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Yacon effects in immune response and nutritional status of iron and zinc in preschool children

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A B S T R A C T

Objective: The aim of this study was to evaluate the effect of yacon flour on iron and zinc nutritional status and immune response biomarkers in preschool children.
Methods: Preschool children ages 2 to 5 y were selected from two nurseries and were placed into a control group ($n = 58$) or a yacon group ($n = 59$). The yacon group received yacon flour in preparations for 18 wk at a quantity to provide 0.14 g of fructooligosaccharides/kg of body weight daily. Anthropometric parameters were measured before and after the intervention and dietary intake was measured during the intervention. To assess iron and zinc status, erythrograms, serum iron, ferritin, and plasma, and erythrocyte zinc were evaluated. Systemic immune response was assessed by the biomarkers interleukin IL-4, IL-10, IL-6, and tumor necrosis factor-alfa (TNF-α). Intestinal immune response was analyzed by secretory IgA (sIgA) levels before and after the intervention. Statistical significance was evaluated using the paired *t* test ($\alpha = 5\%$).
Results: Before and after the study, the children presented a high prevalence of overweight and an inadequate dietary intake of zinc and fiber. The yacon group presented with lower hemoglobin, mean corpuscular hemoglobin, and mean corpuscular hemoglobin concentration at the end of the study ($P < 0.05$). Erythrocyte zinc was reduced in both groups at the end of the study ($P < 0.05$). Yacon intake increased the serum levels of IL-4 and fecal sIgA ($P < 0.05$). The control group had lower serum TNF-α after the study period ($P < 0.05$).
Conclusion: Yacon improved intestinal immune response but demonstrated no effect on the nutritional status of iron and zinc in preschool children.

Introduction

Yacon (*Smallanthus sonchifolius*) originates from the Andean region and has spread across South America and Europe. In contrast with most roots, yacon stores its carbohydrates in fructooligosaccharides (FOS) and can contain 40% to 70% of its FOS in its root dry matter [1,2].

FOS are fructose oligosaccharides joined by β-(2→1) or β-(2→6) bonds with a prebiotic role [1]. Prebiotics are non-digestible but fermentable oligosaccharides specifically designed to change the composition and affect the activity of one or a limited number of bacteria of the intestine, with the goal of promoting the health of the host [3]. In the colon, FOS acts as a substrate for the growth of beneficial bifidobacteria and lactobacilli [4].

Recently, great interest has been focused on the positive effects of dietary fructooligosaccharides on mineral bioavailability. Studies involving humans indicate that they promote greater mineral bioavailability [5–7]. In agreement with these findings, studies performed in animals demonstrated changes in the

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Table 1
Profile of the study population, anthropometric parameters, and nutritional status of preschool children in the yacon and control groups before and after intervention

	Yacon n = 41		Control n = 48	
Age (mo)	47 ± 13		41 ± 11	
Sex (%)				
Male	53		54	
Female	47		46	
	Before	After	Before	After
Anthropometric parameters				
Weight (kg)	17.85 ± 3.93	18.75 ± 4.29*	16.39 ± 2.85	17.25 ± 3.17*
Height (cm)	104.33 ± 10.14	107.65 ± 10.0*	99.96 ± 7.73	103.42 ± 7.59*
BMI (kg/m^2)	16.32 ± 1.94	16.06 ± 2.02*	16.32 ± 1.38	16.04 ± 1.66
Nutritional status (%)				
Slimness	2.08	2.08	2.44	4.88
Eutrophic	62.50	64.58	58.54	60.98
Risk for overweight	22.92	16.67	29.27	24.39
Overweight	12.50	16.67	9.76	7.32
Obesity/severe obesity	0.00	0.00	0.00	2.44

BMI, body mass index
Values are means ± SD
* Paired-samples t test comparing each group before versus after; $P < 0.05$.

intestinal architecture with dietary FOS treatment: Increases in intestinal crypt number, depth, and bifurcations and in the production of short-chain fatty acids, and a decrease in luminal pH [8,9]. Particularly, these three types of effects can be the main reasons for better mineral absorption, which increases their bioavailability [10–12].

