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Research Article

Effect of the Incorporation of Virgin Coconut Oil Byproduct in the Optimization Process of a Baked Snack

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Snack consumption contributes to the prevalence of noncommunicable diseases because snacks contain high quantities of fat, sodium, and sugar. It is possible to reformulate these foods to improve their nutritional composition by incorporating coconut byproducts. This study aims to improve the nutritional profile of a snack by adding coconut flour to it. A Box–Behnken design was used to study the effects of coconut flour (40-60%), baking time (15-20 min), and temperature (140-160°C) on the physicochemical properties of the snack. There were considered response variables color aspects (L^*, a^*, b^*, C^*, and h^*), *aw*, moisture, BI, and hardness. The R^2 was over 0.73 for *aw*, moisture, a^*, and b^*; meanwhile, as for the rest of the variables, it was lower to 0.71, except for the hardness, for which the model was not significant. For that, the variables considered for the optimization were *aw*, moisture, a^*, and b^*. It was found that the moisture content and a^* and b^* values decreased as the amount of coconut flour increased. Time and temperature reduced the moisture content and the *aw* and b^* values. The optimum conditions of coconut flour amount, time, and temperature were 55.3%, 20 min, and 159°C, respectively. The result was a snack with appropriate physicochemical properties and an increase in the content of protein, fat, and ash compared to the nixtamalized corn flour; also, the principal fatty acid of the snack was the lauric acid, characteristic of the coconut. This study validates the production of a snack made with a virgin coconut oil byproduct.

1. Introduction

Snack consumption is a generalized practice by most of the population around the world; however, many snack foods include a high amount of sugar, fat, or sodium in their formulation [1]. The development of snacks may be considered the lack of nutrients in daily consumption. Therefore, snack consumption could provide nutritional and health benefits if the snack includes the correct amount of nutrients according to the rest of the diet of the consumer [2].

There are several alternatives to reduce the amount of some snack ingredients, such as modification of texture to alter the effect of sweeteners [3] or the enhancement of the perception of salty or sweet taste by modifying the particle size of sugar and salt [4–6]. The heterogeneous incorporation of salt in hot-layer snacks and hamburgers [7, 8] and the reduction of added salt [9], among others, have also been proposed to reduce the amount of sodium and sugar necessary to flavor foods.

In the case of snacks, due to their versatility, they can also be used to incorporate food byproducts, improving their nutritional content. For example, grape pomace has been incorporated into soft sweets [10], and coffee silverskin has been used as a fat replacer in cakes [11]. The incorporation of byproducts also can alter some physical characteristics of the product, for that not all the mechanisms to reduce components like sodium, fat, or sugar or to increase some nutrients may be used in the same way.

Other byproducts that contain significant amounts of nutrients are derived from coconut (*Cocos nucifera* L.). For example, the resulting flesh after obtaining the coconut water dried by different methods is used to generate a snack made of only dried coconut. The coconut showed a different behavior depending on the temperature and drying technique. The reduction in moisture and water activity (*aw*) was reached with the cabinet dryer and the pulsed fluid bed dryer, but at a higher drying temperature, the level of luminosity decreased [12].

Other examples of coconut byproducts are the pastes produced from the extraction process of coconut milk and oil that have been used to obtain a protein concentrate that showed interesting physical properties. The protein concentrate demonstrates a high capacity for emulsification, foaming, and water retention, so it can be an option for the development of food products [13].

It is important to consider that there are two types of coconut oils, distinguished by their extraction method, and this can determinate also be the characteristics of their byproduct. The extraction of virgin coconut oil (VCO) is distinguished from that of coconut oil (CO) by a lack of a subsequent refining process after the extraction. VCO can be obtained using coconut milk or the dried meat of the coconut. The most common techniques applied are wet extraction for coconut milk or the dry processing method for the meat. For the dry processing method, the meat is dried to between two to five percent moisture, and the oil is extracted using a press without applying heat. This method is commercially used due to its high performance [14].

