ISSN 2175-6813

Revista Engenharia na Agricultura

Viçosa, MG, DEA/UFV - DOI: 10.13083/reveng.v30i1.15122 v.31, p.158-167, 2023

OBTAINING AND PHYSICOCHEMICAL CHARACTERIZATION OF YACON DERIVATIVES

Ana Paula de Freitas Coelho[1], Flavia Fracalossi Baioco[2], Camilla Sena da Silva[1]* & Luis Cesar da Silva da Silva[3]

1 - Federal University of Viçosa, Department of Agronomy, Viçosa, MG, Brasil

2 - Federal University of Espírito Santo, Department of Food Engineering, Alegre, ES, Brasil

3 - Federal University of Viçosa, Department of Agricultural Engineering, Viçosa, MG, Brasil

Keywords:
Smallanthus sonchifolius
Yacon juice
Syrup
Flour

ABSTRACT

The present study aimed to develop and evaluate methodologies of yacon root processing for the production of whole juice, syrup and flour. The physicochemical and color attributes of the derivatives were evaluated through the parameters L*, b*, h. C. ANOVA and Tukey's test were used to analyze the obtained data, at a 5% significance level. The bleaching treatment was effective in the preparation of the juices by keeping the color coordinates constant and preserving the physicochemical characteristics. Regarding the color coordinates, the syrup with citric acid presented a higher L* value, which indicates greater clarity than the others; a h value near 90°, which indicates greater proximity to the yellow color; and a higher C value, which reveals greater color purity. The pie flour presented high crude fiber content and, together with the control syrup, the highest ash content. The syrup with the antioxidant citric acid presented the best color coordinates and a pH close to 4.5, which makes it the best yacon derivative among those analyzed in this study.

Palavras-chave:
Smallanthus sonchifolius
Suco de yacon
Xarope
Farinha

OBTENÇÃO E CARACTERIZAÇÃO FÍSICO-QUÍMICA DE DERIVADOS DE YACON

RESUMO

O presente estudo teve como objetivo o desenvolvimento e avaliação de metodologias de processamento das raízes de yacon visando a produção de suco integral (com e sem branqueamento), xarope (sem aditivos e com ácido cítrico, ácido ascórbico e combinação de ácido cítrico e ascórbico) e farinha (integral e da torta). Foram avaliados os atributos físico-químicos (umidade, pH, cinzas, proteína, lipídeos, glicídios redutores em glicose e glicídios não redutores em sacarose, sólidos solúveis e fibra bruta) e de cor (L*, a* b*, h e C) dos derivados. Os dados obtidos foram analisados através da ANOVA e teste de Tukey a 5% de significância. O tratamento de branqueamento foi eficaz na elaboração dos sucos, por manter constantes as coordenadas de cor e não alterar as características físico-químicas. O xarope com o antioxidante ácido cítrico apresentou as melhores características físico-químicas e de cor, com maior valor de L*, indicando maior claridade em relação aos demais, e valor de h próximo de 90°, indicando maior proximidade à cor amarela, e maior valor de C, mostrando maior pureza, podendo ser um potencial substituto de adoçantes e açúcares comum. A farinha da torta de yacon apresentou alto teor de fibra bruta e lipídios, podendo ser usado como ingrediente enriquecedor no preparo de alimentos.

Received 13 Dec, 2022 • Accepted 21 Jul, 2023 • Published 30 Oct, 2023

Email (corresponding author)*: camillasenasilva@gmail.com

SECTION EDITOR IN CHARGE

Renata Cássia Campos

INTRODUCTION

Yacon (*Smallanthus sonchifolius Poep. Endl.*) is a tuberous root of Andean origin, which grows in temperate and subtropical regions (GRAU & REA, 1997). Popularly known as diet potato (SANTANA & CARDOSO, 2008), it is one of the main natural sources of fructooligosaccharides (FOS). FOS are carbohydrates resistant to the digestive process, which produce low energy and do not raise blood glucose levels. (MOLIS *et al*., 1996; MANRIQUE *et al*, 2005). As they reach the large intestine intact, FOS are fermented, thus acting as prebiotics. (SALES & COSTA, 2010; ROLIM *et al*., 2011).

Yacon is predominantly consumed fresh, raw and in salads, or dehydrated (GRAU & REA, 1997; AYBAR *et al* 2001), but there are also products derived from its leaves and roots. The root derivatives available on the market for direct consumption include flour (PEREIRA, 2009; VASCONCELOS, 2010 a), mixed juices (SUÁREZ *et al*., 2022), syrups (MENDES, *et al*. 2019) and dehydrated slices (REIS *et al*., 2012).It is also widely used as a culture medium in laboratories, for the development of microorganisms of interest (PRPICH *et al*., 2023).

Due to its chemical composition, rich in water and polyphenols (Bertolo, 2017), fresh yacon is a highly perishable food that tends to darken quickly during processing. Thus, new yacon processing techniques are developed to enhance FOS extraction, increase the shelf life of derivatives, preserve nutritional characteristics and facilitate the use and consumption of the tuber.

