade é uma doença crônica multifatorial com alta prevalência em mulheres no Brasil. Pode causar alterações nos perfis glicêmico, lipídico e antropométrico, ocasionando doenças adjacentes. Xarope de yacon contém prebióticos que têm demonstrado ter um efeito positivo sobre doenças originadas da obesidade. Nosso estudo avaliou o efeito do uso prolongado de xarope de yacon sobre os perfis lipídicos, glicídicos e antropométricos e sobre marcadores de dano oxidativo em mulheres com sobrepeso ou obesidade assistidas em um projeto de extensão universitária. Neste ensaio clínico randomizado, duplo-cego, 15 mulheres adultas foram alocadas em grupo yacon (n=10) e grupo controle (n=5). Elas consumiram 12 mL de xarope de yacon (5,3 g de frutooligossacarídeos) e 12 mL de xarope de maltodextrina (placebo) por 30 dias, após o café da manhã, e seguiram um plano alimentar individualizado. Amostras de sangue foram coletadas e uma avaliação antropométrica foi realizada antes (D1) e após (D2) os 30 dias de intervenção. Não houve alteração significativa da glicemia de jejum em nenhum dos grupos avaliados (P<0,05). Houve diminuição da quantidade de gordura corporal, colesterol e 8-isoprostano após 30 dias de suplementação com xarope de yacon (P<0,05). O uso crônico do xarope de yacon não teve efeito sobre o perfil glicêmico, mas diminuiu os níveis de colesterol total, gordura corporal e 8-isoprostano em mulheres com sobrepeso ou obesidade.

Palavras-chave: Smallanthus sonchifolius; yacon; obesidade; mulheres; estresse oxidativo.

Cite this article as

CABRAL, M. M.; CARIOCA, A. A. F.; SOUSA, G. M. de A.; FREITAS, P. A. . de; TAHIM, J. . C.; GARCES, T. S.; MOREIRA, T. M. . M.; MAGALHÃES, S. C.; SOUZA, A. N. C. de; OLIVEIRA, A. C. de; MELO, M. L. P. de; OLIVEIRA, K. A. de O. Yacon syrup supplementation improves cholesterol and body composition in overweight and obese women: a double-blind randomized clinical trial . Nutrivisa Revista de Nutrição e Vigilância em Saúde, Fortaleza, v. 11, n. 1, 2024. DOI: 10.52521/nutrivisa.v11i1.14314. In: https://revistas.uece.br/index.php/nutrivisa/article/view/14314.

INTRODUCTION

Obesity is a chronic non-transmissible disease of multifactorial origin, which affects a significant portion of the Brazilian population and represents one of the major risk factors for other chronic non-communicable diseases, such as cardiovascular diseases and diabetes (DIAS *et al.*, 2017). According to the Surveillance Survey of Risk and Protective Factors for Chronic Diseases by Telephone Survey (VIGITEL), the frequency of obesity is slightly higher in women (20.7%) than in men (18.7%) (BRASIL, 2022).

The age at menarche, the number of children and the use of contraceptives are some inherent conditions of female physiology that can contribute to overweight and obesity, which can lead to the emergence of complications related to overweight, such as glucose intolerance, dyslipidemia and hypertension, which are cardiovascular risk factors (PETERS *et al.*, 2016).

New nutritional strategies, capable of helping to prevent and control excess body weight in a safe and effective way, are emerging. Lifestyle modifications are recommended, such as the consumption of prebiotics and probiotics, which play a significant role in the prevention of diseases such as type 2 diabetes, dyslipidemia and metabolic syndrome. Prebiotics, such as inulin and fructooligosaccharides (FOS), are non--digestible food elements, selectively fermentable by the intestinal microbiota, conferring benefits to the health of the host, that is, they are the trophic substrates of probiotic microorganisms that confer intestinal modulation-associated health benefits to the host (SCHEID *et al.*, 2014).

Yacon (SMALLANTHUS SONCHIFOLIUS), a plant native to the Andean region and integrated into Brazil (HONG *et al.*, 2008), is known for its prebiotic property (OJANSIVU I; FERREIRA CL; SALMINEN S; 2011) due to its excessive concentration of inulin and FOS (SACRAMENTO MD; SILVA PS; TAVARES MI; 2017) and for containing phenolic compounds, especially acid chlorogenic, which acts as an antioxidant (SOUSA *et al.*, 2015). FOS selectively favors the growth and activity of the intestinal microbiota, and may contribute as an adjunct to the treatment of Diabetes Mellitus (DM) (SACRAMENTO MD; SILVA PS; TAVARES MI; 2017).

As related to the decrease in glucose absorption and insulin sensitivity, FOS have the ability to increase the production of glucagon-like peptide - 1 (GLP1), a hormone that increases as glucose is absorbed and the production of glucagon decreases. Also, GLP1 promotes the production of insulin. Furthermore, as they are not digested, FOS reduce the effectiveness of enzyme hydrolysis and slow down the speed at which glucose enters the bloodstream, preventing a sudden increase in the glycemic curve, thus having the ability to increase the period of satiety. Another action on metabolism is linked with short-chain fatty acids (SCFA), which are produced during fermentation, and increases glucose tolerance (SACRAMENTO MD; SILVA PS; TAVARES MI; 2017).

Studies carried out by Machado *et al.* (2019; 2020) show the effects of yacon flour in controlling excess body weight, increasing plasma antioxidant capacity, reducing oxidative stress and short-chain fatty acids in overweight adults Furthermore, the use of a yacon-based product with a high FOS/inulin content proved to be effective in bone health, intestinal constipation and modulation of the glycemic index (GRANCIERI *et al.*, 2016). In obese women, yacon syrup has been shown to reduce body weight, waist circumference and BMI, as well as increase feelings of satiety (GENTA *et al.*, 2009).

Given the high prevalence of overweight and obese women in Brazil and the health implications of excess weight, such as hyperglycemia, dyslipidemia, increased body fat and oxidative stress, yacon supplementation could help in the dietary treatment and reducing those health implications. Therefore, the objective of this study was to evaluate the effect of yacon potato syrup consumption on lipid, glycemic, body composition and oxidative stress profiles in overweight and obese women.

MATERIALS AND METHODS

Study design and subjects

A randomized, double-blind, placebo-controlled clinical trial was carried out to evaluate the chronic effect of yacon syrup in adult women during the period from July to October 2022. The study was carried out with overweight and obese women, assisted by the Program of Integrated Activities in Nutrition – PAIN, an extension project linked to the Postgraduate

Program in Nutrition in Health (PPGNS), at the State University of Ceará (UECE). The study was carried out with women who participated in the clinical trial, with an average interval of 30 days. Randomization and blinding were performed by a researcher who did not participate in the volunteer recruitment and intervention stages. The unblinding was performed only after data analysis.

The study was registered in the Brazilian Registry of Trials (RBR-33WF46) and approved by the ethics committee for research with human beings of UECE (CAAE Nº 56094516.4.0000.5534), following all the recommendations of Resolution 466/12 from the National Health Council. The informed consent form was signed by all volunteers.