VCO is comprised of saturated fat, especially medium-chain fatty acids (MCFAs), which contain between 8 and 12 carbons. It has been proposed that MCFAs have health benefits that are primarily associated with blood lipid levels. For example, in healthy participants, it was found that the consumption of 30 mL per day of VCO increased the levels of high-density lipoprotein cholesterol (HDLP-C), without the alteration of other parameters like weight, total cholesterol, and triglycerides [15]. Therefore, incorporating these kinds of fats and substituting other kinds of fats may be of interest for the development of foods [16].

In addition to the oil's characteristics, the protein of the coconut contains a significant amount of essential and non-essential amino acids. It is important to consider this because, after the extraction of the oil, most of this protein remains in the byproduct [13].

In this sense, some authors have reported values of 35.57-39.2 and 15.4-20.12 g/100 g, of fat and protein, respectively; in the coconut byproduct or coconut flour [17, 18]. It is because of these amounts of nutrients that coconut flour has been used to elaborate a variety of foods, including muffins [17], rusks [19], and pasta [20]. In these cases, the proximate composition was modified compared with the cereal-based version after the addition of coconut flour.

In the case of salty snacks, there are some reports of extruded second-generation snacks, in which 20 and 28% coconut flour was incorporated [18, 21], replacing cereal as the main component of the snack. One of these cereals is corn; it is considered in conjunction with rice and wheat as the main cereals for consumption worldwide. These cereals usually have a low quantity of protein but are high in carbohydrates, being one of the reasons that the modification of snack foods including other components like legumes or byproducts to reduce the lack of nutrients in the cereals has been proposed [22, 23].

There are several factors to consider when developing a snack, such as the effect of the different components included in its formulation and the processing parameters. For example, some physical characteristics, such as color values, have been used to identify quality parameters. In this case, the color variations not only indicate a modification in the quality of the product but also permit easy identification of reactions, such as nonenzymatic browning [24].

Domingo et al. [25] elaborated on an optimized version of *bukayo* (a soft coconut toffee). They identified a moderate positive correlation between *aw* and acceptability. Similarly, color parameters were strongly positively associated with acceptability. These correlations may be related to the type of product, because *bukayo* is a soft candy, with a color tendency of brown. Based on these findings, the researchers proposed that controlling these parameters can help in the design of *bukayo*.

Due to all these factors, the use of experimental designs, for example, the Box–Behnken design, may facilitate the production process of a food product [26]. This research is aimed at incorporating coconut oil byproducts into the formulation of a salty snack by applying a Box–Behnken design to obtain an optimized product version using parameters of color, water activity (*aw*), and moisture as critical response variables.

2. Materials and Methods

2.1. Raw Material. The ingredients used to elaborate the snacks included virgin coconut oil byproduct or coconut flour, nixtamalized corn flour Maseca®, and iodized sodium chloride (referred to as salt). The flours used to elaborate the snack were analyzed to evaluate the particle size distribution with the method 55-60.01 [27]. Briefly, the sieves were arranged according to the Tyler numbers from 40, 60, 80, and 100, to the collector or bottom (>0.290, 0.160, 0.125, 0.100, and <0.100 mm, respectively). 50 g of each flour was placed on the mesh 40 and allowed to agitate for five minutes in a Ro Tap equipment (Advantech Manufacturing, USA). After, the flour retained on each sieve was weighed. This weight represents the percentage of the particle distribution.

The proximate composition was analyzed with different techniques [28]. The process to obtain the coconut flour is described in the next section.

2.1.1. Coconut Oil Byproduct Flour. To obtain coconut flour, coconuts of the *Alto Pacifico 2* cv species from Yucatan, Mexico, with 12 months of maturity were used. The endosperm of the coconut was ground (Urschel, Comitrol Processor® model 3600, Valparaiso, IN, USA) and dried at 50°C (convection oven Enviro-Pak, Micro-Pak, series MP500, Clackamas, OR, USA) until it reached a moisture content of 3.70 ± 1.27%. After that, the oil was extracted by applying a pressure between 160.45 and 237.07 kg/cm^2 for 10 min using a hydraulic Carver® press Model 3851-0 (Wabash, IN, USA). The resulting paste was recovered and frozen at −10°C, milled using an Osterizer® blender for 35 s in portions of 40 g each, and stored at −10°C.

