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FULL PAPER

Acceptability of yacon flakes (*Smallanthus sonchifolia*) for dietary use with inulin

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Abstract

This study aimed to elaborate on yacon flakes and determine the proximal composition of fresh yacon and final flakes, made at different temperatures (120°C, 150°C and 180°C) for 20 mins. We measured the acceptability of the sensory attributes: taste, texture, odour and colour and the global acceptability at the laboratory level, using semi-trained panellists and an unstructured hedonic scale. The acceptability of the flakes was measured at different temperatures. Our results indicate that the flakes made at 180°C had the highest acceptance (87%), and the flakes made at 120°C had 80% of unacceptability. Our data were analysed according to the analysis of variance (ANOVA) and Tukey's test. We found significant differences between the averages of the taste scores (T0:7.1; T1:7.6; T2:6.7; T3:4.6), $p<0.05$; texture (T0:7.1; T1:7.2; T2:5.7; T3:4.5), $p<0.05$; and odour (T0:7.2; T1:7.6; T2:5.1; T3:3.3), $p<0.05$. The amount of fructooligosaccharides on a fresh basis was $\bar{X}\pm SD$ (31.60±0.650) and on a dry basis (37.44±1DS). Microbiological analysis shows that the flakes are fit for human consumption. It is concluded that yacon flakes contain significant amounts of inulin, being a good substitute alternative for the preparation of snack-type dietetic products.

1. Introduction

Yacon, tuberous root of Andean origin, is an important source of fructooligosaccharides (FOS) and inulin (Nieto, 1991; Chirinos, 1999; Inga *et al*., 2015), which presents reduced caloric values (1 to 1.5 cal/g) because the β (2-1) bonds between fruiting units cannot be hydrolysed by human digestive enzymes (Mayta *et al*., 2001). Inulin is an oligofructose of nutritional importance and yacon contains this important nutrient, similar to other foods such as garlic, onions, artichokes, chicory among others.

In the food industry, inulin is used in the production of beverages as a substitute for sugars, and fructose syrup, this ingredient prevents foaming and forms a gel used as a substitute for fats in dairy products, spreads, dressings and sauces (Castañeda *et al*., 2008). Inulin and fructooligosaccharides are defined by the Food and Drug Administration (FDA) as GRAS (Generally Recognized as Safe) food ingredients or safe for consumption (Gibson *et al*., 2010). They can be used as a dietary supplement to prevent and treat chronic diseases (Caetano *et al*., 2016).

Flakes (NTP 209.226) (ININTEC) are defined as food products made from roots and tubers in the form of thin slices of one centimetre thick. The use of yacon to make flakes is a promising resource for nutrition and medicine, being an alternative for patients with diabetes, since sugars are stored in the form of inulin, a fructose polymer or levulose, these fructans are not metabolized and they do not raise blood glucose, in addition, they promote the proliferation of bifidobacterium in the colon (Mayta *et al*., 2001; Gill *et al*., 2006; Cabanillas *et al*., 2009; Sivieri *et al*., 2014).

This study aimed to prepare yacon flakes at different temperatures and baking times and to evaluate the physical, chemical, microbiological and sensory characteristics.

2. Materials and methods

2.1 Raw material

In this applied experimental research, we collected fresh and ripe yacon. They were bought in the markets of

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the city of Huacho, Perú, during May and June 2015.

2.2 Preparation of the flakes

The pulp was cut one centimetre thick, they were dehydrated with dry heat, free of artificial sweeteners and preservatives or other chemical additives. At this stage, three temperatures were considered for baking: (T1 = 180°C, T2 = 150°C, T3 = 120°C). The duration of baking was 20 mins (Figure 1).

