Chemical composition and functional properties of chocolate cakes formulated with yacon tube roots (*Smallanthus sonchifolius*)

Caracterização e propriedades funcionais de bolos de chocolate formulados com raízes tuberosas de yacon (*Smallanthus sonchifolius*)

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ABSTRACT

This present work aimed at developing a cake using yacon flour (20% and 40%), for replacing partially the wheat flour. The products were characterized on the nutritional composition, glycemic index, glycemic charge and *in vitro* prebiotic effect. The physicochemical analyses showed a high fiber concentration in the experimental cakes**,** in compliance with the legislation in force, being 7.49g% for the cake A (yacon 20%) and 10.75g% for the cake B (yacon 40%). Low concentrations of available carbohydrates of 11.22g% and 9.35g% were found in both cake A and B**,** respectively. Glicemic index lower than 55 and glycemic charge lower than 10 were detected. The prebiotic effect was observed by keeping the lactic bacteria above 10^6 UFC/g of substrate. On that account, cakes containing high fiber concentrations were achieved. Regardless of the added amounts of yacon flour to the experimental cakes, they were classified as of low glycemic index and glycemic charges products, besides their *in vitro* prebiotic effect.

Keywords. yacon flour, cake, prebiotic effect, glycemic index, glycemic charge.

RESUMO

No presente trabalho, foram desenvolvidos bolos adicionando-se farinha de yacon [20% (bolo A) e 40% (bolo B)], em substituição parcial a farinha de trigo. Os produtos foram avaliados quanto às características de composição nutricional, índice glicêmico, carga glicêmica e efeito prebiótico *in vitro*. As análises físico-químicas mostraram concentração elevada de fibra nos bolos experimentais, de acordo com a legislação vigente, cujos valores foram de 7,49g% para o bolo A e 10,75g% para o bolo B. Ambos os bolos A e bolo B demonstraram baixa concentração de carboidratos disponíveis, respectivamente, de 11,22g% e 9,35g%. O índice glicêmico foi inferior a 55 e a carga glicêmica inferior a 10. O efeito prebiótico foi observado pela manutenção das bactérias lácteas acima de 10^6 UFC/g de substrato. Neste estudo, foram obtidos bolos com alto teor de fibras. Independentemente da quantidade de farinha de yacon adicionada aos bolos experimentais**,** estes foram classificados como de baixos índice e carga glicêmicos, e de efeito prebiótico *in vitro*.

Palavras chave. farinha de yacon, bolo, efeito prebiótico, índice glicêmico, carga glicêmica.

INTRODUCTION

Yacon (*Smallanthus sonchifolius*) is a spare tube roots plant, fusiform**,** containing a fleshy, sweet and clear pulp, even reaching 20 cm of length, presenting an external brown color and an internal cream-like staining. Its roots are eaten raw and still under the shape of a juice, syrup or dehydrated. They own a sweet flavor due to its fructan, inulin/ fructooligosaccharide content – FOS[1].

Despite fructans perform functional properties as fiber fractions do, according to FAO/WHO recent report, these fructans are not classified as fibers, for being spare carbohydrates of vegetables[2]. Fuctans, upon reaching intact the large intestine, are fermented by probiotic cultures, mainly of the gender *Bifidobacterium e Lactobacillus*. As an aftermath, a series of compounds, including short chain fatty acids (AGCC) mainly acetate, propionate and butyrate, which are absorbed and used by human epithelial cells, nurturing the salt and water uptake, the growth of epithelial cells and the intestinal movement[3].

Fructooligosaccharide fructans, known as "non-conventional", present a relatively low fat value (1-2 Kcal/g) that might influence upon the glycemic response[4].

There is in the literature, yacon application (extracts, flour) on several food products, among them chocolate cakes light developed by Padilha et al.[5], bread made without fat by Rolim et al.[6], jelly of yacon, guava and acerola no added sugar produced by Prati et al.[7] and yacon juice produced by Lago et al.[8]. Among these, the cake is not considered a basic food, it is highly accepted by the population as a whole, on presenting a soft and porous texture, plus a sweet flavor. Notwithstanding, its intake is limited for diabetic and overweight individuals[9].

Before the exposed results, it was agreed to develop formulations on chocolate cakes with yacon flour, aiming to assess the nutritional characteristics and the effects concerning the glycemic response and the prebiotic potential.

MATERIAL AND METHODS

Yacon flour processing and cake preparation

The *in natura* yacon roots were washed and immersed in a sodium hypochloride solution at 200 ppm by 15 minutes. After, they were peeled on running water and cut by sharp-edged blades. The blades were immersed in a calcium chloride solution, containing 1,0 g . 100 g^{-1} during 30 minutes. Then the blades were deposited on polyethylene trays and dried in an oven with forced ventilation at 55 °C for 24 hours. Subsequently, yacon was triturated in a dry mill rotor to obtain a product with characteristics of flour, which was packed in polyethylene bags, sealed and stored under refrigeration.

