

Article

Partial Replacement of Maltodextrin by Sweet Potato Flour (*Ipomoea Batatas* L. Lamarck) in the Development of a Shake Beverage

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Abstract: Sweet potato flour contains low-glycemic complex carbohydrates and, when it is ingested, prevents insulin spikes and prolongs the feeling of satiety. The aim of this study was to elaborate and to verify the acceptability of the shake with the total or partial substitution of maltodextrin for sweet potato flour. To elaborate the shake beverage, we used a 2² factorial design, with three central points, thus generating seven formulations. For the taste, color, texture, appearance, acceptance and attitude of purchase properties, sensory tests were conducted using a nine-point hedonic scale and panelists ($n = 50$). The highest acceptability formulations, formulations 3 (10% sweet potato flour; 25% maltodextrin) and 7 (0% sweet potato flour; 25% maltodextrin), were submitted to pH, moisture, ash, protein, lipid, crude fiber and total carbohydrate analyses. The statistical difference between the formulations from the T test ($p < 0.05$) was verified for the moisture, ash and lipid parameters. Formulation 3 presented higher values of moisture (93.26 ± 0.57) and lipids (1.91 ± 0.01), and formulation 7 had higher values of ash (0.39 ± 0.01). The results of the sensorial and physicochemical analyses of the shake indicate that sweet potato flour shows potential for the elaboration of this drink.

Keywords: carbohydrates; sensory evaluation; shake beverage; factorial design approach; hedonic scale; low-glycemic

1. Introduction

Sweet potato (*Ipomoea batatas* L. Lamarck) is the main tuber root cultivated in Brazil due to high tolerance to drought and offers a wide adaptation to the climate and land [1]. According to the Food and Agriculture Organization (FAO) statistics, the world's production of sweet potatoes in 2016 was concentrated in Asia and Africa [2]. It is considered one of the main sources of food, animal feed and raw material for the industry. In the development of food, sweet potato is widely used in the extraction of starch but is little explored in beverage preparations [3].

This tuberous root is rich in starch and other nutrients [4]. Sweet potato has a composition of high value to the human diet, which is important in meeting human nutritional needs such as carbohydrates, fibers, potassium, vitamins A and C and high-quality protein. Sweet potato is consumed in different ways; it is boiled, baked, fried or mashed. It can also be used for the preparation of breads and starch in the industry [5,6].

Some studies have been carried out to further the development of carbohydrate solutions for athletes, with a view to improving performance during long-term physical activities besides an increase in glycemic levels [7–10]. One of the energetic supplements used in this field is maltodextrin, which is a saccharide-based polymer containing D-glucose units linked by glycoside bonds, which is an easily absorbed carbohydrate that is obtained from the partial hydrolysis of starch. It is beneficial to athletes, for example, when running, playing soccer or tennis, as it provides energy during training [11,12]. In conformity with the benefits mentioned above, energy drinks are also marketed as an option for people who are not athletes but are looking for a way to decrease tiredness and boost energy, enabling weight loss and enhancing mental alertness [13].

Sports drinks can be ingested before, during and after exercise. When ingested before exercise, they can prevent or even delay homeostatic disorders that can accompany physical activities [14]. In addition, pre-exercise consumption can improve the circulation of blood glucose concentrations through the supply of carbohydrates. When sports drinks are consumed during exercise, the carbohydrates can improve performance, as demonstrated by Carter et al. [15].

The consumption of carbohydrate and protein supplements is recommended by the Brazilian Society of Sports Medicine, aiming to favor a maximum resynthesis of muscular and hepatic glycogen [16]. Ballistreri et al. [17] performed a study to establish the drinking pattern of energy drinks among physical education students from an institution in Argentina. Most of these drinks contain ingredients such as taurine, caffeine and vitamins. Considering that the potential risks of energy drink consumption can be increased when consuming them concomitantly with, for example, alcohol, the results denote the importance of reducing consumption among young people and also reinforce the importance of adequate eating to achieve good performance in any physical activity.