The present work aimed to generate useful information for the development of technologies targeting the production of yacon derivatives, such as juice, syrup and flour, and evaluate the physicochemical characteristics of these products.

MATERIAL AND METHODS

The experiments were carried out using yacon roots acquired from a rural property in the municipality of Viçosa – Minas Gerais. They were stored under refrigeration until the time of processing, which was performed within seven days, as recommended by Kotovicz (2011).

The roots were washed in running water to remove dirt and, with the help of a stainless steel knife, portions unsuitable for consumption were removed, such as those rotten or darkened, for the preparation of juices, syrups and flour. Then, the roots were immersed in a 200 ppm free residual chlorine solution, for 10 minutes, for sanitization (PADILHA *et al*., 2010). Next, the roots were peeled with a fixed blade, cut into approximately 0.5-cm thick slices and subsequently weighed (SCHER *et al*., 2009; ROLIM *et al*., 2011). The yield of flour and juice was calculated by the ratio between the initial mass of the roots and the final mass in the extraction stage. Regarding the syrup, it was considered the ratio between the initial volume of the juice and the final volume after concentration.

1. Obtaining yacon derivatives

1.1. Juice

The yacon slices were subjected to two treatments to obtain juice: (T1) use of the blanching heat treatment, with the immersion of the slices in water at the temperature of 100 °C, for four minutes, followed by immersion in water at room temperature (SCHER *et al*., 2009); and (T2) without the use of heat treatment. The slices were crushed for the extraction of the juice, using a Black & Decker Excellence juice extractor, and then strained through a sieve until the liquid phase was completely drained.

Three samples of each type of juice were obtained to determine the color coordinates and physicochemical parameters. The color coordinates were measured six times. The first one, 30 minutes after extraction, and the others, every 15 minutes, until 150 minutes, when the values stabilized.

1.2 Syrup

The syrup was made from yacon juice extracted from slices subjected to bleaching (T1). The juice was randomly divided into four fractions, and an antioxidant treatment was added to three of them: (X1) citric acid, in the proportion of 0.18 g/kg of peeled root; (X2) ascorbic acid, in the proportion of 0.18 g/kg of peeled root; (X3) combination of citric and ascorbic acid in the proportion of 50% each, and in the proportion of 0.9 g/kg of peeled root; and the fourth fraction (X4) received no addition of antioxidant (control). The addition of ascorbic and citric acid, besides other combinations, is commonly used in the food industry to prevent enzymatic oxidation (MANRIQUE *et al*., 2005).

After adding the antioxidants, the juices were gravity filtered through a sieve for the removal of solid particles, and then concentrated under continuous heating, using an evaporator with automatic agitator, for two hours, at 80 °C (adapted from MANRIQUE *et al*., 2005).

The physicochemical properties and color coordinates were determined in three replications, for each type of syrup.

1.3 Flour

Two types of flour were prepared: wholemeal flour (F1), obtained through slices submitted to bleaching and drying, at 60 °C, in a cabin dryer, until the formation of a constant mass, after which the slices were crushed in a blender (Philips Walita RI 7625 (adapted from MARANGONI, 2007); and pie flour (F2), obtained from the solid material from the juices used in the preparation of syrups.

For the preparation of F2, the remaining solids were packed in cotton fabric sachets, subjected to compression in dough cylinder rolls for the extraction of excess moisture and, then, to drying in a cabin dryer at 60 °C, until constant mass condition was obtained.

For each type of flour, the drying process and the physicochemical and color coordinated analyses were carried out with three replications.

2. Procedures for analysis and characterization of yacon derivatives

2.1 Physicochemical parameters

The following physicochemical characteristics were determined for the derivatives obtained from yacon roots: moisture, pH, ash, protein, lipids, reducing carbohydrates in glucose and non-reducing carbohydrates in sucrose, soluble solids and crude fiber. The methodologies proposed by the Adolfo Lutz Institute (2008) were adopted.

3. Color coordinates

The coordinates of L*, a* and b* were determined using the CIELAB system and the Konica-Minalta CM-5 reflectance and transmittance spectrophotometric colorimeter. Furthermore, the hue (h), chroma (C) and total color difference (ΔE) values were calculated, according to Equations 1, 2 and 3 (HUNTERLAB, 2000):

$$h = tan^{-1}\left(\frac{b}{a}\right) \quad (1)$$

$$C = \sqrt{(a^2 + b^2)} \quad (2)$$

$$\Delta E = \sqrt{(\Delta L^2 + \Delta a^2 + \Delta b^2)} \quad (3)$$

Where:
L* = Luminosity
a* = red/green coordinate (+a indicates red and –a indicates green)
b* = yellow / blue coordinate (+b indicates yellow and –b indicates blue)
h = color tone;
C = degree of color saturation;
ΔE = total color difference.