Nutritional deficiencies of micronutrients, mainly iron and zinc, are common in preschool-aged children [13]. Lack of certain micronutrients, especially zinc and iron, can lead to clinically significant immunodeficiency and infections in children. Thus, in this group the addition of prebiotic food can increase mineral bioavailability and strengthen the immune system.

Fructan consumption can increase immune system efficiency [14]. In animals, yacon flour ingestion stimulates the local immune response by increasing the levels of secretory immunoglobulin A (sIgA), interleukin IL-10, and IL-4. Its immunomodulatory effect may be indirect, by influencing the growth of bifidobacteria and lactobacilli, or through a direct interaction with the immune system [4]. However, to our knowledge, there are few studies about the effects of FOS on the immune response in humans [14].

In this context, the aim of this study is to evaluate the effects of yacon on the iron and zinc nutritional state and immune response in preschool children.

Methods

Participants

One hundred seventeen preschool children ages 2 to 5 y from two full-time public nurseries were recruited for this study. The children were submitted to an initial blood sampling after the consent of their parents or guardians. The exclusion criteria were hemoglobin <11 mg/dL and the use of ferrous sulfate, vitamins, or mineral supplements. Children from one nursery were placed in the control group (n = 58), whereas the other group received yacon flour (n = 59) for 18 wk. The children were evaluated for anthropometric and biochemical parameters and local and systemic immune response (Fig. 1). General characteristics of the children are presented in Table 1. The study was approved by the Ethics Committee on Human Subject of the Federal University of Viçosa, MG, Brazil, protocol number 028/2012, and by the local education secretary.

Obtaining the yacon flour

Two hundred kg of yacon was purchased weekly from a rural producer of Santa Maria do Jetibá, Espírito Santo, Brazil. After selecting, washing, sanitizing, and peeling, the tubercle was processed and immersed in a citric acid solution (0.5%) for 10 min as adapted from an earlier method [15]. After this procedure, it was dried (24 h at 60°C) in an airflow dryer (Polidryer). The flour was stored in plastic bags, 2 to 5 kg each, at a temperature of −10°C. The FOS content was determined as indicated previously [16]. The levels of protein, carbohydrates, lipids, fiber, ash, and humidity were evaluated using AOAC method [17].

Dietary intervention

The children in the yacon group received yacon for 18 wk in amounts to provide 0.14 g FOS/kg body weight daily [18], which was calculated according to the mean body weight of each school class and the yacon flour FOS level. To enhance the yacon acceptability, it was offered in preparations such as candy (fed after lunch and prepared with yacon, water, and milk powder), cake, and cookies (fed at breakfast time). The preparations were offered daily (Monday through Friday). The offered preparations and the leftovers were weighed daily to evaluate the acceptability. Parents and teachers were asked about the possible presence of adverse effects throughout the intervention period.

The caloric content of the preparations was calculated based on the chemical composition of the yacon flour and other ingredients, using the Avanutri program, version 1.0 for Windows.

Dietary assessment

For dietary assessment, the food consumption average of 3 nonconsecutive d was evaluated by direct food weighing method and 24-h recall. The foods ingested at the nurseries were weighed on 2 non-consecutive weekdays [19]. Food portions were weighed on a digital portable scale of 2-kg capacity and 1-g precision. The number of repeats and the leftovers were recorded. Meals fed at home were evaluated by 24-h recall based on information provided by the children's guardians on the same weekday of the direct food weight in the nurseries and on a weekend day. Food composition was analyzed by using Avanutri. The adequacy of macronutrients was evaluated based on the acceptable macronutrient distribution range (AMDR), and micronutrients based on the estimated average requirement (EAR) or adequate intake [20,21].

Anthropometric assessment

The weight and height of the children were determined according to a previous method [22] before and after dietary intervention. For weight measurements, an electronic digital portable scale (150 kg capacity and 50 g precision) was used. A stadiometer was used for height measurement. These parameters were used to calculate the body mass index for age (BMI/A), which was compared with the reference z score and classified according to the World Health Organization recommendations [23].

Hematologic evaluation

Samples of blood were collected by venous puncture. The blood was analyzed for red blood cells (RBCs), hematocrit (Htc), hemoglobin (Hb) concentration, mean cell volume (MCV), mean cell hemoglobin (MCH), and mean cell hemoglobin concentration (MCHC). Serum was taken for ferritin and iron