To collect socioeconomic data, the women filled out a Google form prior to the intervention. The socioeconomic data collected were: age, income, level of education, among others. On the first day of the intervention, a protocol was applied for the acquisition of anthropometric data such as: weight, height, percentage of fat (triceps, suprailiac and thigh skinfolds), circumferences (waist, hip and abdominal) of the participants and usual food recall. Blood collection was performed after a 12-hour fast.

After evaluating the medical records and making telephone contact, the initial study sample consisted of 31 women. However, on day 0 of the intervention, 5 women withdrew for personal reasons and 1 was eliminated from the study after nutritional diagnosis of eutrophy. Thus, 25 women were randomly assigned, 16 to the yacon group and 9 to the placebo group. During the 30 days, 4 participants dropped out of the placebo group due to abdominal discomfort, while in the yacon group, 6 dropped out due to excessive flatulence, making a total of 15 women (10 in the yacon group and 5 in the placebo group) as shown in Figure 1. A questionnaire was not carried out on the appearance and frequency of those discomforts, but their appearance was monitored.

The study inclusion criteria were: being between 20 and 50 years old; being overweight or obese according to BMI, might having chronic disease and not having a history of autoimmune diseases (systemic lupus erythematosus, rheumatoid arthritis, primary systemic vasculitis, psoriasis, type 1 diabetes) and kidney disease. Inclusion criteria were self-reported, collected by Google online form, and assessed.

Exclusion criteria were: pregnant or lactating women; current (or within the past 30 days) smoker; daily ethanol consumption greater than 15g for women; refusing to participate in the research; not attending the blood collection; abandoning treatment; current (or within the past 30 days) use of illegal substances, laxatives, or weight-loss medications; being eutrophic.

Preparation and nutritional composition of Yacon syrup

Yacon syrup was produced by Embrapa Tropical Agroindustry (FORTALEZA - CEARÁ - BRAZIL) from yacon roots. Complete information on syrup processing is available in Silva, Dionísio, Abreu *et al.* (2018). Analytical techniques, including nuclear magnetic resonance spectroscopy (NMR), Ultra High Performance Liquid Chromatograph or Ultra-High Performance Liquid show that this syrup contains caffeic acid, tryptophan and chlorogenic acid derivatives (SILVA *et al.*, 2018).

The syrup was divided into 12 mL portions, containing 5.3 g (35%) of FOS, 3.80 g (31.9%) of glycemic carbohydrate, 0.18 g (1.5%) of protein, 0.0084 g (0.07%) of lipid and 16 Kcal. The volunteers were instructed to store the syrup under refrigeration (5ºC) during the 30 days after consumption.

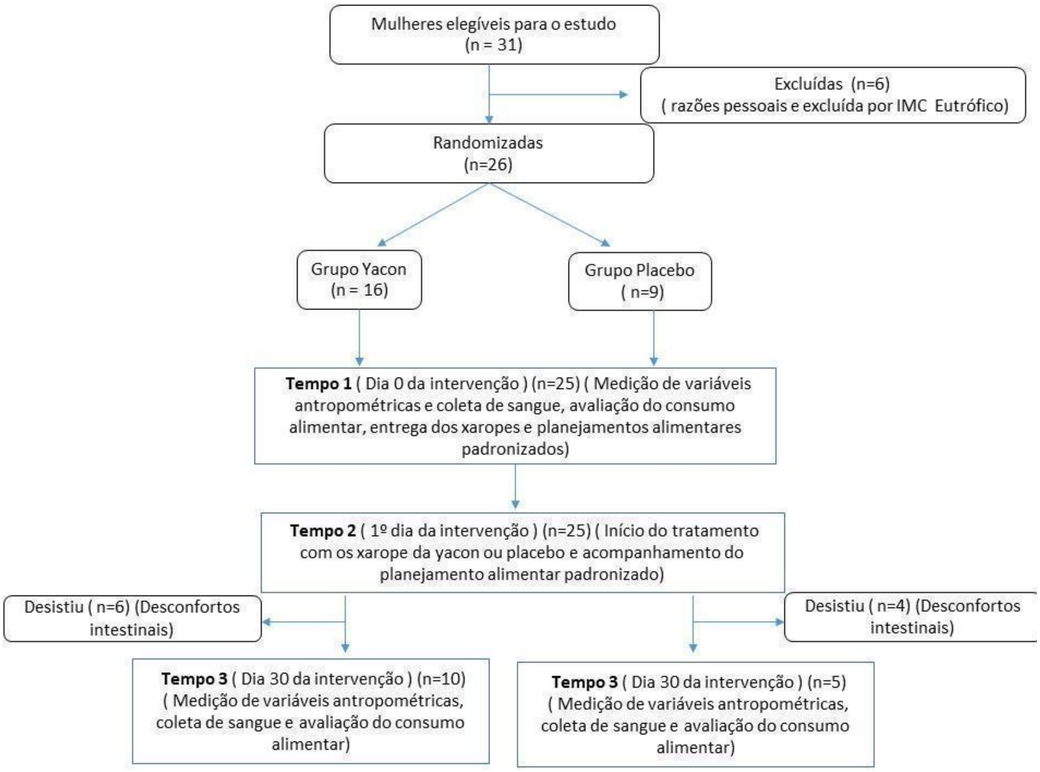
Placebo

The placebo used showed similarity in visual appearance and texture with the yacon syrup. Its composition was adapted from the formula used by Adriano *et al.* (2019) and had a composition of 42.21% mltodextrin, 2.66% citric acid and 0.04% caramel coloring and had 20 Kcal, diluted in drinking water. Standardization of the final product was performed at a pH of 3.7. Fractionation was carried out in 12mL portions and at a 5º C storage.

Interventions

The participants were divided into two groups, the yacon group (n = 10), who received 12 mL of yacon syrup (containing approximately 5.3g of fructooligosaccharides) and the placebo group (n = 5), who received 12 mL of maltodextrin syrup in the morning,

Figure 1 - Flowchart of the sample losses.



for 30 consecutive days. The amount of syrup to be ingested daily was defined so that it would not cause abdominal discomfort in the participants, as this was a long-term study.

At the beginning (d1) and after 30 days of treatment with yacon or placebo (d2), anthropometric, biochemical and food consumption data were collected. On d1, the day of the first appointment with the nutritionist, after applying the usual recall and anthropometric data collection forms, the participants received a meal plan calculated based on guidelines from the Brazilian Association for Obesity Studies (ABESO, 2016) with a reduction of 500Kcal of Total Energy Expenditure (TEE) and macronutrient patterns distributed as follows: 20% to 30% of fats, 55% to 60% of carbohydrates and 15% to 20% of proteins. The volunteers reported not following any previous food plan and were instructed to follow the diet prescribed by the study's nutritionists and not change their lifestyle during the intervention.

The diet plan, the syrup intake and the placebo intake were monitored daily by the nutritionist responsible for the research through a messaging app. Two groups were created in the app with the participating women, one group for those who took the yacon syrup and one group for those who took the placebo. Every day they were asked how they were following their food planning and syrup intake. Any difficulties or questions the participants had were answered by the nutritionist.