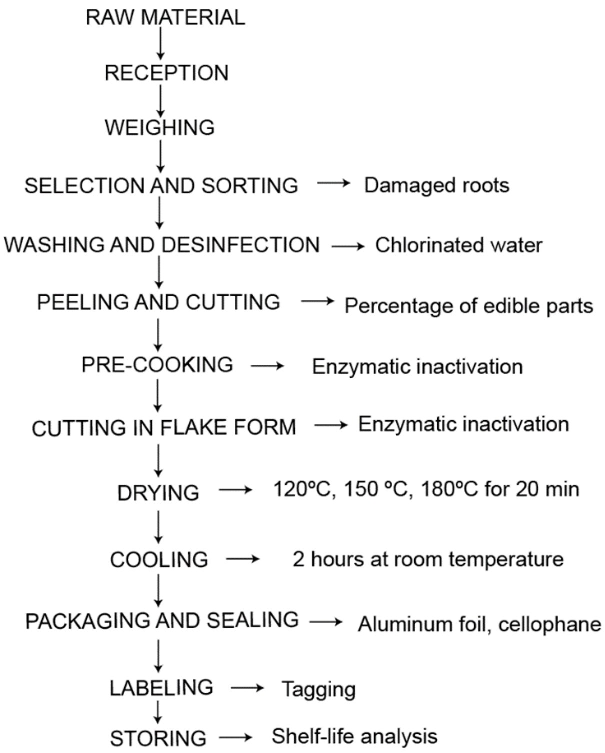

Figure 1. Yacon flakes preparation

2.3 Proximal chemical analysis

The yacon flakes were pulverized. We determined the following analyses: a) humidity percentage according to the gravimetric method (NTP 205.037-1975) at 100-105°C; b) the crude protein content with the Kjeldahl method (AOAC, 920.87-2005); c) the fat content according to the Soxhlet method (NTP 205.041-1976); d) the determination of ashes by direct incineration (FAO-Food and Nutrition paper Vol. 14/7- 1986); e) determination of crude fibre by acid-alkaline hydrolysis (NTP 2005-003-1980); f) nitrogen-free extract (ELN) was calculated by difference (Collazos, 1993); g) determination of direct and indirect reducing sugars with the Lane-Eynon volumetric method (AOAC, 2000); h) determination of inulin content was carried out by the method recommended by Campos 199 and finally; i) we determined the total acidity by the volumetric method (DIGESA-MINSA).

2.4 Sensory analysis

The sensory analysis (Espinosa, 2020), smell, colour, flavour, texture and acceptability of the yacon flakes was carried out according to the three treatments used. The panel was made up of ten semi-trained people, whose results were validated using the analysis of variance technique, ANOVA. We applied the hedonic method, on a scale of nine points, in which each one of them is marked by a number and by an expression that reflects the intensity of the feeling of acceptance or rejection.

2.5 Microbiological analysis

Microbiological analysis of yacon flakes included total coliform count, viable mesophilic aerobic count, and yeast and fungi count (North American Method) (ICMSF, 2011; Solano, 2010). The data were processed in the statistical program SAS, using the PROC ANOVA instruction. The level of probability used for all statistical analyses was $p<0.05$.

2.6 Statistical analysis

Proximal chemical and microbiological analysis (post-test) of the selected flakes was carried out in the sensory and statistical analysis. The physical, chemical and microbiological analyses were determined in the Food Quality Control laboratory, in the Microbiology laboratory of the Faculty of Bromatology and Nutrition of the José Faustino Sánchez Carrión National University and the Quality laboratory of the Agrarian University La Molina-Lima.

3. Results

3.1 Proximal chemical analysis of the yacon root

According to Table 1, in the fresh yacon root (commercial sample), the water content was 86.27±0.210 and the carbohydrates content was 71.82±1DS.

The results show that the highest percentage of total solids corresponds to inulin with 5.35±0.230 with a coefficient of variation of 4.30 (fresh base), which represents 39.10±1DS, in a dry sample. In addition, the content of monosaccharides, mainly fructose, was 2.68±0.430 g with a coefficient of variation of 16.04 (fresh base), which represents 19.60±1DS in dry sample.

3.2 Sensory analysis of yacon flakes, according to treatments

The results show that the treatment at 180°C for 20 mins stands out over the other two, with average values from 7.4 to 7.6; that corresponds to a sensory quality between "I like it moderately and I like it a lot" (Figure 2).

Products baked at temperature levels of 120 to 150° C did not score as well, essentially the desired flavour and texture. It is necessary to point out that the time of

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Table 1. Proximal analysis of yacon on fresh and dry basis

Components	Fresh basis		Dry basis
	X±DS	C.V. (%)	X±DS
Humidity	86.27±0.210	0.24	
Protein	0.92±0.012	1.30	6.72±1 DS
Lipids	0.43±0.024	5.58	3.16±1 DS
Ashes	0.80±0.041	5.13	5.84±1 DS
Fibre	1.75±0.041	2.34	12.77±1 DS
Carbohydrates (By difference)	9.84±0.290	2.95	71.82±1 DS
Soluble solids	7.67±0.470	6.13	56.00±1 DS
Free fructose	2.68±0.430	16.04	19.60±1 DS
Free glucose	1.61±0.670	41.61	11.50±1 DS
Saccharose	1.37±0.100	7.30	9.80±1 DS
Fructooligosaccharides/Inulin	5.35±0.230	4.30	39.10±1 DS

