Partial substitution of wheat flour with orange sweet potato flour (*Ipomoea batatas*) and its effect on the bromatological and sensory properties of sweet cookies

Sustitución parcial de harina de trigo por harina de camote naranja (*Ipomoea batatas*) y su efecto en las propiedades bromatológicas y sensoriales de galletas dulces

Substituição parcial da farinha de trigo pela farinha de batata doce de laranja (*Ipomoea batatas*) e seu efeito nas propriedades bromatológicas e sensoriais de biscoitos doces

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Rev. Fac. Agron. (LUZ). 2024, 41(3): e244125
ISSN 2477-9407
DOI: https://doi.org/10.47280/RevFacAgron(LUZ).v41.n3.05

Received: 20-05-2024
Accepted: 16-07-2024
Published: 06-08-2024

Food technology
Associate editor: Dra. Gretty R. Ettiene Rojas
University of Zulia, Faculty of Agronomy
Bolivarian Republic of Venezuela.

Keywords:
Sweet potato
Cookies
Ipomoea batatas
Texture profile
Tubers

Abstract

The objective of the research was to evaluate the partial substitution of wheat flour with orange sweet potato flour (Ospf) in the preparation of sweet cookies. A completely randomized design with a factorial arrangement was applied. The factor under study corresponded to the concentrations of Ospf (10, 20, and 30 %) plus a control treatment. Bromatological parameters, texture, and sensory profile were evaluated. The LSD Fisher and Kruskal Wallis multiple comparison tests were used at 5 % significance. The proximate composition of the orange sweet potato flour presented in protein 3.99 ± 0.02 %; moisture 8.65 ± 0.00 %; dry matter 91.34 ± 0.06 %; ash 4.24 ± 0.00 %; pH 6.41 ± 0.01; acidity 0.69 ± 0.01 % and particle size 354 ± 0.02 µm. In the processed products (sweet cookies), except for the energy parameter, the other bromatological variables presented statistical significance ($p<0.05$). Regarding the texture profile, the parameters hardness, brittleness, and adhesive force were significantly different ($p<0.05$) between the treatments, while, for adhesiveness, cohesiveness, gumminess, elasticity, and chewiness a $p>0.05$ (no significant) was obtained. At the sensory level, the untrained tasters expressed the acceptability of "I neither like it nor dislike it" in the attributes, flavor, smell, texture, and consistency; however, in color, the formulations with the factor under study presented greater acceptance. The sweet cookies met the requirements established in the INEN 2085 reference standard for cookies.

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Resumen

La investigación tuvo como objetivo evaluar la sustitución parcial de harina de trigo por harina de camote naranja (Hcn) en la elaboración de galletas dulces. Se aplicó un diseño completamente al azar con arreglo factorial. El factor en estudio correspondió a las concentraciones de Hcn (10, 20 y 30 %) más un tratamiento testigo. Se evaluaron parámetros bromatológicos, perfil de textura y sensorial. Se emplearon las pruebas de comparación múltiple LSD Fisher y Kruskal Wallis al 5 % de significancia. La composición proximal de la harina de camote naranja presentó en proteína 3,99 ± 0,02 %; humedad 8,65 ± 0,00 %; materia seca 91,34 ± 0,06 %; ceniza 4,24 ± 0,00 %; pH 6,41 ± 0,01; acidez 0,69 ± 0,01 % y tamaño de partícula 354 ± 0,02 µm. En los productos elaborados (galletas dulces), a excepción del parámetro energía, las demás variables bromatológicas presentaron significancia estadística (p<0,05). En cuanto al perfil de textura, los parámetros dureza, fragilidad y fuerza adhesiva fueron significativamente diferentes (p<0,05) entre los tratamientos, mientras que, para la adhesividad, cohesividad, gomosidad, elasticidad y masticabilidad se obtuvo un p>0,05 (no significativo). A nivel sensorial, los catadores no entrenados, manifestaron una aceptabilidad de ni me gusta – ni me disgusta en los atributos, sabor, olor, textura y consistencia, sin embargo, en color, las formulaciones con factor en estudio presentaron mayor aceptación. Las galletas dulces cumplieron con los requisitos establecidos en la norma de referencia INEN 2085 para galletas.