The cakes were prepared using the ingredients of the Table 1. The formulations showed different amounts of sugar, milk reconstituted powder and yacon meal. The sugar content reduced in the formulation as increased the amount of flour added yacon, because yacon fructooligosaccharides present a third of the sweetening power of sucrose[5]. The mass of the cakes was prepared in mixer Kitchen Aid model K555, Hz 50-60. The margarine and the sugar were homogenated for 2 minutes at speed 2. After that, the other ingredients were added and homogenated for 3 minutes. At room temperature, the eggs were blended for 3 minutes at speed 1. Finally, the egg whites were added to the dough manually. The samples were baked in an oven at a temperature of 180 °C, for 30 minutes.

Table 1. Proportions of ingredients in the cakes formulation

Ingredients	Formulations		
	Standard sample P (%)	Experimental sample A (%)	Experimental sample B (%)
Eggs	98 g	98 g	98 g
Margarine (80% of lipids)	100 g	100 g	100 g
Milk reconstituted powder	100 mL	90 mL	80 mL
Crystal sugar	100 g	70 g	40 g
Cocoa powder	6 g	6 g	6 g
Chocolate	36 g	36 g	36 g
Wheat flour	100 g	80 g	60 g
Yacon powder	-	20 g	40 g
Baking power	16 g	16 g	16 g
Salt	3 g	3 g	3 g

Microbiological analysis on yacon flour

In order to check the yacon flour innocuity, coliform analysis were carried out at 45 °C, *Bacillus cereus* e *Salmonella* spp.[10].

Yacon flour and cake Centesimal Composition

The yacon flour and chocolate cake centesimal composition was determined in triplicate according to AOAC method[11] humidity (method 935.29); fixed mineral residues (method 930.22-32.308), proteins (method 991.20-33.2.11), ether extract (method 963.15-31.4.02), total food fiber (985.29-45.4.08), total fructans[12], and other carbohydrates by difference.

"In vitro" Glycemic Index Determination and Glycemic Charge

The glycemic index determination (GI) was carried out according to the method developed by Gõni et al.[13]. The glucose curve obtained to calculate the glycemic index, using the white bread as food reference and the software Autocad (2008), to calculate the area.

The GI acquired was classified according to Brand-Miller and Gilbertson[14] that follows the American Diabetic Association ADA[15] recommendation, being the GI considered low values ≤ 55 and high values ≥ 70. The glycemic charge (GC = GI x carbohydrate available in the portion / 100) was classified as low (≤ 10) or high (≥ 20) according to Lajolo and Menezes[16].

Determination of the "in vitro" power prebiotic

The prebiotic effect was checked through fermetation of three formulations according to the methodology proposed by Cambrodón and Martín-Carrón[17], with changes suggested by Silveira et al.[18].

The 100 mg-samples were set in test tubes with 8 mL of the middle of fermentation[19], incubated at 37 °C, in Gaspak jar with anaerobic system, during 12 hours. 2mL of inoculum were added to each test tube, prepared from infants´ feces lifted up in the middle of fermentation, in proportion of 10 mL/g of feces, a 37 °C, under anaerobiosis for 12 hours.

Then, tubes were kept in anaerobic system, in double boiler under agitation and controlled (37 °C), remaining on these conditions during the fermentation period. In an interval of 2 hours, a 1 mL-aliquot of the metabolic liquid was used to count the bacteria.

In order to quantify and identify *Bifidobacterium* e *Lactobacillus,* the differential means HHD Agar[20] was used. The samples of the metabolic liquid were incubated through surface plate, at 37 °C ± 1 °C, for 72 h in anaerobic environment.

Statistic Treatment

The results were submitted to variance analysis (ANOVA), being the Duncan test carried out to be compared among the averages obtained at a 5% meaning level. In order to check the correlation among the samples, the software "statistic for windows" was used[21].

RESULTS

The microbiological analysis for coliforms at 45 °C/g (< 3,0), *Bacillus cereus* at UFC/g (< 1,0) and *Salmonella* spp./25 g (absence) presented results according to legislation[22], (10 for coliforms at 45 °C NMP/g, 3×10^3 for *Bacillus cereus* at UFC/g and absence in 25 g for *Salmonella*) being under safe conditions for human intake.

The results of the centesimal composition (Table 2) of the yacon flour were similar to the ones reported by literature. According to the centesimal composition (Table 3), experimental cakes presented a higher humidity, minerals and fibers contents. On the other hand, presented reduced content of carbohydrates (compared to the standard sample).