4. Statistical procedures

The randomized block design (DIC), with three replications, was adopted for the three trials relating to the preparation of juice, syrup and flour. The public domain software systems R Development Core Team (2011) and Action® (2013) were used to produce the Analysis of Variance (ANOVA), considering the significance level of 5% probability, using the F test. When relevant, the Tukey test was applied at 5% significance. Regression models were created to evaluate the variation in the color coordinates of the juices over time.

RESULTS AND DISCUSSION

1. Physicochemical parameters and color coordinates

1.1 Juice

In this work, the average yield observed for the extraction of yacon juice was 0.45 liters for each kilogram of fresh yacon root, which corresponds to a percent yield of 45%, while Quinteros (2000) determined a percent yield of 76%, without the use of enzymes; and up to 88%, with the use of enzymes.

The analysis of variance revealed that the physicochemical parameter pH presented significant difference for the F test at, 5% probability, for T1 and T2.

According to the data in Table 1, blanching did not change the physicochemical composition of the juice. Only the pH differed statistically, which can be explained by differences in the composition of the roots employed.

Suárez *et al.* (2023) also carried out the physicochemical characterization of yacon juice and found an average of 4.50 soluble solids; 0.26 ash; 2.40 reducing sugar; and 7.50 pH. Regarding pH, Castro *et al*. (2013) prepared suspensions from yacon pulp, and found pH equal to 6.0 and 6.5. In fresh yacon, Bertolo *et al*. (2017) found pH equal to 6.57. Such variations in physicochemical characterization can be explained by planting conditions, soil characteristics and climate (OLIVEIRA *et al*., 2018).

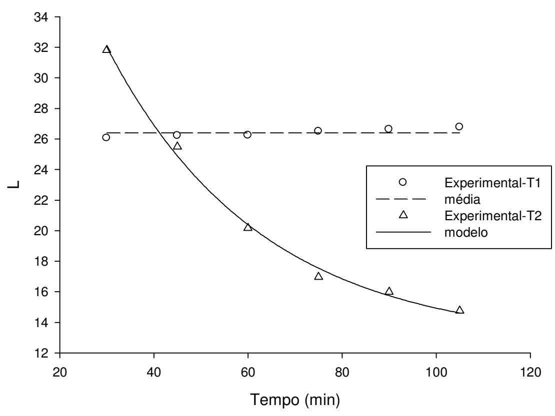
Regarding the color parameters L*, a*, b*, C, h and ΔE, significant differences were also observed using the F test at 5% probability, for T1 and T2. In the analyses of L*, b*, h and C, treatment T1 presented constant mean values, while treatment T2 decreased linearly over time (Figures 1 and 2). As expected, the interruption of oxidative processes due to the application of the bleaching heat treatment in T1 increased the ΔE of T2 (0.79 and 26.28, respectively). The enzyme polyphenoloxidase is a catalyst for several oxidative reactions and is stable to heat, which is the reason why it can be used as an indicator of the suitability of heat treatments (FREITAS *et al*., 2008). On the other hand, no statistical difference was observed for the a* coordinate.

Table 1. Means and standard deviation of the physicochemical parameters of yacon juice with blanching (T1) and control (T2)

Parameters	T1	T2
Soluble solids (°Brix)	6.89a ± 1.54	6.93a ± 1.13
pH	6.07a ± 0.05	5.85b ± 0.02
Protein (% m/m)	0.28a ± 0.03	0.25a ± 0.05
Ashes (% m/m)	0.13a ± 0.04	0.15a ± 0.02
Water content (% m/m)	92.82a± 1.82	92.46a ± 1.63
Reducing carbohydrates (% m/m)	3.58a ± 0.62	4.01a ± 0.54
Non-reducing carbohydrates (% m/m)	2.66a ± 1.67	2.30a ± 1.12

Means followed by the same letters in the lines indicate that they do not differ statistically according to the Tukey test at a minimum significance level of 5%

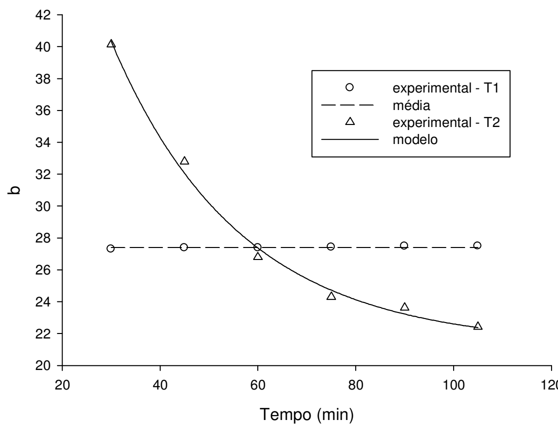
The means are presented followed by the standard deviation value