Palabras clave: camote, galletas, *Ipomoea batatas*, perfil de textura, tubérculos.

Resumo

O objetivo da pesquisa foi avaliar a substituição parcial da farinha de trigo pela farinha de batata doce de laranja (Hcn) no preparo de biscoitos doces. Foi aplicado delineamento inteiramente casualizado com arranjo fatorial. O fator em estudo correspondeu às concentrações de Hcn (10, 20 e 30 %) mais um tratamento controle. Foram avaliados parâmetros bromatológicos, textura e perfil sensorial. Foram utilizados os testes de comparações múltiplas LSD Fisher e Kruskal Wallis, com nível de significância de 5 %. A composição proximal da farinha de batata doce com laranja apresentou 3,99 ± 0,02 % de proteína; umidade 8,65 ± 0,00 %; matéria seca 91,34 ± 0,06 %; cinzas 4,24 ± 0,00 %; pH 6,41 ± 0,01; acidez 0,69 ± 0,01 % e tamanho de partícula 354 ± 0,02 µm. Nos produtos industrializados (biscoitos doces), com exceção do parâmetro energia, as demais variáveis bromatológicas apresentaram significância estatística (p<0,05). Quanto ao perfil de textura, os parâmetros dureza, fragilidade e força adesiva foram significativamente diferentes (p<0,05) entre os tratamentos, enquanto, para adesividade, coesividade, gomosidade, elasticidade e mastigabilidade foi obtido p>05 (não significativo). A nível sensorial, os provadores não treinados expressaram aceitabilidade de nem gosto nem desgosto nos atributos, sabor, cheiro, textura e consistência, porém, na cor, as formulações com o fator em estudo apresentaram maior aceitação; Os biscoitos doces atenderam aos requisitos estabelecidos na norma de referência INEN 2085 para biscoitos.

Palavras-chave: batata doce, biscoitos, *Ipomoea batatas*, perfil de textura, tubérculos.

Introduction

Cookies are among the foods of mass consumption with low nutritional contribution for the consumer, however, over the years they have gained demand in their consumption by all age groups thanks to their easy affordability, storage, and transport (Arcaya Moncada *et al*., 2020). These types of products, besides having a long shelf life are ideal for including unconventional flours/powders in their formulation to improve their nutritional content, thus providing a healthier food option to the consumer. In this regard, Ahmed *et al*. (2021) indicated that 40 % of barley meal generates up to 12 % antioxidant activity, and according to Ramya and Ashwini (2020), pumpkin flour provides 36.80 µg.100 g^{-1} total carotene (on a dry basis) for cookies.

On the other hand, Colina *et al*. (2016) point out that there is a great scientific contribution in the cookie industry, however, it is necessary to include native raw materials such as tubers (foods rich in antioxidants, fibers, vitamins) which, through agro-industrial transformation into flour, can reduce production costs (considerably reducing the import of wheat) in the manufacture of cookies.

Sweet potato (*Ipomoea batatas*) is a tuber that belongs to the family *Convolvulaceae* (Barkessa, 2018), and it is grown worldwide in diverse environments, often by smallholder farmers on marginal soils, using few inputs (Adeyeye *et al*., 2016). More than 105 million metric tons are produced annually in the world, and more than 95 % of this amount in developing countries (Vásquez *et al*., 2019). In Ecuador, its production and consumption are concentrated in the rural sectors of the Coast, Sierra, and Amazon, grouped according to the color of the pulp: orange, yellow, white, and purple (Armijos *et al*., 2020). In the province of Manabí, sweet potato roots are cultivated in about 396 ha approximately, which produced 1266 $t.year^{-1}$ in 2008, reflecting a productivity of 3.19 $t.ha^{-1}$ (Motato Alarcon *et al*., 2016).