2.2. Preliminary Design. A 2^k factorial experimental design was used to establish the minimum and maximum coconut : nixtamalized corn flour ratio and the initial baking temperatures and times. In this initial experiment, the effects of time of bake and coconut flour proportion were explored, with limits of 150-300 s and 20-50%, respectively, as minimum and maximum, baked at 230°C. The times and temperatures were selected according to an investigation by Kayacier & Singh [29], in which the same brand of nixtamalized corn flour was used and baked as the cooking process of tortilla chips. Because there were no identified other works in which coconut flour was a factor, and the process of elaboration was similar, these parameters were considered.

After analyzing the results, it was identified that the effect of the combination of variables was not significant for color and water activity ($p > 0.05$), and only the coconut flour had a significant enhancing effect over L^*, and reducing the effect of a^*, C^*, and h^* (data not shown). Because the reduction of *aw* was one of the objectives of this initial experiment, other temperatures and times were explored.

Afterward, a baking dynamic was applied to a version of the snack with 50% coconut flour (if more quantity was incorporated, the dough turned with poor ease of handling) to establish the bake times, using a temperature of 180°C and taking samples every 2 min to measure water activity (data not shown). For this experiment, the temperature was considered because in other works, fried tortilla chips with the incorporation of byproducts were cooked in oil at this temperature [30]. According to the results, the values of *aw* were reduced to 0.289 ± 0.027 at 18 min, but the snack acquired a darker color (low L^* and positive a^* and b^* values). For that, it was necessary to reduce the temperature and increase the time of bake.

With these results, another 2^k factorial experimental design was applied to establish the definitive limits. In this experiment, temperature (120 and 150°C) and time of bake (12 and 20 min) as a minimum and maximum, respectively, and maintaining 50% of coconut flour were established as variables. It was identified that these combinations reduced *aw* to a minimum of 0.284 (according to the analysis of the model); as we want a lower *aw*, the temperature was raised lightly in the final design.

The proportions of coconut flour to nixtamalized corn flour were viable at a minimum of 40 : 60 and a maximum of 60 : 40; we want to incorporate the maximum viable. Temperatures and times lower than 140°C and 12 min, respectively, did not reduce the water activity to values under 0.5. Additionally, temperatures and times over 160°C and 20 min, respectively, burnt the snack. Therefore, these temperatures and times were not considered in the design of the subsequent experiments.

2.3. Snack Preparation. Salt (0.76 g/100 g dry matter) or an equivalent to 300/mg of added sodium (value obtained according to the sodium content of sodium chloride) was dissolved into purified water until all of the granules visually disappeared. The amount of water used to dissolve the salt and to prepare the dough was equivalent to a proportion of 1 : 1 dry matter (coconut byproduct and corn nixtamalized flour) : water. For example, if 100 g of flour was prepared, 100 g of water was used. After that, salty water was added to the coconut byproduct until all of the water was absorbed. According to the Mexican norm NOM-051-SCFI/SSA1-2010, to consider a dry food to not have sodium excess, the sodium content must not surpass 300 mg for 100 g of product [31].

Then, hydrated coconut flour and nixtamalized corn flour were mixed with the use of a hand mixer M32 Hamilton Beach® (Glenn Allen, VA, USA) with a power of 290 watts for 2 min. The resulting paste was manually integrated and allowed to repose for 30 min to hydrate. The dough was extended with a rolling pin to a thickness of 2 mm and cut using a triangular cutter of 5 cm per side. The snacks were elaborated according to the experimental design presented in Table 1.

Time, temperature, and amount of coconut flour were considered independent variables. The snacks were baked in a conventional oven (National® Mfg. Co., NE, USA) directly on aluminum trays. The elaboration process was the same for the optimized formula of the snack, except for the proportions of ingredients, baking time, and temperature (see Section 3.3).