It is due to these concerns that the shake beverage is presented as an alternative product. It is easy-to-prepare and also aids in gym training by providing energy. It is also a natural food source and a natural product, thus lowering the chances of causing complications in consumers. To further increase the applicability of sweet potato as a major source of carbohydrates, in this study, we tested sweet potato flour as a partial replacement for maltodextrin in a shake beverage.

2. Methodology

2.1. Sweet Potato and Sweet Potato Flour

Sweet potatoes (*Ipomoea batatas* L. Lamarck) were kindly provided by the Department of Agronomy, State University of the Center-West (Parana, Brazil)-CEDETEG Campus (Parana, Brazil).

The tubers were selected, washed, weighted and grated. Thereafter, the samples were dried in a drying oven at 65 °C for 24 h. After drying, the samples were crushed and processed to obtain sweet potato flour [18].

2.2. Preparation of Shake Beverage

The shake beverage was elaborated and one batch was made from a formulation that uses maltodextrin as a basis for the determination of the percentages of the other ingredients in the shake (Table 1). The original shake beverage formulation was modified by the addition of sweet potato flour at different concentrations according to a 2² factorial design with three central points, thus generating 7 formulations (Table 1).

The other ingredients used in the shake beverage formulation were, as fixed parts, xanthan gum Aminna[®] (2.50%), refined sugar União[®] (35.00%), grape flavoring hydroalcoholic artificial aroma Duas Rodas[®] (0.05%), purple artificial liquid dye Duas Rodas[®] (0.10%), whole milk integral powder Sancor[®] (21.00%); and as variable parts: sweet potato flour (10.00 and 20.00%) and grape flavor commercial maltodextrin Body Action[®] (5.00 and 25.00%). The ingredients in maltodextrin are maltodextrin, citric acid (acidulant), tricalcium phosphate (acidity regulator), caramel dye, sucralose (sweetener), bordeaux dye and indigotine blue dye.

Table 1. The 2² factorial design, with three central points, for the addition of sweet potato flour in the formulation development.

Formulations	Variables	
	Sweet Potato Flour	Maltodextrin
1	+1 (20%)	-1 (5%)
2	+1 (20%)	+1 (25%)
3	-1 (10%)	+1 (25%)
4	-1 (10%)	-1 (5%)
5 (C) ¹	0 (15%)	0 (15%)
6 (C) ¹	0 (15%)	0 (15%)
7 (C) ¹	0 (15%)	0 (15%)

(C)¹ represents the central point.

2.3. Proximate Composition of Sweet Potato Flour

The protein (Kjedahl, N × 6.25 for flour), ash (gravimetric), lipid and fiber brut contents of sweet potato flour were determined using AOAC 2005 methods [19]. The total carbohydrate content was calculated as the difference between the initial mass of the sample (100 g) and the total mass of the proteins, lipids, fixed mineral residues and fibers.

2.4. Physicochemical Analysis

All analyses were performed for sweet potato flour and the shake beverage. The moisture content analysis was performed through the adaptation of the method in [20], by drying the samples in a conventional oven at 105 °C for 8 h. The pH was evaluated by direct measurements through a potentiometer (bench thermometer for aqueous solutions Mpa-210, Tecnoyon) of the samples prepared in a solution at a 1:10 (w/v) ratio with distilled water before using the potentiometer.

The colorimetric analysis [21] was performed only for the shake drink, using CIELAB color system L* a* b* and colorimeter (Konic Minolta CR-400) with illuminant C and a 10° angle that was previously calibrated. The parameters analyzed in triplicate were: L* (lightness) where L* = 0 means black and L* = 100 means white, for a* and b* (set as chromaticity) where +a* means red and −a* means green; −b* means blue and +b* means yellow [22].

The particle size of the flour was determined with a system consisting of five sieves. The mesh opening diameters of the sieves were: 10 (nominal aperture of 2.00 mm), 12 (nominal aperture of 1.68 mm), 14 (nominal aperture of 1.41 mm), 35 (nominal aperture of 0.500 mm) and 48 (nominal aperture of 0.300 mm).