Dietary fiber, carbohydrates, vitamin A (as β-carotene), vitamin B6, vitamin C, copper, manganese, potassium, and iron are found in the tuber of *I. batatas* (Mohammed *et al*., 2021). Additionally, it has anticancer, cardiovascular, anti-inflammatory, antitumor, antimicrobial, and antioxidant properties, which protect against neuronal degeneration, liver damage from alcoholic beverages, and kidney failure (Carrera *et al*., 2021).

Indeed, sweet potato has a variety of bioactive compounds of importance for human health, however, this raw material is an Andean crop that over time in Ecuador has been relegated by other more profitable ones or, in turn, due to the lack of knowledge of its nutritional components, functional and physicochemical properties, and, therefore, of its use and potential applications in the food industry (Salazar *et al*., 2021). According to the above, in this study, the partial substitution of wheat flour for orange sweet potato flour and its effect on the bromatological and sensory properties of sweet potato cookies was evaluated.

Materials and methods

Trial location

The process of making sweet potato flour and cookies was developed in the Laboratory of Agroindustrial Processes, in the area of fruits/vegetables and grains/cereals of the Faculty of Agrosciences, Technical University of Manabí, Ecuador.

The physicochemical, bromatological, and microbiological analyses of the flour and the processed product (sweet cookies) were carried out in the biochemistry, bromatology and microbiology laboratories of the Faculty of Agrosciences of the Technical University of Manabí.

Raw materials

For the development of the research, the orange variety sweet potato grown in the province of Imbabura – Ecuador (Agrícola Arenas commercial brand) was used. The inputs (wheat flour, sugar, butter, baking powder, ground cinnamon, salt, and vanilla essence) required for the cookie-making process were purchased at the local Akí supermarket in the Chone canton in the province of Manabí.

Obtaining orange sweet potato flour

Orange sweet potato tubers were received, which did not present mechanical damage or the presence of fungi. Then the raw material was washed with a sodium hypochlorite solution at 20 ppm, subsequently, the respective removal of the peel was continued with a stainless steel knife.

The sweet potato was laminated using a stainless steel mandoline, which was used to obtain slices approximately 0.5 cm wide, which were dehydrated at a temperature of 50 °C for 24 hours in a dehydrator (BYR brand) with a capacity of 12 stainless steel trays.

Subsequently, the dehydrated sweet potato slices were milled in an electric mill (with stainless steel blades) for 30 minutes, and the sweet potato flour was continuously sieved in a No. 45 metal mesh sieve to obtain a particle size of 354 μm, and then the experimental material was packaged in vacuum-sealed double-sealed polyethylene plastic bags. The samples were stored at a temperature of 28 °C.

Production of sweet cookies

The reception of orange sweet potato flour, wheat, and other ingredients was carried out, subsequently, the respective weighing of raw materials and inputs established in table 1 was made. For each treatment under study, an experimental unit of 500 g of mixture was obtained for the production of sweet cookies.

The mixture of wet ingredients (butter and vanilla essence) was carried out using a hand mixer (Oster 5V 2499-013 240W brand) for two minutes, then the other dry ingredients (sugar, salt, baking powder, ground cinnamon) were added, it continued mixing for one minute, wheat flour and sweet potato flour were added to the base mixture. Subsequently, manual kneading was carried out for 10 minutes until a homogeneous dough was obtained, and it was left to rest for 5 minutes. The molding of the cookie dough continued, for this process a lamination of the dough was made using a wooden roller, followed by molds of figures (rectangular, star, circular, square) of stainless steel, each treatment under study was molded and identified.

The cookies were baked in a baking oven at a temperature of 120 °C for 12 minutes. They were then allowed to cool to room temperature, packed in vacuum-sealed polyethylene bags, and stored at a temperature of 28 °C.