Dietary and socioeconomic data

Self-reported data on age, education, family income, occupation and health status were collected using Google forms sent to the participants.

Weight was measured using a Tanita® BC 601 FC platform-type scale, with a sensitivity of 100 g and a capacity of 150 kg. The volunteers were weighed without shoes and wearing light clothes, standing upright, with parallel feet fully covered by the scale, with eyes on the horizon and arms alongside the body. Height was measured using a Sanny® stadiometer with a scale in millimeters (WHO, 2005). Waist circumference (WC), abdominal circumference (AC) and hip circumference (HC) were measured with an inelastic measuring tape, according to the WHO protocol (WHO, 1998), where WC was measured by positioning the tape at the midpoint between the last rib and the upper part of the iliac crest, AC was measured at the level of the umbilicus and the HC was measured in the most prominent place in the gluteal region. From those measurements, the waist/hip ratio (WHR) was determined.

Body composition was measured through skinfolds using the Compact Clinical Adipometer - Cescorf® using the 3-fold Pollock protocol (JACKSON AS, POLLOCK ML; 1978). Anthropometric data were collected in duplicate by properly trained researchers.

Dietary data were collected through the usual face-to-face recall in each period of data collection (d1 and d2). Daily consumption (calories, macro and micronutrients) was quantified using the Web Diet® program.

Blood collection and biochemical analysis

Blood samples were collected by a trained professional after fasting for 10 - 12 hours. The collection was carried out in dry tubes, the samples were centrifuged at 1500g for 10 minutes at 4ºC. In serum samples, glucose concentrations, liver markers, oxaloacetic transaminase (GOT) and pyruvate transaminase (GPT), kidney markers, urea and creatinine, lipid variables of total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C) and triacylglycerols (TAG) were measured by spectrophotometry (BECKMAN COULTER, UNITED STATES). The low-density lipoprotein (LDL) cholesterol content was determined using the formula LDL = TC - HDL - TG/5 (FRIEDEWALD WT, LAVY RI, FREDRICKSON DS; 1972). Non-HDL cholesterol was calculated using the formula non-HDL = TC – HDL-c, according to the Brazilian Society of Cardiology (SBC) (FALUDI, 2017). All analytical techniques followed the protocols provided by the kit for each biomarker proposed by their respective manufacturer.

8-Isoprostane levels were measured in plasma using a colorimetric assay kit (8-Isoprostane Assay kit, Cayman Chemical Company, United States), following the manufacturer's instructions.

Statistical analysis

Socioeconomic, health profile, physical activity, anthropometric and food consumption variables were presented descriptively. The normality of the variables was tested using the Kolmogorov Smirnov test. Student's t test and chi-square test were used to compare means and proportions, respectively. The effects of placebo and yacon interventions were compared using two-way ANOVA repeated measures, followed by Bonferroni multiple comparison, to assess the effect of time, the effect of the intervention, and the effect of intervention x time. Unpaired Student's t-test was used to compare the effect between women living with obesity before and after yacon supplementation. Associations between anthropometric and biochemical categorical variables with syrup consumption were verified using Pearson's chi-square test. Statistical analyzes were performed using GraphPad Prism®, version 8.0. Values of $p < 0.05$ were considered significant.

RESULTS AND DISCUSSION

According to Table 1, the study participants (placebo and yacon) in D1 had completed high school, an income of 1 to 3 minimum wages, did physical activity and did not consider their health status to be very good or good. The mean age was 39 and 37 years in the placebo and yacon groups, respectively. Regarding anthropometric data, in D1, the study participants in both groups were obese, with a high percentage of fat and high waist, hip and abdominal circumference.

After 30 days of treatment with yacon, there was a significant reduction in body fat, with no significant changes in body weight and BMI. A meta-analysis carried out by John *et al.*. (2018) investigated the effect of prebiotics and symbiotics on body weight, and it was possible to observe that they were able to reduce body weight and BMI in a period of more than 12 weeks, while body fat was reduced in less than 12 weeks. Thus, yacon syrup likely helps in the loss of body fat associated with a healthy diet and physical activity, and changes in weight could be observed in a period longer than the present study (supplementation time > 30 days). There was a significant increase in fiber consumption in the yacon group compared to the placebo group after 30 days after consuming the syrup.

Table 1- Socioeconomic and anthropometric characteristics of participants who completed the study.

	Placebo (n=5)		Yacon (n=10)	
	D1	D2	D1	D2
Age (years), mean (SD)	39.60 (11.28)		37.00 (10.55)	
Weight (Kg)	78.46 (10.42)	77.06 (10.33)	87.16 (10.07)	86.44 (10.63)
Income:				
<1 minimum wage, n(%)	0 (0)		1 (10)	
1 a 3 minimum wages, n(%)	5 (100)		9 (90)	
Education, %				
Complete high school, n(%)	3 (60)		7 (70)	
Physical activity, %				
Sedentary, n(%)	1 (20)		4 (40)	
Health condition, %				
very good and good, n(%)	0 (0)		3 (30)	
MBI (Kg/m^2), mean (SD)	32.14 (2.641)	31.82 (2.454)	35.34 (3.661)	35.04 (3.923)
WHR, mean (SD)	0.8080 (0.0277)	0.8040 (0.0403)	0.8330 (0.0893)	0.8400 (0.1058)
% Body fat Corporal, mean (SD)	38.34 (4.484)	34.30 (3.220)	42.38 (4.140)	**38.80[b] (4.705)**
Lean mass (Kg), mean (SD)	44.88 (5.328)	44.81 (5.409)	48.12 (4.169)	47.91 (4.275)
WC (cm), mean (SD)	89.38 (4.830)	88.18 (5.306)	94.89 (6.619)	93.89 (7.433)
AC (cm), mean (SD)	100.8 (7.967)	99.94 (5.828)	106.9 (7.789)	106.6 (8.653)
HC (cm), mean (SD)	110.7 (5.602)	109.6 (5.286)	115.1 (8.874)	113.5 (8.331)

b Significant difference within the yacon group before and after 30 days, verified by Student's t test. P value considered significant if less than or equal to 0.05.
BMI: body mass index/ WHR: waist-hip ratio / WC: waist circumference /AC: abdominal circumference / HC: hip circumference.

As to the consumption of micronutrients, a significant increase in calcium consumption was found at the beginning of the study, where the placebo group consumed 356.2 mg (230.1) and the yacon group 650.8 mg (397.6). There was a significant reduction in consumption of zinc between the placebo (11.88mg) and yacon (9.05 mg with 30 days of study) groups, but when compared within the yacon group, there was a significant increase in zinc (8. 87 mg to 9.05 mg) after 30 days of syrup consumption. Except for fiber, calcium and zinc, no statistical differences were observed in the other micronutrients at any time of the study (Table 2).

Table 2 - Food consumption at the beginning and after 30 days of placebo or yacon intervention.