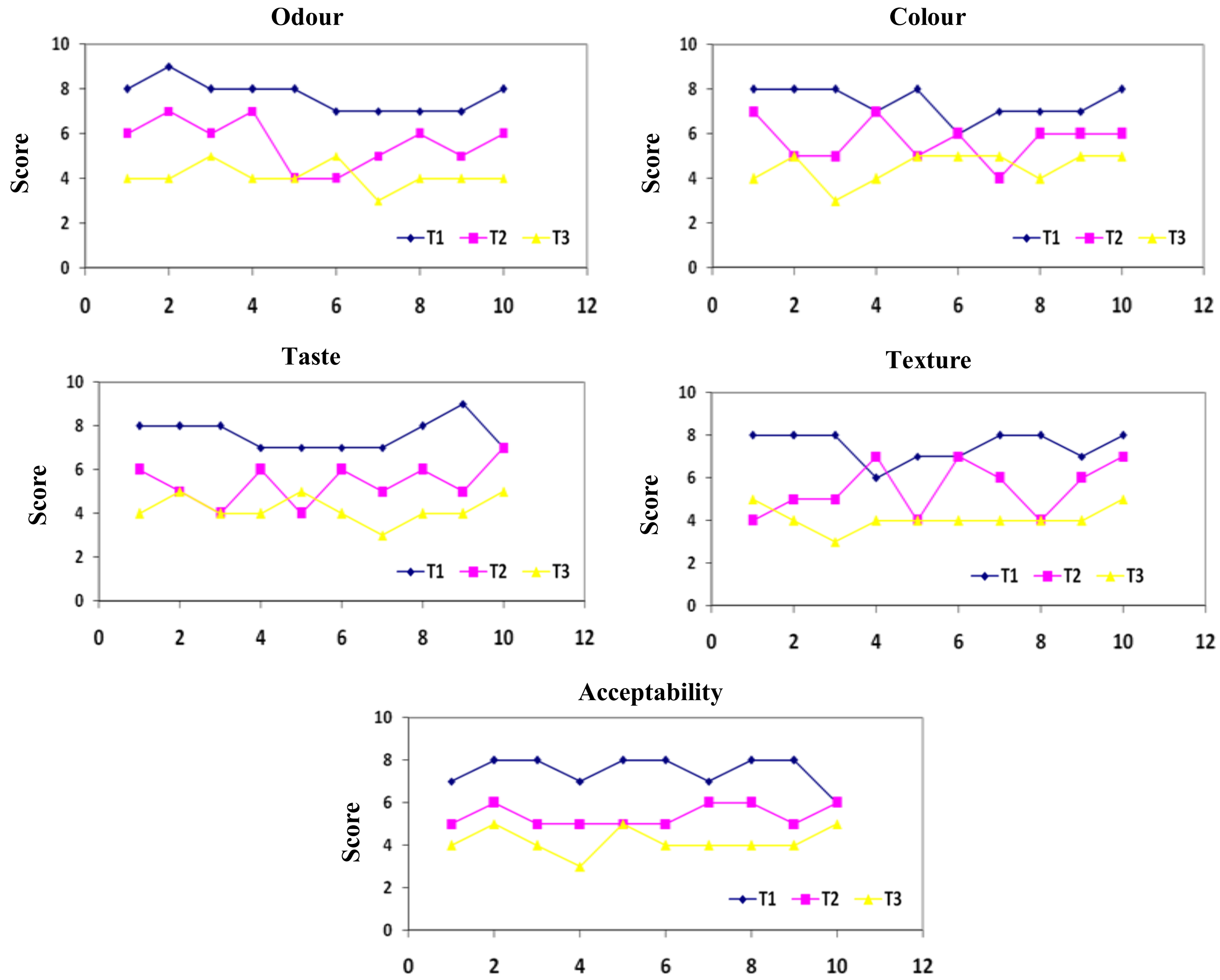

Figure 2. Histograms of the organoleptic variables according to the different temperatures used in the elaboration of the yacon flakes.

20 mins was chosen because it guarantees less degradation and loss of nutrients during the thermal exposure process.

Consumer preference is distributed as follows: 84% taste and texture sensation, 77% odour perception and 65% visualization of colour and presentation.