Physicochemical and microbiological properties of orange sweet potato flour

For the physicochemical and microbiological analyses in sweet potato flour, the INEN 616:2015 Ecuadorian standard was taken as a reference, the following parameters established in the standard were evaluated: protein (6.24) (NTE INEN-ISO 20483), moisture and dry matter (NTE INEN-ISO 712), ash (NTE INEN-ISO 2171), pH (10 %) (NTE INEN-ISO 1842), acidity percentage of sulfuric acid (NTE INEN 521), particle size (NTE INEN 517:2013), *E. coli* (ISO 16649-1:2019), molds and yeasts (NTE INEN 1529-10).

Bromatological analysis and pH determination in sweet cookies

For the bromatological analysis of sweet cookies, the parameters established in the INEN 2085:2005 standard for cookies were considered, being the following; protein (6.25) (NTE INEN-ISO 20483), moisture and dry matter by the test method (NTE INEN-ISO 712), ash (NTE INEN-ISO 2171), fat (AOAC 2003.06), crude fiber (AOAC 962.09), nitrogen-free extract (proximal calculation), energy (calculation) and pH (potentiometric).

Texture profile analysis in sweet cookies

The texture profile analysis was performed using a texturometer (Shimadzu Universal Tester EZTest EZ-LX) which was applied to all experimental formulations. The variables analyzed were; hardness (N = Newtons), brittleness (N = Newtons), adhesiveness (J = Joules), cohesiveness, adhesive force (N = Newtons), gumminess (N = Newtons), elasticity and chewiness (N = Newtons).

Sensory analysis in sweet cookies

The sensory acceptability of the cookies was evaluated by a panel of 90 untrained judges, who were provided with a hedonic test with a scale of seven (7) points, with 1 being the lowest acceptance and 7 being the highest acceptance (1 = I dislike it a lot, 2 = I moderately

Table 1. Formulation of the treatments under study for sweet cookies.

Raw materials and inputs	Treatments							
	T0 $_{0\ \%\ Ospf}$		T1 $_{10\ \%\ Ospf}$		T2 $_{20\ \%\ Ospf}$		T3 $_{30\ \%Ospf}$	
	%	g	%	g	%	g	%	g
Wheat flour	50.0	250.0	40.0	200.0	30.0	150.0	20.0	100.0
Sweet potato flour	0.00	0.00	10.0	50.0	20.0	100.0	30.0	150.0
Sugar	27.0	135.0	27.0	135.0	27.0	135.0	27.0	135.0
Butter	22.0	110.0	22.0	110.0	22.0	110.0	22.0	110.0
Baking powder	0.4	2.0	0.4	2.0	0.4	2.0	0.4	2.0
Ground cinnamon	0.2	1.0	0.2	1.0	0.2	1.0	0.2	1.0
Salt	0.1	0.5	0.1	0.5	0.1	0.5	0.1	0.5
Vanilla essence	0.3	1.5	0.3	1.5	0.3	1.5	0.3	1.5
Total	100.0	500.0	100.0	500.0	100.0	500.0	100.0	500.0

dislike it, 3 = I slightly dislike it, 4 = I neither like nor dislike it, 5 = I slightly like it, 6 = I moderately like it, 7 = I like it a lot) taste, smell, color, texture and consistency.

Experimental design and statistical analysis

In the proposed study, a CRD (completely randomized design) was applied with a factorial arrangement, the factor under study corresponded to the concentrations of orange sweet potato flour at 10, 20 and 30 %, four treatments were formulated, including a control, with three replicates, respectively, obtaining a total of 12 experimental units (table 2).

Table 2. Treatments under study from the experimental design.