Table 2. Centesimal composition of yacon flour

Physical-chemical analysis	Yacon flour
Moisture	13,24
Ash	4,2
Protein	3,36
Lipids	0,19
Carbohydrate*	66,8
Total soluble fiber	2,76
Total fructans	1,45
Insoluble fiber	9,45
Total dietary fiber	12,21
V.C.T (Kcal)	282,35

* calculated by difference

According to the results depicted in the Table 4, the GI and GC values found for formulations with yacon flour were considered low[14-16]. Brand-Miller and Gilbertson[14] that follows the American Diabetic Association ADA[16] recommendation, being the GI considered low values ≤ 55 and high values ≥ 70. The glycemic charge (GC = GI x

Table 3. Centesimal composition of chocolate cakes

Analysis (humid basis g/100 g)	Standard cake (without yacon flour)	Sample A (20% of yacon flour)	Sample B (40% of yacon flour)
Moisture	35,85 ± 0,56c	42,59 ± 0,55b	45,72 ± 1,15a
Ash	2,15 ± 0,02c	2,66 ± 0,02b	3,20 ± 0,01a
Protein	7,21 ± 0,26a	7,06 ± 0,11a	6,59 ± 0,04b
Lipids	31,23 ± 0,40a	28,98 ± 0,26b	24,39 ± 0,58c
Carbohydrates*	19,93 ± 0,13a	11,22 ± 0,12b	9,35 ± 0,25c
Total soluble fiber	2,15 ± 0,02c	4,47 ± 0,04b	4,94 ± 0,05a
Total fructans	-	0,84 ± 0,01a	1,06 ± 0,01a
Insoluble fiber	1,48 ± 0,08c	3,02 ± 0,05b	5,81 ± 0,02a
Total dietary fiber	3,63 ± 0,02c	7,49 ± 0,02b	10,75 ± 0,03a
V.C.T (Kcal)	389,63 ± 2,03a	333,94 ± 1,10b	283,27 ± 2,04c

Same letter horizontally do not differ significantly at 5% significance level
* calculated by difference

carbohydrate available in the portion/100) was classified as low (≤ 10) or high (≥ 20) according to Lajolo and Menezes[16].

Table 4. Glycemic index and glycemic charge of standard and experimental cakes

Sample	Glycemic Index	Glycemic Charge (100 g da portion of food)
Standard cake (without yacon flour)	73,18	17,08
Sample A (20% of yacon flour)	25,22	2,82
Sample B (40% of yacon flour)	17,16	1,6

The results (Table 5) showed that experimental cakes presented a satisfactory quantities of probiotics bacteria, mainly *lactobacillus*. According to Saad[23], for changes favorable in the composition of intestinal microbiota are observed at doses of 100 g of food product containing 10^9 CFU of probiotic micro-organisms (10^7 CFU/g of product).

DISCUSSION

Centesimal composition of yacon flour

The results of the centesimal composition (Table 3) of the yacon flour were similar to the ones reported by Marangoni and Collares[24] and Fuke et al.[25], except for protein values. Ribeiro[26] reported percentages of protein and total food fiber similar to the data depicted in the Table 3, in yacon flour obtained through the same drying temperature (55 °C). Viega et al.[27] also found similar values to such work, regarding the percentage of ashes, fibers and lipids. On the other hand, Moscatto et al.[28] found distinct values for all the parameters analyzed. The divergences could be explained through different times and drying temperature deployed, apart from the yacon growing and harvesting, and the state of maturation of the vegetable studied[29].

Centesimal composition of chocolate cakes

According to the centesimal composition (Table 4), the experimental cake B, presented a higher humidity content compared to the other cakes, result expected due to the higher yacon flour content, raw material containing a high number of hidroxyls available for water bond[30].

Regarding minerals, the experimental cakes presented a higher content, possibly by the calcium (23 mg/g) and the phosphorus (21 mg/g) in the yacon[31].

And as for the other parameters, meaningful differences were observed among the experimental samples (Table 4). Upon observing the fiber content, the cakes A and B were considered products high in fiber, according to the current legislation that classifies a product as rich in fibers when it presents 3% of fibers and high for a percentage of 6% of fibers[31].