3.3 Tukey's statistical test to determine differences between the sensory variables of the compared products.

In the study, the treatment variable has three baking categories, which are identified as T-1 (180°C for 20 mins), T-2 (150°C for 20 mins) and T-3 (120°C for 20 mins). Table 2 shows the results of Tukey's multiple comparison test known as HSD (Truly significant difference), to determine which pairs of means are significantly different.

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Table 2. Acceptability of the yacon flakes based on the odour, colour, taste, texture, according to the level of baking (T1, T2, T3).

Variable	Difference between Treatments	T-Value	Pa	Significance
Odour	/T2 –T1/ = -2.100	-5.850	0.0000	***
	/T3 –T1/ = -3.600	-10.030	0.0000	***
	/T3 –T2/ = -1.500	-4.178	0.0008	***
Colour	/T2 –T1/ = -1.700	-4.791	0.0002	***
	/T3 –T1/ = -2.900	-8.172	0.0000	***
	/T3 –T2/ = -1.200	-3.382	0.0061	**
Taste	/T2 –T1/ = -2.200	-6.312	0.0000	***
	/T3 –T1/ = -3.400	-9.755	0.0000	***
	/T3 –T2 = -1.200	-3.443	0.0052	*
Texture	/T2 –T1/ = -2.000	-4.966	0.0001	***
	/T3 –T1/ = -3.400	-8.442	0.0000	***
	/T3 –T2/ = -1.400	-3.476	0.0048	**
Acceptability	/T2 –T1/ = -2.100	-7.530	0.0000	***
	/T3 –T1/ =-3.300	-11.830	0.0000	***
	/T3 –T2/ = -1.200	-4.303	0.0006	***

*Significant difference, **Very significant difference, ***Highly significant difference

The results show that there are significant differences between each pair of means of the treatments. From the analysis of the differences found between the confidence intervals for each possible pair formed, we noticed that the difference between the values of T1 in relation to T2 and T3, greatly exceed the critical level HSD, with a “highly significant” difference between /T2 - T1/ and /T3 - T1/; however, in the pair/T3 - T2/, we observed between “very significant” and “significant” differences, so this data suggest that the flakes baked at 180°C for 20 mins (T1) are preferred.

3.4 Proximal chemical analysis of yacon flakes

Table 3 shows the results of the average proximal chemical analysis of run in triplicate, carried out on the yacon flakes, on a fresh and dry basis. The elaborated product has an added value due to the contribution of fructooligosaccharides (FOS) with a low degree of polymerization (DP), a particular type of sugar with low digestibility that contributes few calories to the body and does not raise the level of glucose in the blood.

3.5 Microbiological analysis of the yacon flakes

Table 4 shows the average results of the microbiological analysis (run in triplicate), carried out on the elaborated product. The yacon flakes had two evaluations during the storage period, at 15 and 30 days. The result of aerobic mesophylls is below the Peruvian technical standard, as is the fungi count. Coliforms were absent in the samples.

4. Discussion

4.1 Proximal chemical analysis of yacon root

The water and carbohydrate contents are within the ranges reported by other groups such as Chasquibol *et al*. (2002). Our carbohydrate content on a fresh basis (9.84±0.290) was lower than that reported by Zapana and

Table 3. Proximal chemical analysis of yacon flakes** (*Smallanthus sonchifolia*)

Components	Fresh basis		Dry basis
	X±DS	C.V. (%)	X±DS
Humidity	15.58±0.085	0.55	
Protein	5.58±0.024	0.43	6.61±1DS
Lipids	2.37±0.024	1.01	2.81±1DS
Ashes	4.68±0.062	1.32	5.55±1DS
Fibre	4.75±0.041	0.86	5.63±1DS
Carbohydrates (By difference)	67.04±0.062	0.10	79.40±1DS
Free Fructose	16.40±0.300	1.84	19.31±1DS
Free glucose	9.30±0.360	2.35	18.13±1DS
Saccharose	8.10±0.260	1.93	16.00±1DS
Fructooligosaccharides/Inulin	31.60±0.650	2.06	37.44±1DS
Acidity	0.21±0,010	476	0.25±1DS

**Flakes were selected in the sensory analysis (Hedonic Scale) and statistical (ANOVA and Tukey's test) (180°C for 20 mins).