Treatments	Codes	% Orange sweet potato flour (Ospf)	Replicates
1	T_0	0	3
2	T_1	10	3
3	S_2	20	3
4	S_3	30	3

For data processing, the InfoStat statistical software version 2020 was used. For the bromatological data of the cookies, an analysis of variance and Fisher's least significant difference (LSD) method for multiple comparisons at 95 % confidence and 5 % significance were applied. In the case of sensory panel data, non-parametric ANOVA and Kruskal Wallis tests were used at 95 % confidence and 5 % significance. Results were expressed as mean ± standard deviation.

Results and discussion

Physicochemical and microbiological properties in orange sweet potato flour

Table 3 presents the results of the physicochemical and microbiological properties of orange sweet potato flour.

Table 3. Physicochemical composition and microbiological count in orange sweet potato flour (Ospf).

Physicochemical parameters	Results
Protein (%)	3.99 ± 0.02
Moisture (%)	8.65 ± 0.00
Dry matter (%)	91.34 ± 0.06
Ash (%)	4.24 ± 0.00
pH (10%)	6.41 ± 0.01
Acidity (%)	0.69 ± 0.01
Particle Size (µm)	354 ± 0.02
Microbiological parameters	**Microorganism count**
E. coli ($CFU.g^{-1}$)	0
Molds and Yeasts ($UP.g^{-1}$)	1.39 x 10

The protein content of orange sweet potato flour was 3.99 ± 0.02 %, this result is lower than that required in the INEN 616 reference standard (2015), which indicates that flours for cookies must have a minimum of 7 % protein, particularly, this parameter is controlled when the flour to be used in the production of cookies is the main component, in this study, *I. sweet potato* flour is used as a partial substitution for wheat flour, however, it is important to verify the protein content that vegetable flours can contribute to the final product. On the other hand, the moisture presented a value of 8.65 ± 0.00 %, a result that is within the maximum limit of 14.5 % moisture required by the INEN 616 reference standard (2015) for flours intended for the cookie industry.

Concerning dry matter (DM), a value of 91.34 ± 0.06 % was obtained for orange sweet potato flour. According to Sebben *et al*. (2016), DM values can vary depending on the tuber genotype, in their study they presented results of 100.0 % DM in orange-fleshed sweet potato flour.

For the ash parameter, a content of 4.24 ± 0.00 % was obtained, this value is higher than that required in the INEN 616 Ecuadorian standard (2015), which establishes a maximum of 0.8 %, the ash content can increase in tuber flours due to their high concentration of minerals.

Orange sweet potato flour had a pH value of 6.41 ± 0.01 and acidity of 0.69 ± 0.01 %, higher than that established in the INEN 616 Ecuadorian standard (2015) which requires a limit of 0.2 % acidity for flours intended for cookie products. Tortoe *et al*. (2017) reported a pH between 5.8 – 6.2 (slightly acidic) and acidity values between 0.50 – 0.84 % in 12 varieties of sweet potato flour.

The particle size of sweet potato flour is 354 ± 0.02 µm, this parameter varies according to the type of sieve used when sieving the vegetable flour.

Regarding the count of microorganisms, the flour complied with the limits required in the INEN 616 standard (2015) which establishes a maximum of 1 x 10^4 $CFU.g^{-1}$ for molds and yeasts, while for *E. coli* a minimum of <10 $CFU.g^{-1}$ is required.

Bromatological analysis and pH of sweet cookies

Table 4 shows the analysis of variance applied to the bromatological properties and pH of sweet cookies with orange sweet potato flour.

With the exception of the energy parameter, the other variables were statistically significant ($p<0.05$ %).

The protein value of sweet cookies with orange sweet potato flour presented significant results, it was determined that the treatment with the highest protein content was T0 with 8.89 ± 0.01 % and the lowest value was T3 (30 % Ospf) with 6.70 ± 0.01 %, this meant that as the partial substitution of wheat flour for sweet potato flour increases, protein levels decrease considerably, probably because tubers such as sweet potatoes have a lower protein content than cereals, however, all treatments were found to be higher than the minimum limit of 3.0 % established by the INEN 2085 standard (2005) for cookies.