2.5. Sensory Evaluation

This part of the study was approved by the Ethics Committee in Research of the State University of the Center-West (Parana, Brazil) under the project identification code no. 81426725. The sensory analysis was performed by 50 panelists, comprising students from the CEDETEG Campus of the State University of the Center-West. Two methods were chosen for the sensory evaluation of the formulations. The acceptance test [23] was conducted to assess whether the panelists liked the appearance, flavor, color and texture of the shake beverage, applying the 9-point hedonic scale categorized as 9 “like extremely”; 8 “liked”; 7 “liked moderately”; 6 “liked slightly”; 5 “neither liked nor disliked”; 4 “dislike somewhat”; 3 “dislike moderately”; 2 “dislike very much”; and 1 “dislike extremely” to express their overall impression. The formulations that obtained higher acceptance levels were submitted to physicochemical analysis. The purchase intent test was measured using a five-point structured scale (from 1 = definitely would not buy to 5 = definitely would buy) adapted from [24,25].

The samples were prepared with 10 g of shake powder added to 100 mL of cold water at 6 °C. Each panelist received seven samples of approximately 50 mL of the shake beverage presented in

plastic cups which were previously coded with three-digit random numbers. The panelists evaluated the samples from left to right and cleansed their palate with water between samples.

2.6. Statistical Analysis

Results are expressed as mean and standard error of the mean. Differences between formulations were analyzed using ANOVA, followed by the Tukey test or Student test, with $p < 0.05$ considered significant. All analyses were performed using the Assisat Software version 7.7 beta (DEAG-CTRN-UFCEG, Pernambuco, Brazil) [26].

3. Results and Discussion

3.1. Proximate Composition

3.1.1. Shake Formulation

Formulations 3 and 7 were deemed the most acceptable formulations by the panelists. Thus, physicochemical analyses were only performed for these formulations (Table 2).

Between formulations 3 and 7, the results of moisture, ash and lipid parameters showed no statistical differences. However, formulation 3 presented higher values of moisture and lipids compared with formulation 7. On the other hand, ash content presented higher values in formulation 7 than in formulation 3. It was not possible to find values for the physicochemical analyses of the shake beverage formulations using sweet potato in any forms for comparison. To date, no shake beverages based on sweet potato flour were found.

Table 2. pH, moisture, ash, protein, lipid, fiber and total carbohydrate values for the shake beverage produced with sweet potato flour.

Formulation	pH	Moisture	Ash	Protein	Lipid	Fiber	Carbohydrats
3	7.34 ± 0.01a	93.26 ± 0.57a	0.35 ± 0.01b	0.17 ± 0.01a	1.91 ± 0.01a	0.23 ± 0.04a	97.34 ± 0.75a
7	7.32 ± 0.01a	91.80 ± 0.04b	0.39 ± 0.01a	0.17 ± 0.01a	1.70 ± 0.03b	0.27 ± 0.09a	97.47 ± 0.11a

Data represent mean values for each formulation mean and standard error of the mean. Means followed by different lowercase letters in the same column show statistical difference between formulations ($p < 0.05$). The results are presented in % (*w/v*) with the exception of pH.

3.1.2. Sensory Evaluation

The development of the shake beverage with the partial or total replacement of maltodextrin showed statistical differences in the sensory evaluation of all analyzed items. The panelists did not like the formulations in which the concentration of sweet potato flour was 25%. The best scores were obtained for the formulation containing 10% sweet potato flour (Table 3).

The highest values for sensory acceptance were found for formulations 3 and 7, based on the appearance, overall acceptance and shake texture (Figure 1A). Regarding the intention of purchase test, there were higher values in the intention to buy for formulations 3 and 7 (Figure 1B), where formulation 3 contains 10% sweet potato flour and formulation 7 contains 15% maltodextrin. These results show the possibility of developing this product with good acceptance values.