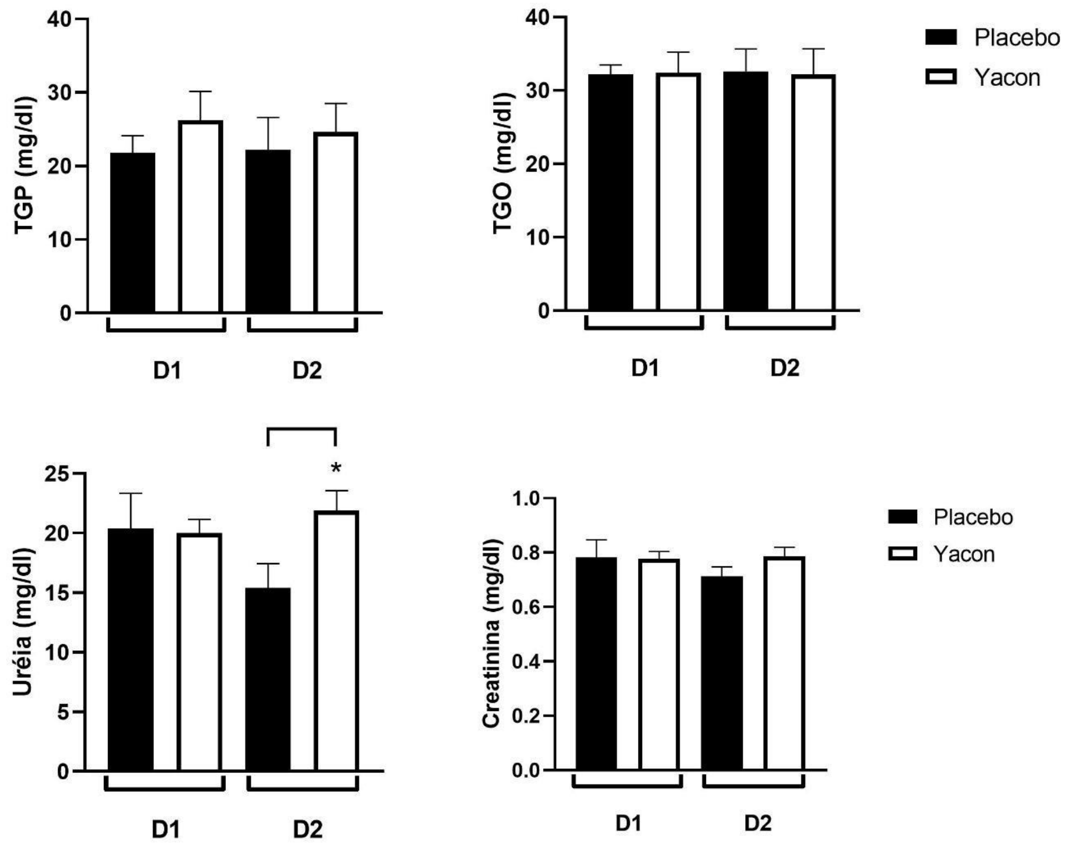
	Placebo (n=5)		Yacon (n=10)		
	Basal Mean (SD)	30 days Mean (SD)	Basal Mean (SD)	30 days Mean (SD)	EAR/RDA/AI
Energy (Kcal)	1510 (363.5)	1725 (658.5)	1745 (769.4)	1532 (393.4)	-
Carbohydrate (g)	187.5 (50.11)	228.3 (89.38)	226.1 (132.4)	178.7 (63.88)	130
Lipid (g)	49.48 (12.98)	55.32 (25.16)	56.68 (25.26)	50.51 (20.71)	61
Cholesterol (mg)	555.6 (409.3)	405.7 (119.1)	612.8 (280.7)	568.8 (193.1)	<300
AGS (g)	13.74 (4.91)	19.76 (10.62)	19.81 (10.95)	19.15 (7.64)	<10% Total Lipid
AGPI (g)	10,94 (5,19)	8,280 (4,73)	9.85 (5.12)	8.37 (2.69)	5 - 10% of TEE
AGM (g)	15.48 (3.51)	17.60 (6.26)	16.33 (7.88)	16.34 (6.81)	15% of TEE
Protein (g)	79.49 (25.79)	85.12 (29.89)	90.53 (26.18)	75.82 (30.9)	46
Fiber (g)	18.96 (10.10)	15.06 (5.12)	18.87 (7.77)	25.03 (8.78[a])	25
Potassium (mg)	1822 (469.4)	1923 (381.2)	2191 (906.8)	2218 (601.4)	4700
Sodium (mg)	1154 (444.0)	1012 (402.8)	1388 (676.8)	1255 (704.11)	1500
Phosphor (mg)	1137 (448.0)	1081 (462.0)	1297 (374,6)	1111 (502.3)	700
Iron (mg)	8.220 ± 2.95	11.68 (9.93)	9.04 (5.149)	8.52 (2.48)	18
Calcium (mg)	356.2 (230.1)	755.6 (746.0)	650.8 (397.6[c])	751.6 (373.5)	1000
Magnesium (mg)	183.4 (74.16)	176.5 (52.30)	197 (75.36)	222.1 (66.4)	320
Zinc (mg)	6.060 (1.13)	11.88 (5.68)	8.87 (4.11)	9.05 (4.94[a, b])	8
Vitamin A (RE)	472.7 (394.9)	625.3 (379.2)	501 (285.5)	846.7 (932.8)	N/A
Vitamin E (mg)	14.18 (11.27)	15.98 (26.88)	7.4 (5.81)	5.15 (2.11)	15
Vitamin D (mcg)	4.000 (2.83)	3.940 (5.97)	4.42 (1.67)	3.72 (1.71)	15

EAR: Estimated Average Requirement. RDA: Recommended Dietary Allowance. AI: Adequate Intake. AGM: Monounsaturated Fatty Acid. AGPI: Polyunsaturated Fatty Acid. AGS: Saturated Fatty Acid. [a] Significant difference between placebo and yacon groups with 30 days of study (p<0,05). [b] Significant difference within the yacon group before and after 30 days of study (p<0,05). [c] Significant difference between placebo and yacon groups at baseline (p<0,05).

According to Figure 2, there was no significant change in liver markers GOT and GPT intra or between groups, in any of the study moments. In renal markers, a significant increase in urea was observed between the placebo and yacon groups after the use of yacon supplementation. There was no significant difference in creatinine concentrations.

There was no significant change in fasting glucose intra or between groups, at any time of the study (Figure 3). Regarding the lipid profile, a significant reduction in total cholesterol was observed in the yacon group between days d1 and d2. In the other markers of the lipid profile, no significant differences were observed. However, LDL-cholesterol showed a reduction in the yacon group before and after supplementation.

Figure 2 - Effect of yacon syrup on renal and liver markers.