The experimental formulations had a moisture content between 7.73 ± 0.16 – 6.95 ± 0.16 %, with the T3 treatment being lower (30 % Ospf). All values were within the limit required in the INEN 2085 reference standard (2005) for cookies, which indicates a maximum of 10 % moisture. Regarding ash content, sweet cookies had a value of 1.55 ± 0.01 % for T0, 1.65 ± 0.01 % (T1), 1.88 ± 0.01 % (T2), and 1.93 ± 0.01 % (T3), this parameter increased as wheat flour was partially substituted by sweet potato flour. According to Temesgen *et al*. (2015), the increase in ash in cookies may be due to the high amounts of minerals present in compound flours (sweet potato/wheat).

Table 4. Results of bromatological analysis and pH of sweet cookies.

Bromatological parameters	Treatments under study				Sig. LSD
	T0 $_{0\ \%\ Ospf}$	T1 $_{10\ \%\ Ospf}$	T2 $_{20\ \%\ Ospf}$	T3 $_{30\ \%\ Ospf}$	
Protein (%)	8.89±0.01 ^{a}	8.27±0.01 ^{b}	7.12±0.01 ^{c}	6.70±0.01 ^{d}	0.0001
Moisture (%)	7.73±0.16 ^{a}	7.08±0.16 ^{b}	7.03±0.16 ^{b}	6.95±0.16 ^{b}	0.0272
Ash (%)	1.55±0.01 ^{a}	1.65±0.01 ^{b}	1.88±0.01 ^{c}	1.93±0.01 ^{d}	0.0001
Dry matter (%)	92.26±0.16 ^{a}	92.96±0.16 ^{b}	92.91±0.16 ^{b}	93.04±0.16 ^{b}	0.0275
Fat (%)	18.33±0.04 ^{a}	18.52±0.04 ^{b}	19.06±0.04 ^{c}	20.89±0.04 ^{d}	0.0001
Crude fiber (%)	6.97±0.56 ^{a}	7.87±0.56 ^{ab}	8.47±0.56 ^{ab}	9.13±0.56 ^{b}	0.0115
NFE (%)	56.51±0.60 ^{a}	56.63±0.60 ^{a}	56.35±0.60 ^{a}	53.38±0.60 ^{b}	0.0059
Energy (kcal.g^{-1})	4.26±0.03 ^{a}	4.26±0.03 ^{a}	4.25±0.03 ^{a}	4.32±0.03 ^{a}	0.2834
pH	6.19±0.01 ^{a}	6.00±0.01 ^{b}	6.19±0.01 ^{a}	6.01±0.01 ^{b}	0.0001

Results of parametric analysis of variance and Fisher's LSD mean comparison test. Means that do not share a letter in superscripts are significantly different. NFE: Nitrogen-free extract.

The dry matter results for the sweet cookies varied between 92.26 ± 0.16 % for T0, which was considered the formulation with the lowest DM value, however, in the T3 treatment a higher value of 93.04 ± 0.16 % was determined. Lower values (88.27 ± 1.65 %) were reported by Cerón Cárdenas *et al*. (2014), for cookies with 50 % potato flour in formula.

For the fat variable, a value of 18.33 ± 0.4 % was determined for the T0 treatment (0 % Ospf), while the formulation with the highest fat content was T3 with 20.89 ± 0.04 %. Namrata Ankush and Bhagwan Kashiram (2021) obtained a fat variation between 21.73 ± 0.06 and 16.85 ± 0.04 % in the formulation of gluten-free cookies with orange sweet potato flour.

The results for crude fiber showed that adding up to 30 % of sweet potato flour in partial substitution of wheat flour increases the value to 9.13 ± 0.56 % for this nutritionally important compound, while the control cookie presented the lowest crude fiber value of 6.97 ± 0.56 %. According to Florence *et al*. (2020), crude fiber helps reduce the risk of constipation, it also serves as a functional ingredient that protects against cardiovascular disease.