Table 3. Results per sensory attribute of the shake beverage with the partial replacement of maltodextrin with sweet potato flour.

Formulations	Appearance	Aroma	Flavor	Texture	Color	Overall Acceptance	Purchase Intent
1	4.84 ± 1.76bc	5.64 ± 1.52bc	4.74 ± 1.98cd	5.28 ± 1.96b	4.56 ± 1.97bc	4.70 ± 1.75d	2.44 ± 1.11bc
2	5.06 ± 1.77bc	5.98 ± 1.58abc	5.32 ± 2.00bc	5.56 ± 1.75b	4.84 ± 1.81bc	5.36 ± 1.84 c	2.86 ± 1.15ab
3	5.26 ± 1.90 b	6.38 ± 1.38ab	6.28 ± 1.69ab	6.18 ± 1.57ab	5.24 ± 1.96b	6.62 ± 1.51ab	3.36 ± 1.03a
4	5.04 ± 1.72bc	5.62 ± 1.58bc	5.10 ± 1.75cd	5.74 ± 1.72ab	4.90 ± 1.95bc	5.64 ± 1.46bc	2.72 ± 1.22abc
5	5.14 ± 1.81bc	5.84 ± 1.59bc	5.32 ± 1.89bc	5.76 ± 1.66ab	4.98 ± 1.93bc	5.30 ± 1.81c	3.08 ± 1.10ab
6	4.22 ± 1.84c	5.20 ± 1.68c	4.18 ± 1.83d	5.16 ± 2.07b	4.12 ± 2.20c	3.98 ± 1.80d	2.04 ± 1.07c
7	7.20 ± 1.03a	6.86 ± 1.38a	6.52 ± 1.59a	6.76 ± 1.30a	7.20 ± 1.20a	6.66 ± 1.62a	3.34 ± 1.65a

Data represent mean values for each formulation mean and standard error of the mean. Means followed by different lowercase letters in the same column show statistical difference between formulations ($p < 0.05$).

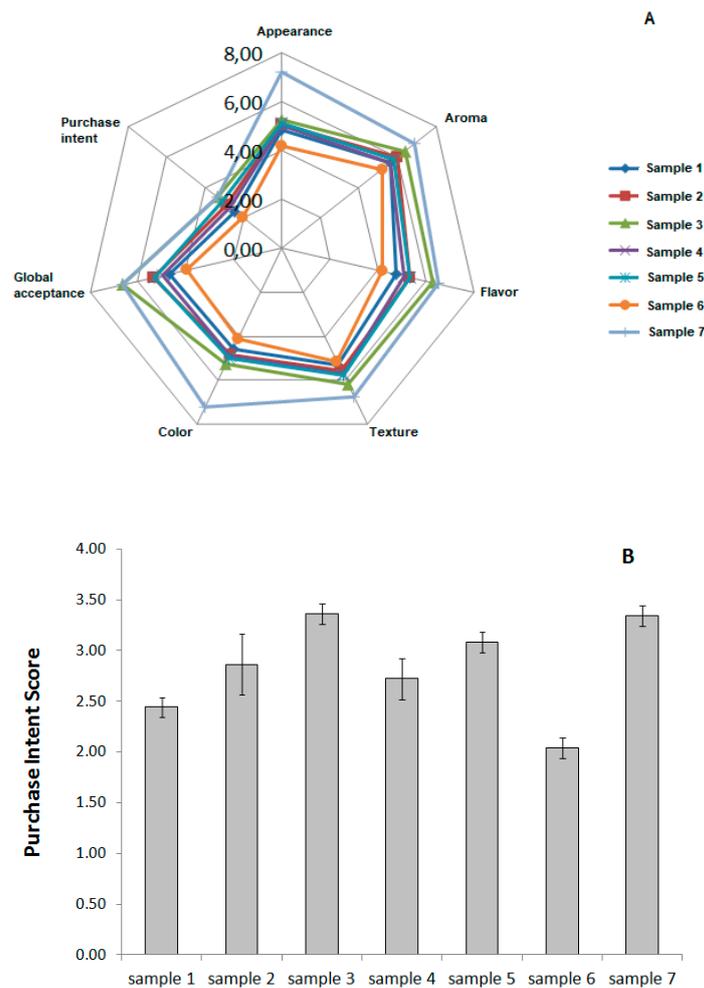


Figure 1. Sensory profile analysis of the shake beverage formulation tested. (A) Histogram sensory evaluation-purchase intent test (B).