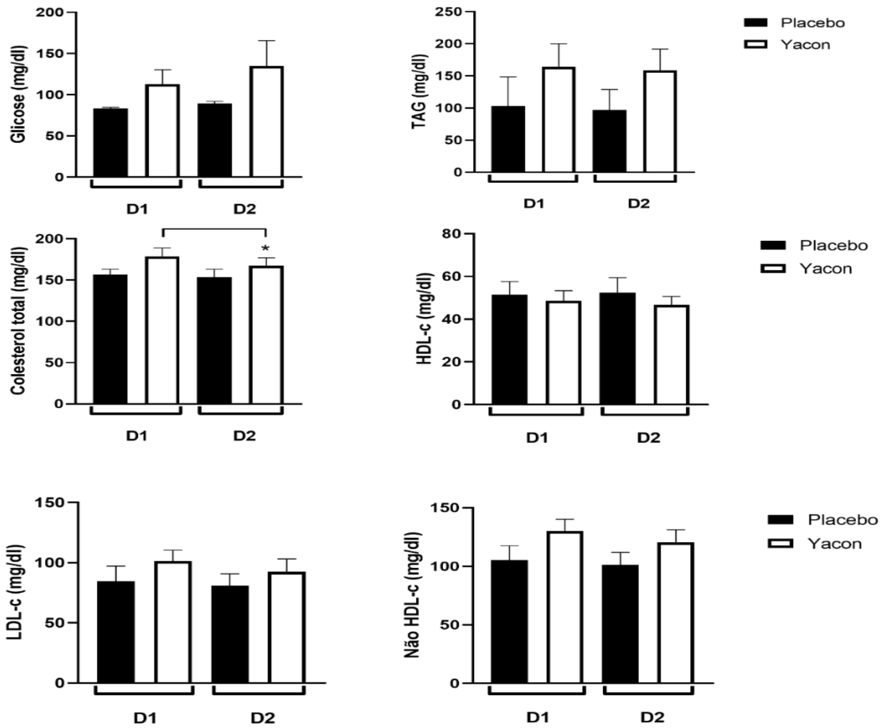


The panels show GPT- glutamic pyruvic transaminase (panel **A**), GOT- glutamic oxaloacetic transaminase (panel **B**), urea (panel **C**) and creatinine (panel **D**) before (D1) and after 30 days (D2) of the treatment with yacon syrup (5.3 g FOS) or maltodextrine (placebo group). Results are means ± SE, yacon syrup (n= 5) and placebo group (n =10), *p < 0.05 vs. D1. Data were analyzed by ANOVA followed by Bonferroni post-test and Student's t-test (for intragroup).

Although there is no direct scientific evidence linking yacon syrup to increased serum urea, intestinal fermentation of undigested carbohydrates can lead to excessive production of SCFA, compromising the kidneys' ability to excrete it and increasing urea levels. Studies have shown that SCFA, especially butyric acid, can be converted to uric acid in the liver, thereby increasing urea levels (LI, MA E FU, 2017).

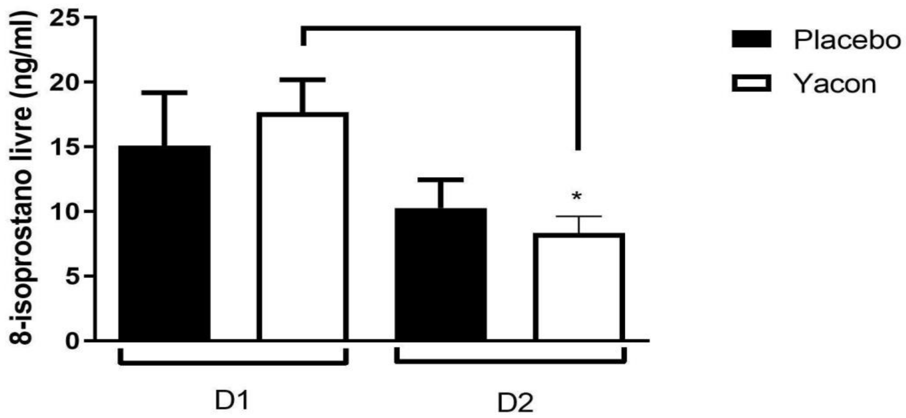
There was a significant reduction in plasma 8-isoprostane levels in overweight or obese women after 30 days of supplementation (D2) with yacon syrup when compared with values before supplementation (D1) (Figure 4).

Figure 3 - Effect of yacon syrup on glycemic and lipidic profile markers.



The panels shows glucose (panel **A**), TG (panel **B**), total cholesterol (panel **C**), HDL-c (panel **D**), LDL-c (panel **E**) and non-HDL-c (panel **F**) before (D1) and after 30 days (D2) of the treatment with yacon syrup (5.3 g FOS) or maltodextrine (placebo group). Results are means ± SE, yacon syrup (n= 5) and placebo group (n =10), *p < 0.05 vs. D1. Data were analyzed by ANOVA followed by Bonferroni post-test and Student's t-test (for D1xD2).

Figure 4 - Plasma 8-isoprostane levels of overweight and obese before (D1) and after 30 days (D2) of the treatment with yacon syrup (5.3 g FOS) or maltodextrine (placebo group).



Results are means ± SE, yacon syrup (n= 5) and placebo group (n =10), *p < 0.05 vs. D1. Data were analyzed by ANOVA followed by Bonferroni post-test and Student's t-test (for D1xD2).

The present study demonstrated that the daily ingestion of yacon syrup for 30 days with 5.3 g of FOS was enough to decrease the levels of total cholesterol, 8-isoprostane and body fat percentage in overweight or obese women without altering the liver and kidney markers and blood glucose levels.

The hypolipidemic effects of yacon have been demonstrated in experimental studies. The alcoholic extract of yacon leaves administered to rats on a high-fructose diet for 8 weeks reduced body weight, adiposity, total cholesterol, triglycerides and LDL-c (JANG *et al.*, 2020). Another study with aqueous extract of yacon in diabetic rats that received yacon for 30 days significantly decreased serum levels of cholesterol and LDL-c and increased levels of HDL-c compared to the control group (OLIVEIRA GO, BRAGA CP, FERNANDES AAH; 2013). In the form of flour, yacon supplementation in diabetic animals for 90 days resulted in a reduction in serum levels of triacylglycerol and VLDL (HABIB *et al.*, 2011). Dried yacon root (340 mg and 6800 mg FOS/kg body weight) administered as a dietary supplement to healthy, non-obese Wistar rats significantly reduced postprandial triacylglycerol serum levels (GENTA *et al.*, 2005).

Although the hypolipidemic effects of yacon roots have been demonstrated in preclinical studies, evidence from human trials is still sparse. The consumption of yacon syrup (0.14 g of FOS/kg of body weight) for 120 days showed a reduction in fasting LDL and visceral fat levels in a study with mild dyslipidemia and pre-menopause obese women (GRANCIERI *et al.*, 2016). In contrast, such an effect was not reported in a study with elderly people supplemented with lyophilized yacon powder (7.4 g of FOS) for 9 weeks (SCHEID *et al.*, 2014). Similarly, a clinical trial with healthy people who consumed yacon syrup (8.74 g of FOS) for 2 weeks showed no change in the lipid profile (DIONÍSIO *et al.*, 2020).