The nitrogen-free extract was similar for the T0, T1, and T2 treatments whose values are (56.51 ± 0.60, 56.63 ± 0.60, and 56.35 ± 0.60 %). As for the treatment T3 was considered to have the lowest value of NFE in sweet cookies, that is, when adding 30 % of sweet potato flour, the levels of NFE decreased in the experimental product.

Mohammad *et al*. (2018) in their study of cookies with sorbitol obtained results of 64.99 % in NFE.

Regarding the pH in the sweet cookies, there was a variation between 6.00 ± 0.01 – 6.19, ± 0.01, results that are within the range established by the INEN 2085 standard (2005) which establishes a minimum of 5.5 and a maximum of 9.5.

Texture profile analysis in sweet cookies

Table 5 shows the results of the analysis of variance obtained in the texture profile properties for sweet cookies. The variables hardness, brittleness, and adhesive force were statistically significant ($p<0.05$), however, adhesiveness, cohesiveness, gumminess, elasticity, and chewiness were not significantly different ($p>0.05$).

Table 5. Texture profile parameters in sweet cookies.

Profile texture	Treatments under study				Sig. LSD
	T0 $_{0\ \%\ Ospf}$	T1 $_{10\ \%\ Ospf}$	T2 $_{20\ \%\ Ospf}$	T3 $_{30\ \%\ Ospf}$	
Hardness (N)	408.33±41.70^{a}	336.26±41.70^{ab}	302.74±41.70^{ab}	242.78±41.7^{b}	0.0130
Brittleness (N)	131.02±52.67^{a}	91.07±52.67^{b}	32.72±52.67^{c}	49.38±52.67^{c}	0.0001
Adhesiveness (J)	-0.05±0.10^{a}	-0.22±0.10^{a}	-0.01±0.10^{a}	-0.01±0.10^{a}	0.4726
Cohesiveness	3.5±2.9^{a}	3.8±2.9^{a}	4.3±2.9^{a}	1.42±2.9^{a}	0.7432
A-Force (N)	-2.29±1.58^{ab}	-1.77±1.58^{b}	-1.77±1.58^{ab}	-0.43±1.58^{a}	0.0479
Gumminess (N)	1.25±1.10^{a}	1.31±1.10^{a}	1.23±1.10^{a}	1.23±1.10^{a}	0.9999
Elasticity	0.01±0.03^{a}	0.05±0.03^{a}	0.01±0.03^{a}	0.01±0.03^{a}	0.6134
Chewiness (N)	0.02±0.10^{a}	0.20±0.10^{a}	0.03±0.10^{a}	0.03±0.10^{a}	0.5658

Results of parametric analysis of variance and Fisher's LSD mean comparison test. Means that do not share a letter in superscripts are significantly different. A-Force: Adhesive force.

The hardness of the sweet cookies was higher in the T0 treatment (0 % Ospf) with a value of 408.33 ± 41.70 N, however, the incorporation of sweet potato flour decreased the hardness values for the other treatments, T1: 336.26 ± 41.70 N; T2: 302.74 ± 41.70 N and to a lesser extent T3 (30 % Ospf) with 242.78 ± 41.70 N. The cookies with the factor under study had a lower hardness than the control treatment, probably because sweet potato flour has low levels of proteins, which play an important role in the hardness of the cookies. Kudadam Korese *et al.* (2021) reported hardness values between 1,801 and 8,879 kg in cookies composed of unpeeled orange sweet potato flour, according to the authors, variations in hardness may be subject to changes in the internal structure of the cookies that can be attributed to chemical and functional characteristics.

Sweet potato flour cookies in formula presented lower values in brittleness between 32.72 ± 52.67 N - 91.07 ± 52.67 N, as they presented lower newton force indicating a greater risk of brittleness, however, the T0 treatment presented a higher value (131.02 ± 52.67 N), which indicates that the 100 % wheat flour cookie is less prone to brittleness. According to Sayem *et al*. (2024), variations in brittleness may be due to changes in the dough's structural integrity and crumb characteristics.