Table 4. Microbiological analysis of yacon flakes

Reference	15 days			30 days		
	T_1	T_2	T_3	T_1	T_2	T_3
Counting of Viable Mesophilic Aerobes (CFU/g) V°N° = 10^4 - 10^5*	<10	<10	3×10^1	<10	<10	102
Counting of Fungi (CFU/g) V°N° = <10^3*	<10	3×10	102	< 10	< 10^2	102
Coliform counting (MPN/g) V°N° = <3*	0	0	0	0	0	0

CFU: Colony-forming unit; MPN: The most probable number
*Technical specifications according to Codex Alimentarius and Sanitary Standard of Microbiological Criteria for Sanitary Quality and Safety for food and beverages for human consumption.

Arroyo (2010) (they reported a value of 12.5 g). Chasquibol *et al*. (2002) reported a 1.27% fibre content and Manrique (2005) reported values higher than that reported (1.75±0.041). The sugar content in this study was lower than that reported by Pedreschi *et al*. (2003), (19.67 g on a fresh basis). The content of proteins, lipids and ash was higher in the present study than that reported by Salvatierra (2015). When we made comparisons on a dry basis, the carbohydrate level was higher in the present study. Our study shows that the content of free fructose, saccharose and free glucose is low. This indicates that the caloric content of our product is much lower, compared to pineapple, apple, mango, banana (popular fruits), potato, chicken meat and bread, reported by Manrique and Hermann (2003).

Regarding the content of FOS, the levels found are higher than those in chicory, onion, garlic, lettuce and wheat, being within that reported by the Alexander Von Humboldt Research Institute.

The differences are due to the crop, irrigation, harvest, season and sampling conditions (Becette *et al*., 2004). Yacon roots from Peru and Bolivia have the highest percentage of FOS amount that goes up to 67%. It also contains minerals (calcium, phosphorus and iron) and vitamins B and C, as reported by Chasquibol *et al*. (2002) and Peña (2015).

4.2 Proximal chemical analysis of yacon flakes

The proximal chemical composition of the fresh and dry basis of yacon flakes can be comparable to that found in other investigations (Chirinos, 1999), which obtained oligosaccharides with a low degree of polymerization, the quantity being greater in the yacon root.

Regarding the variation in the nutrient content of the yacon roots, it is observed that during baking at 180°C for 20 mins, see Table 3, the product loses approximately 70.35% of the initial water content of the yacon, the elimination of this important quantity of water is not only necessary for its preservation and the flavour of the finished product, but it also allows the concentration of solids, increasing its caloric density. The concentration of natural sugars contained in yacon was increased by 49.8% (from 5.66 g% initial value of total sugars (fructose, glucose and sucrose) to 33.80 g% in the finished product). Moreover, the concentration of FOS in yacon increased by 49.0% (from 5.35 g% of the initial value to 31.6% in the final product). Other studies show that the FOS subjected to bleaching were reduced from 51.36 to 36.29% in dry weight (Limbaga, 2020). The reported values of dietary fibre are high compared to the amounts of fibre provided by dried fruits, breakfast cereals or others such as the product called "flaxseed mouse" (Villaroel *et al*., 2007).

The yacon flakes provide a high content of carbohydrates and fibre, of which the percentage amount of inulin and FOS is in the order of 49%; It should be noted that the highest sugar content corresponds to fructose with 25%, in relation to total carbohydrates, so it can be considered a food supplement for dietary use. It is low in fat and calories since the high percentage of inulin and FOS are indigestible. For such features, yacon flakes are optimal for people who follow weight loss regimens, and this product could be a substitute for other roots and tubers, which store carbohydrates that raise blood glucose very fast (Sivieri *et al*., 2014).

In addition, FOS are found almost exclusively in yacon and are recognized for their dietary fibre and probiotics, reducing glucose, lipids and triglycerides in the blood (Mayta *et al*., 2001).

4.3 Microbiological analysis of yacon flakes.

The technique used has allowed a low count of mesophilic and fungi, which are within acceptable criteria. Coliforms were absent in the samples, measured at 15 and 30 days after storage. This can reduce the use of artificial additives.

5. Conclusion

The yacon flakes prepared in our study at 180°C showed acceptability of 86% and the microbiological analysis showed that the product was adequate for human consumption. The consumption of yacon flakes could be an alternative healthy snack, due to its beneficial effects on health. They provide a high content of carbohydrates, fibre and they have small amounts of fats and calories. In our study, yacon flakes had a high percentage of inulin and FOS; ideal for someone who wants to lose weight. Therefore, it can be considered a food supplement for dietary use.

Conflict of interest

The authors declare no conflict of interest.

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