T1: $L^* = 26{,}4024$

T2: $L * 12{,}6750 + 48{,}5192e^{-0{,}0306442t}$

$r^2 = 0{,}996131$

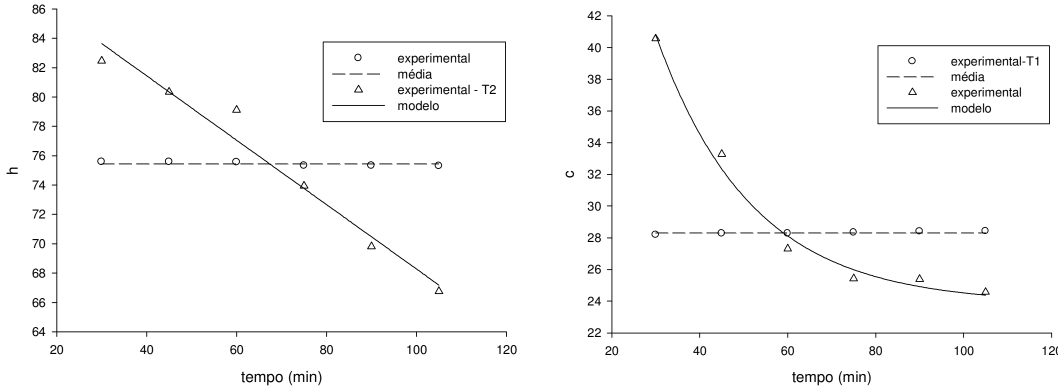


T1: $b^* = 27{,}4041$

T2: $b * 21{,}2747 + 59{,}5814e^{-0{,}0379914t}$

$r^2 = 0,\ 994646$

Figure 1. Luminosity (L*) and yellow region (b*) coordinates evaluated over time for juice with bleaching (T1) and control (T2)



T1: h = 75,4444

T2: $h = 90{,}2202 - 0{,}219399t$

$r^2 = 0,\ 968034$

T1: C = 28,3111

T2: $C = 23{,}8474 + 67{,}3381e^{-0{,}0459968t}$

$r^2 = 0,\ 989304$

Figure 2. Hue (h) and purity (C) evaluated over time for T1 and T2

1.2 Yacon Syrup

Previously, physicochemical analyses were carried out and the color coordinates of the juices that originated the syrups were defined. However, no significant differences were observed after the application of the treatments, which indicates that the juices used to prepare the syrups had a uniform initial chemical composition and that the additions of antioxidants did not change any of the evaluated parameters.

The average yield of transforming roots into syrup was 3.5%, which is lower than the 7-10% value cited by Manrique *et al*. (2005). The analysis of variance demonstrated that pH, ash and non-reducing carbohydrates presented significant difference for the F test, at 5% probability, for X1, X2, X3 and X4.

The results of the physicochemical analyses of the syrups (Table 2) indicate significant difference in pH, ash and non-reducing carbohydrates between the treatments, while the control presented the highest averages.

The increased solution concentration after the addition of antioxidants with different hydrogenionic potentials, usually below 4, may explain pH variation between treatments. According to Hoffmann (2001), at pH values below 4.5, there is no development of pathogenic bacteria. Therefore, syrup with citric acid with pH of 4.49 is the most suitable. The difference in ash content between X4 and the samples that received the treatment can also be explained by the dilution of the solution with the addition of acid, as it presented higher values. Treatment X4 presented 25.27% m/m of non-reducing carbohydrates in sucrose, which is the lowest value among the treatments. No studies were found in the literature for the comparison of the content of non-reducing carbohydrates in yacon syrup.

Mendes *et al.* (2019) analyzed the potential of yacon syrup to be used in the supplementation of yogurt. They performed the chemical and physicochemical analyses of this derivative and found averages equal to 67.88 for soluble solids; 4.06 for pH; 1.65 for proteins; 2.72 for ash; and 21.61 for reducing sugars. The conditions of plant handling in the field and the processing techniques affect the physicochemical composition of the final product. The average values found in the literature reveal that yacon syrups hold the ideal physical and sensory characteristics for replacing sugar, similarly to honey and molasses (SILVA *et al*., 2017).

The comparison of the levels of glucose-reducing carbohydrates in the juices that originated the syrups (Table 3) evidenced that these components did not increase in any treatment. The maintenance of these concentrations demonstrates that the processing used to prepare the syrups promoted no hydrolysis of the complex sugars present in the juice, probably also preserving the FOS content.

The color parameters L*, a*, b*, C, h and ΔE also revealed significant difference for the F test, at 5% probability, between treatments X1, X2, X3 and X4. The results in Table 4 demonstrate that the color coordinates are significantly affected by at least one of the applied treatments.