The adhesive force was higher in the 100 % wheat flour cookies with a value of -2.29 ± 1.58 N, this characteristic decreased to -1.77 ± 1.58 N for T1 and T2, while, in a lower value, it was the formulation 30 % orange sweet potato flour with -0.43 ± 1.58 N. These results are lower than those published by Quoc Dat and Hong Phuong (2017) who obtained an adhesive value of 6.00 ± 0.35 N.s in cookies with coconut flour.

Sensory analysis in sweet cookies

Table 6 shows the results of the non-parametric analysis of variance.

It was established that the factor under study (Ospf) did not significantly influence ($p>0.05$) the sensory response attributes: taste, smell, texture, and consistency, however, the color attribute did present statistical significance ($p<0.05$).

Due to the fact that the color attribute presented statistical significance, the comparison of means was made according to the Kruskal Wallis test, it was determined that the T0 treatment presented the lowest acceptance with a score of 4.98 ± 1.53 and category of "I neither like nor dislike it", while the other treatments with sweet potato flour presented an acceptability of "I slightly like it" with scores between 5.30 ± 1.43 – 5.57 ± 1.32, the T1 formulation being the most accepted by untrained tasters. According to Olajumoke Olomyo *et al*. (2021), Ospf presents in its composition about 18.83 ± 0.2 $mg.100^{-1}$ g in β-Carotenes, which are responsible for the orange pigmentation in the tuber, these pigments are present in the formulation of cookies, favoring the color acceptability of the experimental product.

Conclusions

The physicochemical properties of orange sweet potato flour did not meet the standards required in the INEN 616 reference standard, however, the moisture and the count of microorganisms (*E. coli*, molds, and yeasts) were within the limits allowed by the standard.

The experimental formulations complied with the bromatological requirements established in the INEN 2085 Ecuadorian technical standard (2005), however, it was determined that by adding 30% orange sweet potato flour, crude fiber levels increased considerably in the sweet cookies.

The texture profile analysis determined similar values in the sweet cookies between the treatments for the properties of adhesiveness, cohesiveness, gumminess, elasticity and chewiness, however, in terms of hardness, brittleness, and adhesive force, the T0 treatment presented better characteristics at the level of texture.

The untrained tasters expressed an acceptance of "I neither like nor dislike it" for the attributes taste, smell, texture, and consistency, however, at the color level, the cookies with orange sweet potato flour generated a greater acceptability of "I slightly like it" by the panelists.

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Table 6. Sensory acceptability in sweet cookies.

Sensory attributes	Treatments under study				Sig. K.W.
	$T0_{0\ \%\ Ospf}$	$T1_{10\ \%\ Ospf}$	$T2_{20\ \%\ Ospf}$	$T3_{30\ \%\ Ospf}$	
Taste	$5.66±1.39^a$	$5.67±1.54^a$	$5.83±1.06^a$	$5.66±1.49^a$	0.9681
Smell	$5.13±1.46^a$	$5.57±1.32^a$	$5.49±1.18^a$	$5.30±1.43^a$	0.2293
Color	$4.98±1.53^a$	$5.60±1.50^b$	$5.63±1.17^b$	$5.76±1.24^b$	0.0012
Texture	$5.09±1.57^a$	$5.27±1.57^a$	$5.62±1.04^a$	$5.27±1.57^a$	0.2993
Consistency	$5.36±1.30^a$	$5.60±1.66^a$	$5.69±1.44^a$	$5.46±1.64^a$	0.0998

Results of non-parametric analysis and Kruskal Wallis test. Means that do not share a letter in superscripts are significantly different..

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This scientific publication in digital format is a continuation of the Printed Review: Legal Deposit pp 196802ZU42, ISSN 0378-7818.