All parameters selected for the optimization were introduced into Design Expert 7® using the preestablished optimization option, and a solution was selected with maximum desirability. The proposed solution suggested a snack with 55.34% coconut flour baked at 159°C for 20 min.

2.4. Color Measurement. The color of the raw material and the snacks was evaluated using a Chroma meter Konica Minolta CR-400 (Minolta Sensing, Inc®, Osaka, Japan) with seven repetitions. The CIELAB color system was considered, and the values of L^* (luminosity), a^* ([+red] [-green]), b^* ([+yellow] [-blue]), C^* (chroma), and h^* (hue) were obtained. With this information, the total color difference (ΔE) and the browning index (BI) were calculated by applying the following equations [32, 33]:

$$\Delta E = \sqrt{({L^*}_o - L^*)^2 + ({a^*}_o - a^*)^2 + ({b^*}_o - b^*)^2} \quad (1)$$

$$\mathrm{BI} = \frac{[100(x - 0.31)]}{0.17} \quad (2)$$

$$x = \frac{(a + 1.75L^*)}{5.645L^* + a^* - 3.012b^*)} \quad (3)$$

The subscript "$_o$" indicates the initial value of the color, or in this case, the color values of the optimized snack. The x is the chromaticity coordinate calculated from the XYZ tristimulus [34].

2.5. Proximate Composition, Fatty Acid Profile, Texture Analysis, and Water Activity Measurement. The proximate compositions of the snack and the raw material were determined according to the following techniques: free nitrogen/protein (960.52), moisture (934.01), ash (942.05), and crude fat (920.39). Total carbohydrates were calculated by difference [28].

Table 1: Box–Behnken experimental design.

Runs	Coded	Real value time (min)	Coded	Real value temperature (°C)	Coded	Real value coconut flour (%)
1	0	17.5	0	150	0	50
2	0	17.5	0	150	0	50
3	−1	15	−1	140	0	50
4	1	20	1	160	0	50
5	0	17.5	0	150	0	50
6	1	20	0	150	1	60
7	0	17.5	0	150	0	50
8	1	20	−1	140	0	50
9	0	17.5	−1	140	−1	40
10	0	17.5	1	160	−1	40
11	−1	15	1	160	0	50
12	0	17.5	−1	140	1	60
13	−1	15	0	150	1	60
14	1	20	0	150	−1	40
15	0	17.5	0	150	0	50
16	−1	15	0	150	−1	40
17	0	17.5	1	160	1	60

The fatty acid profile of the nixtamalized corn flour, coconut flour, and optimized snack was determined according to the methodology reported by Valenzuela-Melendres et al. [35] in duplicate. Briefly, the composition of the fatty acid methyl esters (FAMEs) was realized in an agilent gas chromatograph (model 7890 B, Santa Clara, CA, USA) with an autosampler and a flame ionization detector. The samples were run using hydrogen at 17 psi pressure as the carrier and nitrogen as the makeup gas. After the identification of the fatty acids by comparing with the retention times, the total was expressed as a percentage of total fatty acids.

The texture analysis was realized to determine the hardness (H) of the products. For that, it followed the methodology of Alava et al. [36] with modifications. It used a texture analyzer TA-XT2 (Stable Microsystems, Surrey, England), with a spherical-end accessory with 5.0 mm of diameter and a test speed of 1 mm s^{-1}. Individual pieces of snack were placed on the crisp fracture support rig (code TA-101), and the ball probe was allowed to penetrate the center of the snack. The results are reported in Newtons (N) as the maximum force required to break the snack. 10 measures were taken.

For the evaluation of water activity, a Rotronic Hygropalm Aw1® (Bassersdorf, Switzerland) was used with three repetitions for each sample. The sample was placed in the middle of the plate to preserve the integrity of the product in each evaluation, and the value was recorded.

2.6. Questionnaire of Snack Consumption. A questionnaire to obtain information about the habits of salty snack consumption, such as the frequency of ingestion and the factor(s) of utmost relevance for choosing a snack, was sent digitally to each participant to avoid the risk of COVID-19.