Table 2. Means and standard deviation of the physicochemical parameters of yacon syrups with citric acid (X1), ascorbic acid (X2), combination of citric and ascorbic acid (X3) and control (X4)

Parameters	X1	X2	X3	X4
Soluble solids (°Brix)	58.48a ± 4.61	57.41a ± 9.86	61.22a ± 1.49	56.18a ± 4.31
pH	4.49c ± 0.05	4.95b ± 0.13	4.71d ± 0.05	6.14a ± 0.03
Protein (% m/m)	0.35a ± 0.02	0.34a ± 0.04	0.33a ± 0.02	0.33a ± 0.03
Ashes (% m/m)	1.32b ± 0.29	1.26b ± 0.24	1.39b ± 0.16	1.84a± 0.56
Water content (% m/m)	41.57a ± 5.28	41.17a ± 9.60	40.23a ± 1.14	45.50a ± 4.52
Non-reducing carbohydrates (% m/m)	31.37ab ± 8.95	30.13ab ± 9.59	37.97b ± 9.60	25.27a± 4.42
Reducing carbohydrates (% m/m)	28.18a ± 2.85	26.35a ± 5.78	30.82a ± 5.16	30.78a ± 4.92

Means followed by the same letters in the lines indicate that they do not differ statistically, according to the Tukey test, at minimum significance level of 5%

Table 3. Means and standard deviation of glucose-reducing carbohydrates on a dry basis (%) in juices and syrups

Treatment	Control		Ascorbic acid		Citric acid		Ascorbic + citric acid	
Derivative	Juice	Syrup	Juice	Syrup	Juice	Syrup	Juice	Syrup
Average ± DP*	60.89a ± 15.19	56.44a ± 5.64	54.11b ± 4.89	45.00c ± 6.13	51.78d ± 5.16	48.78d ± 7.70	59.56e ± 8.02	51.50e ± 8.50

Means followed by the same letters on the line indicate that they do not differ statistically, according to the Tukey test, at the minimum significance level of 5%

*Standard deviation of the mean

Table 4. Means and standard deviation of color coordinates (L*, a* and b*) and hue (h), chroma (C) and total color difference (ΔE), in yacon syrups with citric acid (X1), ascorbic acid (X2), combination of citric and ascorbic acid (X3) and control (X4)

Coordinates	X1	X2	X3	X4
L*	33.02b ± 2.20	28.62a ± 7.39	28.45a ± 0.82	28.46a ± 2.24
a*	9.89bc ± 1.14	9.02b ± 0.89	10.72c ± 1.15	3.08a ± 0.14
b*	31.99c ± 1.51	23.43b ± 3.43	28.64d ± 1.47	14.56a ± 0.76
h	72.88c ± 1.20	68.82b ± 1.62	69.53b ± 1.13	78.05a ± 0.30
C	33.49c ± 1.76	25.11b ± 3.47	30.59d ± 1.76	14.88a ± 0.77
ΔE	16.73b ± 1.03	10.85a ± 4.66	9.97a ± 0.95	13.98ab ± 1.81

Means followed by the same letters in the lines indicate that they do not differ statistically, according to the Tukey test, at minimum significance level of 5%

X1 was the clearest, as it presented the highest L* value. The averages of the a* and b* coordinates were positive in all syrups, which indicates that the color spectrum ranged between red and yellow. This spectrum variation is ratified by the h coordinate, since all angles were between 0° and 90°. X2 was reddish and the control syrup, yellowish. C differed statically among all treatments, and X1 presented the purest color. The greatest total color difference (ΔE) between the coordinates of the juice that originated the syrup and the syrup itself was found in the citric acid and the control.

Regarding the color of yacon syrup, Mendes *et al*. (2019) also found yellowish tones, whose average color coordinates were: L*= 82.82; a*=1.05; b*=22.27. Such variations in color are similar to the standard of other syrups found on the market. The color of products is extremely relevant in the food industry, as it affects consumer preference and acceptance (Dias *et al*., 2012).

1.3 Yacon flour

When the roots were transformed into flour, the yield for cake flour was 0.16%, and for wholemeal flour, 7%. Vasconcelos (2010b) and Rodrigues *et al*. (2011) found higher values: 7.95%, 3.41% and 9%, respectively, which can be explained by the chemical composition of the raw material and the processing techniques.

Table 5 presents the results of the physicochemical analyses of F1 and F2. Among the parameters that could be compared, lipids and crude fiber differed statistically, and F2 presented the highest values for both.

The physicochemical parameters of flour are important for its use in the food industry and the determination of the potential consumer public. According to Brasil (2005), flour moisture cannot exceed 15%, which affects the consumption profile and, mainly, the storability of the product. This work found the values of 4.89-5.25%, respectively, for F1 and F2, which meet the legal parameters.

Higher values were reported by other works, including Marangoni (2007), Oliveira (2010) and Rodrigues *et al*. (2011), namely, 15.42, 10.23 and 6.9%, respectively. However, Pereira (2009) and Gonçalves (2010) found lower values, 2.1% and 3.56%, respectively. Such differences can be attributed to the efficiencies of the drying methodologies, such as spray drier and drying at 80 °C. Oliveira *et al*. (2021) claim that functional foods must be processed in order to have their nutraceutical properties preserved. They also recommend pre-treatment with pulsed vacuum osmotic dehydration, at 60 °C, for drying yacon.