Furthermore, yacon flour associated with a calorie-restricted diet for 6 weeks in non-dyslipidemic overweight adults did not affect the concentration of lipid variables such as triglycerides, total cholesterol and HDL-c (MACHADO *et al.*, 2019). Thus, it is suggested that yacon syrup can exert its lipid-lowering effect only in metabolically decompensated women who are overweight or obese. Added to that, in the present study, reducing total cholesterol after intervention with yacon syrup, in the experimental period (30 days), without other effects on serum lipids, already suggests a beneficial effect.

Previous studies discuss the possible mechanisms of action of yacon in improving the lipid profile. According to Scheid *et al.*. (2014) treatment with yacon promoted the hypolipidemic effect through the activation of lipoprotein lipase (LPL), which promotes the catabolism of lipoproteins, such as chylomicron and VLDL, preventing the accumulation of lipids in the blood. This effect also appears to be associated with a decrease in de novo lipogenesis in hepatic tissue and with a decrease in the expression of major hepatic lipogenic enzymes, such as fatty acid synthase (KOK *et al.*, 1996).

The soluble fibers present in yacon increase cholesterol catabolism, consequently decreasing the concentration of intracellular cholesterol, which stimulates the expression of LDL membrane receptors in the cell, increasing the internalization and uptake of LDL-c transported in the plasma, which results in decreased serum levels of this lipoprotein. Furthermore, the products of bacterial fermentation of FOS, i.e. short-chain fatty acids, are absorbed from the digestive tract in enterohepatic circulation and limit the synthesis of cholesterol in the liver (OLIVEIRA GO, BRAGA CP, FERNANDES AAH.; 2013).

Daily consumption of yacon syrup was also accompanied by a reduction in plasma levels of 8-isoprostane, which has been referred to as a reliable marker of overall in vivo oxidative load. Isoprostanes are prostaglandin-like compounds formed in vivo via a non-enzymatic mechanism involving arachidonic acid peroxidation initiated by free radicals (CAMPOS *et al.*; 2012). So, they are extremely accurate measures of oxidative damage in vivo. We found that consumption of yacon syrup for 30 days was associated with a significant reduction in plasma 8-isoprostane, thus suggesting possible antioxidant properties of FOS.

A study carried out with 35 different yacon cultivars to evaluate their antioxidant capacity (CA) and total phenolic compounds (CFT), showed that the values found are in agreement with other studies previously carried out by Mikami *et al.* (2009) corroborating that yacon demonstrates AC and high CFT content.

Another finding of this study was a high correlation between CA and CFT (r = 0.89, p < 0.01), indicating that CFTs are mainly responsible for the CA of yacon roots (CAMPOS *et al.*; 2012).

Yacon flour was used for 90 days in an experimental study that showed a significant decrease in the level of malondialdehyde (MDA) and superoxide dismutase (SOD) and catalase (CAT) activities in the liver and kidney of diabetic rats, while levels of glutathione peroxidase (GPx) and GSH increased significantly (HABIB *et al.*, 2015).

In a double-blind clinical trial, adults with excess body weight received a morning drink containing or not containing yacon flour (25g) associated with a calorie-restricted diet for 6 weeks. The ferric reducing antioxidant power (FRAP) in the plasma of the group who received yacon increased significantly, while the carbonyl protein level was significantly lower when compared to the initial value, which did not happen with the control group (MACHADO *et al.*, 2019).

An increase in plasma antioxidant capacity provides greater protection against free radicals. There is also a reduction in the concentration of carbonyl protein, which helps reduce key events in the development of cardiovascular disease. The fact that plasma FRAP increased after consumption of yacon flour and no change was observed in antioxidant enzymes suggests that substances present in yacon flour may increase antioxidant capacity without requiring changes in the antioxidant defense system (MACHADO *et al.*, 2019).

It is known that compounds such as phenolic acids, polyphenols and flavonoids eliminate free radicals such as peroxide, hydroperoxide or lipid peroxyl and thus inhibit oxidative mechanisms that lead to diabetes complications. Five caffeic acid derivatives are found in yacon roots as the main water-soluble phenolic compounds. Two of them are chlorogenic acid (3-caffeoylquinic acid and 3,5-dicaffeoylquinic acid). In agreement with this finding, it was expected that yacon presented high antioxidant activity as demonstrated in the in vitro study with yacon roots (HABIB *et al.*, 2015), with L-tryptophan and chlorogenic acid being the main antioxidant compounds found.

The findings related to the acute effect of yacon on the glucose profile are controversial. In a clinical trial, acute consumption of yacon syrup (14 g of FOS) decreased postprandial serum glucose and insulin concentrations compared with placebo (ADRIANO E COLABORADORES, 2019) Otherwise, it was reported that the consumption of 350 mL of yacon shake (21 g of yacon flour with 7.4 g of FOS), in a study in which 15 healthy adults, on two non-consecutive days, did not affect the glycemic response (MAYUMI *et al.*, 2018).

In the long term, yacon consumption did not show a beneficial effect on the glucose response. In the study by Genta *et al.* (2009), the chronic consumption of yacon syrup (120 days and 10 g FOS/70 kg of body weight/day) was not effective in reducing blood glucose levels in obese women. Similarly, yacon in natura (8 g of FOS) administered chronically, for 3 months, in individuals with type 2 diabetes did not alter fasting glycemia (SATOH *et al.*, 2014).

In this sense, our findings are innovative, as the dose of yacon syrup used in the long term has shown a significant effect in reducing cholesterol, body fat and oxidative stress marker. This result demonstrates yacon syrup as a nutraceutical with potential in the prevention and control of metabolic disorders such as obesity.

As a limitation, our data cannot be generalized to all groups, since we only evaluated the effect on obese adult women. The reduced sample size caused by the difficulty in following the supplementation, due to the presence of intestinal discomfort, and the use of a habitual recall to obtain the participants' food consumption are also limitations of this study. As a strong point, we highlight the study design and the evaluation of variables such as percentage of body fat and oxidative stress.

CONCLUSION

In summary, our findings suggest that chronically used yacon syrup reduces total cholesterol, body fat and 8-isoprostane levels in obese women and may become an auxiliary tool in the treatment of this metabolic disorder.

REFERENCES

ADRIANO, L.S.; DIONÍSIO, A.P.; ABREU, F.A.P.; CARIOCA, A.A.F.; ZOCOLO, G.J.; WURLITZER, N.J.;

PINTO, C.O.; OLIVEIRA, A.C.; SAMPAIO, H.A.C. Yacon syrup reduces postprandial glycemic response to breakfast: A randomized, crossover, diouble-blind clinical trial. Food Research International.;126:108682. 2019. https://doi.org/10.1016/j.foodres.2019.108682. ASSOCIAÇÃO BRASILEIRA PARA O ESTUDO DA OBESIDADE E DA SÍNDROME METABÓLICA. Diretrizes Brasileiras de Obesidade. 4. ed. São Paulo: ABESO, 2016. https://abeso.org.br/wp-content/uploads/2019/12/Diretrizes-Download-Diretrizes-Brasileiras-de-Obesidade-2016.pdf.