The participants were contacted via digital message, e-mail, or call, and if they were willing to participate, they were asked to respond to the questionnaire. Before answering the first question, the participant was informed of the research objective; all the information was confidential and nonidentifying. In total, 102 participants over 18 years old from different regions of Mexico were available to respond to the questionnaire.

2.7. Statistical Analysis. A 2^k factorial experimental design and an optimization Box–Behnken response surface methodology with Design Expert 7® software were used. For the other results, one-way analysis of variance (ANOVA) with the *post hoc* Tukey–Kramer test and a T-test for two samples were performed using NCSS 2021® statistical software.

3. Results and Discussion

3.1. Raw Material Characterization (Particle Size, Color Analysis, and Proximate Composition). The particle size distribution of nixtamalized corn flour was concentrated in the bottom (<0.100 mm) (43.4%), and that of coconut flour was concentrated in sieve 60 (>0.160 mm) (55.22%). These distributions indicate a difference in size, with coconut flour being larger, but regardless of this, it was possible to integrate both flours into the snack. We try to obtain the most similar particle size of coconut flour and nixtamalized corn flour to elaborate a homogeneous dough. Due to the temperature of melting near 26°C of the VCO [37], we want to avoid that due to the milling process of the coconut byproduct, the oil was melted before being incorporated into the formulation. A particle size bigger than the coconut flour [sieve 40 (>0.290 mm) (89.07%)] was not possible to integrate into the formulation because the dough was not extendable.

In other investigations, the effect of different sizes of a particle of flour was also evaluated. In the case of cookies with the addition of black soybean flour, the reduction of

Table 2: Proximate composition of raw material and optimized snack.

Proximate composition (g/100 g)	Nixtamalized corn flour	Coconut flour	Optimized snack
Crude fat	4.25 ± 0.09^{c}	44.42 ± 0.45^{a}	28.61 ± 0.09^{b}
Protein	9.30 ± 0.20^{c}	22.71 ± 0.62^{a}	16.75 ± 0.40^{b}
Ash	1.67 ± 0.29^{c}	3.75 ± 0.35^{a}	2.74 ± 0.01^{b}
Moisture	6.45 ± 0.31^{a}	3.29 ± 0.13^{b}	1.84 ± 0.16^{c}
Total carbohydrates[†]	77.42	25.83	50.06

Data is shown in percentages and mean ± standard deviation on dry basis. Total replicates: 3. [†]Calculated by difference. Different letters in the same line are significantly different ($p \leq 0.05$) with one-way analysis of variance and a post hoc Tukey–Kramer test.

particle size of the soy was proposed to enhance the quality of the cookies [38]. On the contrary, in the case of snack elaborated with corn starch and cowpea, the coarse particle size (73% over 0.420 mm) was best sensorial qualified [39].

Additionally, as seen in Table 2, coconut flour contains greater values of protein, fat, and ash than nixtamalized corn flour, similar to the one reported in other investigations [17, 18]. In contrast, the total carbohydrate and moisture contents were higher in nixtamalized corn flour.

The percentage of substitution depends on the elaboration of the different snacks. In the process of elaboration used in the present research, it was viable to substitute nearly half of the cereal base of the product with coconut flour (value obtained by the optimization process). The level of substitution by incorporating the coconut flour was higher than the one reported in other investigations, in which it was elaborated as a salty extruded snack, also including coconut flour [18, 21].

Other byproducts, such as a mixture of mango peel and roselle, were used to elaborate a corn-baked chip, but in this case, only 10% of the nixtamalized corn flour could be substituted with these byproducts. In addition, the highest amount used generated a bitter taste and poor machinability [30].

In terms of the color of raw material, the L^*, a^*, b^*, C^*, and h^* values obtained were similar for both flours for a^* and statically different for the rest of the parameters, as shown in Table 3. Also, the value obtained for ΔE was 3.74, indicating differences at glance among them [40].