Regarding lipids, F1 presented lower values. Other authors observed values between 0.7 and 1.6% in flour obtained from fresh yacon (MARANGONI, 2007; PEREIRA, 2009; GONÇALVES, 2010; OLIVEIRA, 2010 and VASCONCELOS, 2010). For the crude fiber content, the value found in the present study for F1 was similar to the 4.75% verified by Gonçalves (2010) and 3.86%, verified by Marangoni (2007). The higher porcentagem of these physicochemical parameters observed in F2 was possibly observed because the juice was extracted before the flour was produced, thus increasing the remaining insoluble solids.

Regarding color analyses, the L* value of F2 was 75.82 ± 0.18, which indicates the clarity of the sample. The a* and b* values verified were positive (1.37 ± 0.05 and 19.78 ± 0.35, respectively), which reveals that the sample was located between the red/yellow region. Gonçalves (2010) evaluated the values of L*, a* and b* for the flour obtained from fresh yacon at 60 °C and found that the L* value was similar to that of the present study (76.58), while a* and b* presented higher values (3.55 and 23.50, respectively). The h of 86.04 ± 0.09 also indicates that the shade of the flour was between the angles 0° (red) and 90° (yellow). The C value was 19.83 ± 0.35, and it must be considered that the higher the value, the greater the purity or intensity of the color.

Table 5. Means and standard deviation of the physicochemical parameters of wholemeal flour (F1) of yacon pie flour (F2)

Parameters	F1	F2
Soluble solids (°Brix)	N.d.	1.94 ± 0.17
Ph	N.d.	6.11 ± 0.13
Protein (% m/m)	N.d.	3.96 ± 0.21
Ashes (% m/m)	N.d.	3.29 ± 0.12
Moisture (% m/m)	4.89a ± 1.17	5.25a ± 0.48
Reducing carbohydrates (% m/m)	N.d.	22.02 ± 1.77
Non-reducing carbohydrates (% m/m)	N.d.	17.28 ± 1.33
Lipids (% m/m)	3.01b ± 0.74	4.42a ± 0.49
Raw fiber (% m/m)	4.92b ± 0.33	19.74a ± 0.75

N.d. = not determined

Means followed by the same letters in the lines indicate that they do not differ statistically, according to the Tukey test, at minimum significance level of 5%

CONCLUSIONS

- The use of thermal blanching treatment, with the immersion of the slices into water at the temperature of 100 °C, for four minutes, followed by immersion in water at room temperature, is effective for inhibiting browning and maintaining the values of color coordinates and the physicochemical characteristics of yacon juice.
- The syrup produced from yacon juice with the addition of citric acid, at a concentration of 0.18 g citric acid / kg of peeled root, presents values for color coordinates (L*, h and C) and pH suitable for commercial and industrial parameters.
- The yacon pie flour has high content of crude fiber and lipids and potential for use as a complementary nutraceutical ingredient in human nutrition.

AUTHORSHIP CONTRIBUTION STATEMENT

COELHO, A. P. F.: Data curation, Methodology, Validation, Visualization, Writing – original draft; **BAIOCO, F. F.:** Conceptualization, Formal Analysis, Investigation, Methodology, Validation; **SILVA, C. S.:** Methodology, Visualization, Writing – original draft, Writing – review & editing; **SILVA, L. C. S.:** Conceptualization, Data curation, Formal Analysis, Supervision, Validation.

DECLARATION OF INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

ACTION. [pacote estatístico] disponível em: <http://portalaction.com.br/>. Access in: 27 set. 2013.

AYBAR, M.J.; SÁNCHEZ, R. A.N; GRAU A, S. S. S. Hypoglycemic effect of the water extract of Smallantus sonchifolius (yacon) leaves in normal and diabetic rats. **Journal of Ethnopharmacology,** v. 74, n. 2, p. 125-132, 2001.

BERTOLO, A. P. Batata yacon: caracterização e inativação enzimática. **Revista CSBEA** – v. 3, n. 1, 2017.

BRASIL. Resolução RDC nº 263, de 22 de setembro de 2005, da Agência Nacional de Vigilância Sanitária (ANVISA). Aprova o "**Regulamento técnico para produtos de cereais, amidos, farinhas e farelos"**. Diário Oficial da União; Poder Executivo, de 23 de setembro de 2005.Disponívelem:<http://portal.anvisa.gov.br/wps/wcm/connect/1ae52c0047457a718702d73fbc4c6735/ RDC_263_2005.pdf? MOD=AJPERES>. Access in: 02 de julho de 2022.

CASTRO, A.; CÉSPEDES, G.; CARBALLO, S.; BERGENSTÅHL, B.; TORNBERG, E. Dietary fiber, fructooligosaccharides, and physicochemical properties of homogenized aqueous suspensions of yacon (*Smallanthus sonchifolius*). **Food Research International**, v. 50, p. 392-400, 2013.

DIAS, N. A. A.; LARA, S. B.; MIRANDA, L. S.; PIRES, I. S. C.; PIRES, C. V.; HALBOTH, N. V. Influence of color on acceptance and identification of flavor of foods by adults. **Food Science and Technology**, v. 32, n. 2, p. 296-301, 2012.