The reduced content of carbohydrates available in the cakes A and B, regarding the pattern, it was already expected, due to the partial replacement of the wheat and flour for the yacon flour and the reduction of the sugar in the formulations (Table 1). Moreover, there was a meaningful reduction on the carbohydrates available around 30% for the cake A and 60% for the cake B, if compared to the standard cake providing low-sugar products, previously established by the Brazilian food legislation[32] (Table 4). It was expected because the cakes

Table 5. Count of probiotics bacteria in cake formulations

Samples / Ferment. time	Infant feces (inoculum)		Standard cake (CFU/g)		Cake A (CFU/g)		Cake B (CFU/g)	
	Lacto	Bifid	Lacto.	Bifid.	Lacto.	Bifid	Lacto.	Bifid
0h	INC	$2,0 \times 10^7$	8×10^6	NI	$1,1 \times 10^8$	NI	$3,0 \times 10^7$	$1,5 \times 10^8$
2h	$4,2 \times 10^7$	NI	6×10^6	NI	$1,2 \times 10^8$	NI	INC	INC
4h	$1,2 \times 10^7$	NI	$3,2 \times 10^7$	NI	$1,3 \times 10^8$	NI	INC	INC
6h	$1,5 \times 10^7$	NI	$8,4 \times 10^7$	NI	$1,2 \times 10^8$	NI	INC	INC
8h	$1,0 \times 10^7$	NI	$6,1 \times 10^7$	NI	$9,8 \times 10^7$	NI	$5,1 \times 10^7$	INC
10h	$2,1 \times 10^7$	NI	$3,2 \times 10^7$	NI	$8,3 \times 10^7$	NI	$3,3 \times 10^7$	INC
12h	$1,2 \times 10^7$	NI	3×10^6	NI	$9,6 \times 10^7$	NI	$1,8 \times 10^7$	INC

Lacto. = Lactobacillus, Bifid = Bifidbacteria; C.F.U. = Colony forming units; NI = Non identified; INC = uncountable

A and B contained less sugar in these formulations. However, results of sensory analysis performed by Padilha et al.[5] showed that for the attribute sweet taste, the cake B, formulated with lower content of sugar (40 g) and higher content of yacon flour (40%) had the highest note, which stated that not significantly different ($p < 0.05$) standard sample and proving the performance of the FOS as a sugar substitute[33].

Determination of the glycemic index and glycemic charge

The literature is scarce concerning the determination of the GI in formulated foods with yacon flour. According to the results depicted in the Table 5, the GI values found for formulations with yacon flour were considered low. The cakes´ GC containing yacon were also classified as low[15-17].

These results can be explained by the application of yacon flour and, furthermore, by the fructans' content, as they perform similar effects compared to the fiber fraction, influences the foods' GI[34].

Besides the presence of fructans, the interactions starch-lipid and starch-protein during the thermal process possibly intervened in the GI and GC of the cakes[35]. It´s remarkable to determine such parameters in foods containing starch and fructans, aiming to help individuals to select better foods, especially those bearing disturbance on carbohydrate metabolism[4].

Comparing the results of the standard cake to the literature, it was stated that the latter's GC was higher to the one reported by Brand-Miller and Gilbertson[14] that detected 47, and lower to the FAO chart, which determines the GI of 87±5 for cakes[36]. The divergences in the results described are resulted from the different ingredients used in the formulations, time and temperature of the thermal process, among other factors.

Cakes' Prebiotic Power

The results (Table 6) showed that the inoculum used in the fermentation presented satisfactory quantities of prebiotic bacteria, mainly lactobacillus. Roberfroid[37] agreeing with other works reported that the growth of probiotic bacteria depend on the starting counting of bacteria in the feces (inoculum), regardless of the fructans dose deployed.

There was a remarkable growth of these bacteria during the fermentation of the experimental cakes, stating the yacon flour´s potential as a prebiotic ingredient. According to Brasil[38] the prebiotic cultures counting over 10^6 UFC/g of substrate is able to produce beneficial effects in the organism. Through a work carried out by Pedreschi et al.[39] depicted that *lactobacillus* and *bifidobacterium* were able to ferment the FOS in the yacon roots.

The absence of bifidbacteria in the cake A can be explained through a higher demand on such bacteria, as well as through the lower amount of yacon flour in the formulation at issue, causing a competition among the prebiotic cultures for the substrate[40].

Regarding the fermentation of the cake B, the genders *Bifidobacterium* and *Lactobacillus* presented an outstanding growth, especially the former one, possibly due to its higher fructans content in the formulation, reducing, thus, the competition among the prebiotic bacteria.

Nevertheless, such results must be checked by *in vivo* experimental models, whereas as the other prebiotics, its intake from 20 to 30 g of those might present several effects, however reversible, through the intake interruption[37].

CONCLUSION

The partial replacement of wheat flour by yacon flour favored the production of cakes rich in fiber. In

addition, probably contributed to reduce the content of sugar used in formulations A and B which contributed to obtaining low glycemic index and low glycemic charge. Cakes containing yacon flour presented prebiotic potential for causing the probiotic bacteria growth during the *in vitro* fermentation.

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