3.1.3. Sweet Potato Flour

In Table 4, we present the results of the proximate composition for sweet potato flour. Bezerra et al. [18] elaborated cereal bars with added sweet potato flour. In the pH, moisture, lipid and reducing sugars content analyses, they found 6.07, 8.87, 9.18 and 71.17%, respectively. When comparing those values with the result obtained in this study, there are similarities except for the moisture content, which shows a great difference that can be justified by the botanical origin of the sweet dressing and physical conditions of the raw material.

Table 4. Sweet potato flour proximate composition.

pH	Moisture	Ash	Protein	Lipids	Fiber	Carbohydrates
7.13 ± 0.01	7.13 ± 0.01	1.67 ± 0.03	9.42 ± 0.33	8.21 ± 0.01	2.33 ± 0.11	65.90 ± 0.01

Data represent mean values mean and standard error of the mean. The results are presented in % (*w/v*) with the exception of pH.

Van Hal [27] presented an overview of the information on the processing and storage of sweet potatoes from different sources. In that study, for moisture content, the values were between 4.3 and 13.2%. The results obtained in this study fall within this range. Of the protein content values related in Van Hal's study, the closest value to those obtained in this study is 8.5%. Regarding the total carbohydrate content, the maximum value reported in [27] was 94.1%, whereas we report 65.9%.

3.1.4. Physicochemical Analysis

The parameters of the colorimetric analysis for the shake beverage were $L^* = 3994 \pm 0.06$, $a^* = -1.92 \pm 0.02a$ and $b^* = 1.80 \pm 0.0a$ for formulation 3, and $L^* = 44.65 \pm 0.09a$, $a^* = -0.83 \pm 0.0b$ and $b^* = 1.74 \pm 0.02a$ for formulation 7. Regarding the physicochemical results, it was verified that L^* (lightness) was lighter in formulation 7 compared with formulation 3.

Visually, formulation 7 presented a light purple coloration in contrast to formulation 3 which showed a darker purple coloration. This might be due to the variety of sweet potatoes that were used at the time or in harvest, since they had a purplish pulp, or this may even be related to the antioxidant content. In Table 5, the values regarding the particle size of the flour are shown. The particle size of the flour retained in the final vessel after passing through the last sieve (48) had a size of 300 microns.

Table 5. Particle size distribution of sweet potato flour.

Sieves (mesh)	Retained Portion (g)
10	15
12	20
14	30
35	40
48	20
Final Vessel	75

Data represent the mesh for each sieve in the system approach. Means the sweet potato flour portion in each sieve.

4. Conclusions

According to the results of the sensory analysis, shakes containing 10% sweet potato flour and those with 25% maltodextrin obtained higher scores from the panelists, a greater global acceptance and greater purchase intention. For the appearance, aroma, flavor, texture and overall impression, the values obtained were higher than 5, which denotes "good acceptance".

Sweet potato flour can be used as a raw material in the development of the shake. No statistical differences were found between the formulations in most analyses. For this reason, we consider maltodextrin as a suitable replacement for sweet potato flour, which, in addition to reducing the

final value of the product, is also a low-cost raw material. The replacement of maltodextrin for sweet potato flour is a credible alternative for shakes. According to the sensory evaluation, the replacement had good acceptance values from the panelists, showing that the production of this shake is feasible considering the taste and also a good alternative drink for people who practice physical activities.

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