FREITAS, A. A.; FRANCELIN, M. F.; HIRATA, G. F.; CLEMENTE, E.; SCHMIDT, F. L. Atividades das enzimas peroxidase (POD) e polifenoloxidase (PPO) nas uvas das cultivares benitaka e rubi e em seus sucos e geléias. **Ciência e Tecnologia de Alimentos, v.** 28, p. 72-177, 2008.

GONÇALVES, P. V. M. **Desenvolvimento de massa alimenticia funcional a base de extrato em pó e farinha de Yacon (*Polymnia sonchifolia*) e farinha de arroz por processo de extrusão termoplástica.** Dissertação de Mestrado em Tecnologia de Alimentos. Universidade Estadual de Campinas, Campinas, 120 p., 2010.

GRAU, A., REA, J. Yacon *Smallanthus sonchifolius* (Poepp. & Endl.) H. Robinson. In: HERMANN M.; HELLER, J. **Andean roots and tubers: Ahipa, arracacha, maca and yacon**. Promoting the conservation and use of underutilized and neglected crops, p. 199-256, 1997.

HOFFMANN, F. L. Fatores limitantes à proliferação de microorganismos em alimentos. **Brasil Alimentos**, n. 9, p. 23-30, jul/ago 2001.

HUNTERLAB. What is color and how is measured. Applications Note, v.12, n.5, p.1-8, 2000. Disponível em <http://www.hunterlab.com/appnotes/an05_00.pdf>. Access in: 15/07/2022.

IAL. INSTITUTO ADOLFO LUTZ. **Métodos físico-químicos para análise de alimentos**. 4. Ed. Versão eletrônica. São Paulo: Instituto Adolfo Lutz, 2008. 1020 p. Disponível em: http://www.ial.sp.gov.br/ial/publicacoes/livros/metodos-fisico--quimicos-para-analise-de-alimentos. Access in: 08 de julho 2022.

KOTOVICZ, V. **Otimização da desidratação osmótica e secagem do yacon *(Polymnia sonchifolia)***. Dissertação de Mestrado em Tecnologia de Alimentos. Universidade Federal do Paraná, Curitiba, 89 p., 2011.

MANRIQUE, I.; PÁRRAGA, A.; HERMANN, M. Yacon syrup: Principles and processing. Series: **Conservación y uso de la biodiversidad de raíces y tubérculos andinos: Una década de investigación para el desarrollo (1993-2003)**. International Potato Center, Lima, Peru, 2005.

MARANGONI, A. L. **Potencialidade de aplicação de farinha de yacon *(Polymnia sonchifolia)* em produtos à base de cereais**. Dissertação de Mestrado em Tecnologia de Alimentos. Universidade Estadual de Campinas, Campinas, 105 p., 2007.

MENDES, A. H. D. L.; DIONÍSIO, A. P.; MOUTA, C. F. H.; ABREU, F. A. P. D.; PINTO, C. O.; GARRUTI, D. D. S.; ARAÚJO, I. M. Sensory acceptance and characterization of yoghurt supplemented with yacon syrup and cashew apple extract as a source of bioactive compounds. **Brazilian Journal of Food Technology**, v. 22, 2019. DOI: https://doi.org/10.1590/1981-6723.15318

MOLIS, C.; FLOURIÉ, B.; OUARNE, F.; GAILING, M. F.; LARTIGUE, S.; GUIBERT, A.; BORNET, F.; GALMICHE, J. P. Digestion, excretion, and energy value of fructooligosaccharides in healty humans. **The American Journal of Clinical Nutrition**, v. 64, p. 324-328, 1996.

OLIVEIRA, F. L.; VENTURIM, C. H. P.; SILVA, D. M. N.; QUARESMA, M. A. L.; DALVI, L. P. Mulches for yacon cultivation. **Horticultura Brasileira**, v. 36, p. 389-394, 2018.

OLIVEIRA, L. F.; CORRÊA, J. L.; SILVEIRA, P. G.; VILELA, M. B.; JUNQUEIRA, J. R. D. J. Drying of ‘yacon’pretreated by pulsed vacuum osmotic dehydration. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 25, n.8, p. 560-565, 2021.

OLIVEIRA, L. A. **Yacon (*smallanthus sonchifolius*): compostos fenólicos totais e efeitos sobre a glicemia e estresse oxidativo em ratos diabéticos**. Dissertação de Mestrado em Ciências Nutricionais. Faculdade de Ciências Farmacêuticas, Universidade Estadual Paulista “Júlio de Mesquita Filho”, Araraquara, 99 p., 2010.

PADILHA, V. M.; ROLIM, P. M.; SALGADO, S. M.; LIVERA, A. S.; ANDRADE, S. A. C.; GUERRA, N. B. Perfil sensorial de bolos de chocolate formulados com farinha de yacon (Smallanthus sonchifolius). **Ciência e Tecnologia de Alimentos**, Campinas, v. 30, n. 3, jul./set. 2010.