CAMPOS, D.; BETALLELUZ-PALLARDEL, I.; CHIRINOS, R.; AGUILAR-GALVEZ, A.; NORATTO, G.; PEDRESCHI, R. Prebiotic effects of yacon (SMALLANTHUS SONCHIFOLIUS POEPP. & ENDL), a source of fructooligosaccharides and phenolic compounds with antioxidant activity. Food Chemistry.;135(3):1592–9. 2012. http:// HIPERLhttps://doi.org/10.1016/j.foodchem.2012.05.088.

DIAS, P.C.; HENRIQUES, P.; ANJOS, L.A.; BURLANDY, L. ACadernos de Saúde Pública [Internet]. ;33(7), 2017. https://www.scielosp.org/article/csp/2017.v33n7/e00006016/pt/.

DIONÍSIO, A.P.; SILVA, M.F.G; CARIOCA, A.A.F.; ADRIANO, L.S.; ABREU, F.A.P.; WURLITZER, N.J. Effect of yacon syrup on blood lipid, glucose and metabolic endotoxemia in healthy subjects: a randomized, double-blind, placebo-controlled pilot trial. Food Science and Technology. ;40(1): 194–201. 2020. http:// https://doi.org/10.1590/fst.38218.

FALUDI, A.A.; IZAR, M.C.O.; SARAIVA, J.F.K.; CHACRA, A.P.M.; BIANCO, H.T.; AFIUNE NETO, A.; BERTOLAMI, A.; PEREIRA, A.C.; LOTTENBERG, A.M.; SPOSITO, A.C.; CHAGAS, A.C.P.; CASELLA-FILHO, A.; SIMÃO, A.F.; ALENCAR FILHO, A.C.; CARAMELLI, B.; MAGALHÃES, C.C.; MAGNONI, D.; NEGRÃO, C.E.; FERREIRA, C.E.S.; SCHERR, C.; FEIO, C.M.A.; KOVACS, C.; ARAÚJO, D.B.; CALDERARO, D.; GUALANDRO, D.M.; MELLO JUNIOR, E.P.; ALEXANDRE, E.R.G.; SATO, I.E.; MORIGUCHI, E.H.; RACHED, F.H.; SANTOS, F.C.; CESENA, F.H.Y.; FONSECA, F.A.H.; FONSECA, H.A.R; XAVIER, H.T.; PIMENTEL, I.C.; GIULIANO, I.C.B.; ISSA, J.S.; DIAMENT, J.; PESQUERO, J.B.; SANTOS, J.E.; FARIA NETO, J.R.; MELO FILHO, J.X.; KATO, J.T.; TORRES, K.P.; BERTOLAMI, M.C.; ASSAD, M.H.V.; MINAME, M.H.; SCARTEZINI, M,.; FORTI, N.A.; COELHO, O.R.; MARANHÃO, R.C.; SANTOS FILHO, R.D.; ALVES, R.J.; CASSANI, R.L.; BETTI, R.T.B.; CARVALHO, T.; MARTINEZ, T.L.R.; GIRALDEZ, V.Z.R.; SALGADO FILHO, W. Atualização da Diretriz Brasileira de Dislipidemias e Prevenção da Aterosclerose – . Arq Bras Cardiol 2017;109 (2Supl.1):1-76. 2017. https://doi.org/10.5935/abc.20170121.

FRIEDEWALD, W.T.; LAVY, R.I.; FREDRICKSON, D.S. Estimation to density lipoprotein without use of the preparative ultracentrifuge. Clinical Chemistry. ;18(6):499-502.1972. https://doi.org/10.1093/clinchem/18.6.499.

GENTA, S.B.; CABRERA, W.M.; GRAU, A.; SÁNCHEZ, S.S. Subchronic 4-month oral toxicity study of dried Smallanthus sonchifolius (yacon) roots as a diet supplement in rats. Food and Chemical Toxicology , 43, 1657–1665. 2005. https://doi.org/10.1016/j.fct.2005.05.007.

GENTA, S.; CABRERA, W.; HABIB, N.; PONS, J.; CARILLO, I.M.; GRAU, A.; SÁNCHEZ, S. Yacon syrup: Beneficial effects on obesity and insulin resistance in humans. Clinical Nutrition. ;28(2):182–7. 2009 https://doi.org/10.1016/j.clnu.2009.01.013.

GRANCIERI, M.; MACHADO, P.A.; OLIVEIRA, D.F.; MARCON, L.N.; TOSTES, M.G.V.; COSTA, N.M.B.; IGNACCHITI, M.D.C.; NUNES, L.C.; VIANA, M.L. Efeito da farinha de yacon (SMALLANTHUS SONCHIFOLIUS) na resposta imunológica intestinal no câncer colorretal. Braspen Journal.; 31(4) :35-39. 2016. http://www.braspen.com.br/home/wp-content/uploads/2017/02/10-AO-Efeito-da-farinha.pdf.

HABIB, N.C.; HONORÉ, S.M.; GENTA, S.B.; SÁNCHEZ, S.S. Hypolipidemic effect of Smallanthus sonchifolius (yacon) roots on diabetic rats:

Biochemical approach. 15;194(1):31–9. 2011. https://doi.org/10.1016/j.cbi.2011.08.009.

HABIB, N.C.; SERRA-BARCELLONA, C.; HONORÉ, S.M.; GENTA, S.B.; SÁNCHEZ, S.S. Yacon roots (SMALLANTHUS SONCHIFOLIUS) improve oxidative stress in diabetic rats. Pharmaceutical Biology. 8;53(8):1183–93. 2015. http:// https://doi.org/10.3109/13880209.2014.970285.

HONG, S.S.; LEE, S.A.; HAN, X.H.; LEE, M.H.; HWANG, J.S.; PARK, J.S.; OH, K.W.; HAN, K.; LEE, M.K.; LEE, H.; KIM, W.; LEE, D.; HWANG, B.Y. Melampolides from the Leaves of Smallanthus sonchifolius and Their Inhibitory Activity of LPS-Induced Nitric Oxide Production. Chemical & Pharmaceutical Bulletin. ;56(2):199–202. 2008. https://doi.org/10.1248/cpb.56.199.

JACKSON, A.S.; POLLOCK, M.L. Generalized equations for predicting body density of men. British Journal of Nutrition. ; 40(3):497-504. 1978. https://doi.org/10.1079/bjn19780152.

JANG, H.W.; GO, S.Y.; HONG M.J.; LEE, Y.H. Inhibitory Effect of Yacon Leaf Extract on the Metabolic Syndrome Induced by a High Fructose Diet in Rats. Journal of the Korean Society of Food Science and Nutrition.; 49(12):1301–8. 2020. https://doi.org/10.3746/jkfn.2020.49.12.1301.

JOHN, G.K; WHANG, L; NANAVANTI, J; TWOSE, C.; SINGH, R.; MULLIN, G. Dietary alteration of the gut microbiome and its impact on weight and fat mass: a systematic review and meta-analysis. Genes; 9(3):167. 2018. https://doi.org/10.3390/genes9030167

KOK, N.; ROBERFROID, M.; ROBERT, A.; DELZENNE, N. Involvement of lipogenesis in the lower VLDL secretion induced by oligofructose in rats, British Journal of Nutrition. 76, 881–890. 1996. http:// https://doi.org/10.1079/bjn19960094.

LI, L.; MA, L.; FU, P. Gut microbiota–derived short--chain fatty acids and kidney diseases. Drug Design, Development And Therapy. 11, 3531-3542, 2017. http://dx.doi.org/10.2147/dddt.s150825.

MACHADO, A.M.; DA SILVA, N.B.; CHAVES, J.B.; ALFENAS, R.D. Consumption of yacon flour improves body composition and intestinal function in overweight adults: A randomized, double-blind, placebo-controlled clinical trial. Clinical Nutrition ESPEN [Internet]. ;29:22-9. 2019. https://doi.org/10.1016/j.clnesp.2018.12.082.

MACHADO, A.M.; SILVA, N.B.; FREITAS, R.M.; FREITAS, M.B.; CHAVES, J.B.; OLIVEIRA, L.L.; MARTINO, H.S.; ALFENAS, R.D. Effects of yacon flour associated with an energy restricted diet on intestinal permeability, fecal short chain fatty acids, oxidative stress and inflammation markers levels in adults with obesity or overweight: a randomized, double blind, placebo controlled clinical trial. Archives of Endocrinology and Metabolism [Internet]. 2020. https://doi.org/10.20945/2359-3997000000225.

ROCHA, D.M.U.P.; RIBEIRO, P.V.M.; CALDAS, A.P.S.; SILVA, B.P.; SILVA, A.; ALMEIDA, A.P.; SILVA, N.B.M.; MACHADO, A.M.; ALFENAS, R.C.G. Acute consumption of yacon shake did not affect glycemic response in euglycemic, normal weight, healthy adults. Journal of Functional Foods; 44:58–64. 2018. https://doi.org/10.1016/j.jff.2018.02.029.

MIKAMI, I.; YAMAGUCHI, M.; SHINMOTO, H.; TSUSHIDA, T. Development and Validation of a Microplate-based .BETA.-carotene Bleaching Assay and Comparison of Antioxidant Activity (AOA) in Several Crops Measured by .BETA.-carotene Bleaching, DPPH and ORAC Assays. Food Science and Technology Research.;15(2):171–8. 2009. https://doi.org/10.3136/FSTR.15.171.

MINISTÉRIO DA SAÚDE. Secretaria de Vigilância em Saúde. Departamento de Análise em Saúde e Vigilância de Doenças não Transmissíveis. Vigitel Brasil 2021: vigilância de fatores de risco e proteção para doenças crônicas por inquérito telefônico: estimativas sobre frequência e distribuição sociodemográfica de fatores de risco e proteção para doenças crônicas nas capitais dos 26 estados brasileiros e no Distrito Federal em 2022. Brasília: Ministério da Saúde, 132p. ISBN 978-85-334-2705-1. 2019.

OJANSIVU, I.; FERREIRA, C.L.; SALMINEN, S. Yacon, a new source of prebiotic oligosaccharides with a history of safe use. Trends in Food Science & Technology. ;22(1):40–6. 2011. https://doi.org/10.1016/j.tifs.2010.11.005.

OLIVEIRA, G.O.; BRAGA, C.P.; FERNANDES, A.A.H. Improvement of biochemical parameters in type 1 diabetic rats after the roots aqueous extract of yacon [Smallanthus sonchifolius] treatment. Food and Chemical Toxicology.; 59:256–60.2013. https://doi.org/10.1016/j.fct.2013.05.050.

PETERS, S.A.E.; SINGHATEH, Y.; MACKAY, D.; HUXLEY, R.R.; WOODWARD, M. Total cholesterol as a risk factor for coronary heart disease and stroke in women compared with men: A systematic review and meta-analysis. Atherosclerosis [Internet]. ;248:123–31. 2016. https://www.sciencedirect.com/science/article/pii/S0021915016300910.

SACRAMENTO, M.D.; SILVA, P.S.; TAVARES, M.I. Batata yacon: alimento funcional. Semioses [Internet] ; 11(3). 2017. https://doi.org/10.15202/1981996x.2017v11n3p43.

SATOH, H.; KUDOH, A.; HASEGAWA, K.; HIRAI, H.; WATANABE, T. Yacon supplementation reduces serum free fatty acids and tumor necrosis factor alpha concentrations in patients with type 2 diabetes. Diabetology International v. 5:165–174. 2014. https://doi.org/10.1007/s13340-013-0150-y.

SCHEID, M.M.; GENARO, P.S.; MORENO, Y.M.; PASTORE, G.M. Freeze-dried powdered yacon: effects of FOS on serum glucose, lipids and intestinal transit in the elderly. European Journal of Nutrition [Internet]. 53(7):1457-64. 2014. https://doi.org/10.1007/s00394-013-0648-x.

SILVA, M.F.G.; DIONÍSIO, A.P.; ABREU, F.A.P.; PINTO, C.O.; SILVA, L.M.A.E.; DE BRITO, E.S.; PONTES, D.F. Optimization of enzymatic treatment to produce yacon juice clarified by microfiltration with high levels of chlorogenic acid and fructooligosaccharides. Journal of Food Processing and Preservation, 42(6), 1–8. 2018. https://doi.org/10.1111/jfpp.13641.

SOUSA, S.; PINTO, J.; RODRIGUES, C.; GIÃO, M.; PEREIRA, C.; TAVARIA, F.; Malcata, F.X.; GOMES, A.; Pacheco, M.T.B. Pintado, M.; Antioxidant properties of sterilized yacon (SMALLANTHUS SONCHIFOLIUS) tuber flour. Food Chemistry. ;188:504–9. 2015. https://doi.org/10.1016/j.foodchem.2015.04.047.

WORLD HEALTH ORGANIZATION. Physical status: the use e interpretation of anthropometry. Geneva. 2005.

WORLD HEALTH ORGANIZATION. (1998) Obesity - preventing and managing the global epidemic. Geneva, 1998.

ACKNOWLEDGEMENTS

We gratefully acknowledge to Embrapa Agroindústria Tropical and financial support by grants from the following Brazilian agencies: National Council for Scientific and Technological Development (CNPq), Office to Coordinate Improvement of University Personnel (CAPES), Ceará Foundation to Support (FUNCAP) and the Institutional Program for Scientific Initiation Scholarships at the State University of Ceará – IC/UECE. We are also grateful to the following for their help: Lia Gomes Crisóstomo Saboia and Alessandra da Silva Rocha.

ETHICAL APPROVAL

Trial registration was prospectively registered in the Brazilian Registry of Clinical Trials (number: RBR-33wf46).

RECEBIDO: 23/10/2024
REVISADO: 11/11/2024
ACEITO: 7/12/2024
PUBLICADO: 12/12/2024