PEREIRA, R. A. C. B. **Extração e utilização de frutanos de yacon (*Polymnia sonchifolia*) na funcionalização de alimentos**. Tese de Doutorado em Agronomia (Energia na Agricultura). Faculdade de Ciências Agronômicas, Universidade Estadual Paulista “Júlio de Mesquita Filho”, Botucatu, 154 p., 2009.

PRPICH, P. N.; SANABRIA, E.; GLIEMMO, M. F.; CAYRÉ, M. E.; CASTRO, M. P. Suco de yacon como meio de cultivo e crioprotetor para cepas autóctones de *Latilactobacillus sakei* e *Staphylococcus vitulinus*. **Brazilian Journal of Food Technology**, v. 26, 2023. p. 1-11.

QUINTEROS, E. T. T. **Produção com tratamento enzimático e avaliação do suco de yacon**. Tese de Doutorado em Tecnologia de Alimentos. Faculdade de Engenharia de Alimentos, Universidade Estadual de Campinas, Campinas, 163 p., 2000.

R DEVELOPMENT CORE TEAM. **R: A language and environment for statistical computing.** R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL <http://www.R-project.org/>. 2011.

REIS, F. R.; LENZI, M. K.; MUÑIZ, G. I. B.; NISGOSKI. S.; MASSON. M. L. Vacuum Drying Kinetics of Yacon (*Smallanthus sonchifolius*) and the Effect of Process Conditions on Fractal Dimension and Reihydration Capacity, **Drying Technology**, v.30: n.1, p.13-19,

RODRIGUES, F. C.; CASTRO, A. S. B.; MARTINO, H. S. D.; FERREIRA, C. L. DE L. F. Farinha de yacon (*Smallanthus sonchifolius*): produção e caracterização química. **Revista Do Instituto Adolfo Lutz**, v.70, n.3, p. 290–295,2011.

ROLIM, P. M.; SALGADO, S. M.; PADILHA, V. M.; LIVERA, A. V. S.; ANDRADE, S. A. C.; GUERRA, N. B. Glycemic profile and prebiotic potential “in vitro” of bread with Yacon (Smallanthus sonchifolius) flour. **Ciência e Tecnologia de Alimentos**, Campinas, v. 31, n. 2, p. 467-474, abr./jun., 2011.

SALES, R. L.; COSTA, N. M. B. Yacon: aspectos nutricionais, tecnológicos e funcionais. In: COSTA, N.M.B.; ROSA, C.O.B. **Alimentos funcionais: componentes bioativos e efeitos fisiológico***s*. 1ª ed. Rio de Janeiro (RJ): Ed. Rúbio; p. 229-239, 2010.

SANTANA, I.; CARDOSO, M. H. Raiz tuberosa de yacon (S*mallanthus sonchifolius*): potencialidade de cultivo, aspectos tecnológicos e nutricionais. **Ciência Rural**, v.38, n. 3, p. 898-905, mai./jun. 2008.

SCHER, C. F.; RIOS, A. O.; NOREÑA, C. P. Z. Hot air drying of yacon (*Smallanthus sonchifolius*) and its effect on sugar concentrations. **International Journal of Food Science and Tecnolog*y***, v. 44, p. 2169-2175, 2009.

SILVA, M. F. G.; DIONÍSIO, A. P.; CARIOCA, A. A. F.; ADRIANO, L. S.; PINTO, C. O.; ABREU, F. A. P.; WURLITZER, N. J.; ARAÚJO, I. M.; GARRUTI, D. S.; PONTES, D. F. Yacon syrup: Food applications and impact on satiety in healthy volunteers. **Food Research International**, v. 100, p. 460-467, 2017.

SUÁREZ, D. F. T.; LIMA, L. L. D. A.; STAMFORD, T. C. M.; SILVA, D. C. D.; SANTOS, T. G.; LIMA, G. S. D.; Padilha, V. M.; STAMFORD, T. L. M. Physicochemical and sensorial characterization of yacon mixed juice with bioactive properties. **Ciência Rural**, v. 52, n.6, 2021.

VASCONCELOS, C. M. **Caracterização físico-química e sensorial de iogurte *“light”* com farinha de yacon (*Smallanthus sonchifolius)***. Dissertação de Mestrado em Ciência e Tecnologia de Alimentos. Universidade Federal de Viçosa, Viçosa, 56 p., 2010.

VASCONCELOS, C. M.; SILVA, C. O.; TEIXEIRA, L. J. Q.; CHAVES, J. B. P.; MARTINO, H. S. D. Determinação da fração da fibra alimentar solúvel em raiz e farinha de yacon (*Smallanthus sonchifolius*) pelo método enzimatico-gravimetrico e cromatografia liquida de alta eficiência. **Revista do Instituto Adolfo Lutz**, v. 69, n. 2, p. 188-193, 2010.