3.2. Response Variables of the Box–Behnken Response Surface Design (aw, Moisture, L^*, a^*, b^*, C^*, h^*, BI, and H). Color parameters (L^*, a^*, b^*, C^*, and h^*), *aw*, and moisture were measured as response variables. The model was significant with a p value < 0.05. Additionally, the lack of fit ($p > 0.05$) in all these responses corroborates this finding (data not shown). The responses that were considered most relevant for the posterior optimization and desirability process were *aw*, moisture, a^*, and b^*, because these parameters showed a correlation coefficient (R^2) over 0.73 (Table 4), being the highest among the response variables considered. The effect of these variables is presented in posterior the sections.

The BI values were also identified as a response variable, but the obtained R^2 was under 0.56, indicating that nearly 50% of the results are not explicated by the model. For the other parameters of color (L^*, C^*, and h^*) the tendency was similar, with R^2 values of 0.5611, 0.6196, and 0.7042, respectively. The H was also measured, but the model was not significant for this variable ($p > 0.05$). This might represent that the independent variables considered for the exploration were not the ones that explain the tendency of H. The values obtained for this variable ranged between 19.14 and 37.45 N, and compared to a commercial product (13.46 ± 1.4 N), the values observed in the experimental design were higher. That is the reason why, *aw*, moisture, a^*, and b^* were considered for the posterior optimization process.

Table 3: Color parameters of both flours used to elaborate the snack.

Parameter	Nixtamalized corn flour	Coconut flour
L^*	47.93 ± 0.34^{b}	48.86 ± 0.03^{a}
a^*	-0.47 ± 0.18^{a}	-0.44 ± 0.13^{a}
b^*	7.25 ± 0.07^{a}	3.63 ± 0.07^{b}
C^*	7.27 ± 0.08^{a}	3.66 ± 0.07^{b}
h^*	93.71 ± 1.36^{b}	96.33 ± 2.29^{a}

Data is shown in mean ± standard deviation. Total measures: 7 replicates. L^*: luminosity; a^*: red to green; b^*: yellow to blue; C^*: Chroma; h^*: hue. Different letters in the same line are significantly different ($p \leq 0.05$) with a T-test for two samples.

3.2.1. Effect over Water Activity and Moisture. The effects and interactions of coconut flour amount, temperature, and time on the *aw* and moisture content of the snacks are shown in Figures 1 and 2, respectively. In addition, Table 4 shows the regression models for these response variables. Moisture content and *aw* were significantly affected by time and temperature. Time and temperature have a linear negative effect on *aw* and moisture; that is, as these two variables increase, *aw* and moisture decrease. In the case of moisture, there was a positive effect of time and temperature interaction and a positive quadratic effect of time.

The minimum observed *aw* was 0.22, while the minimum observed moisture was 2.28%. These two responses are of great relevance, as values of *aw* between 0.08 and 0.26 and moisture content lower than 1.3% were observed in other snacks [41]. Nevertheless, the snacks may be considered as low-humidity products, for that, they must have *aw* values lower than 0.85 [42]. It was established that *aw* and moisture are two important factors because they are directly related to the growth of microorganisms if the conditions are adequate.

Table 4: Statistical values and regression coefficients for moisture content, water activity, a^* value, and b^* value of the snack prepared with coconut flour.

Variable	Response			
	Moisture	Water activity	a^*	b^*
R-squared	0.9644	0.8285	0.7689	0.7317
Adjusted R-squared	0.9483	0.7890	0.6919	0.6698
Model (p value)	<0.0001***	<0.0001***	0.0009***	0.0005***
Lack of fit (p value)	0.7671	0.3455	0.4830	0.2550
A time min	<0.0001***	0.0007***	0.0290*	0.1880
B temperature °C	<0.0001***	<0.0001*	0.0028*	0.0022**
C coconut flour %	0.0467	0.6300	0.0096**	0.0008***
AB	0.0220*	NA	0.0074**	NA
AC	NA	NA	NA	NA
BC	NA	NA	NA	NA
A^2	0.0077**	NA	NA	NA
Equation	Moisture = +5.59 − 2.57*A − 3.00*B − 0.53*C + 0.90*A*B + 1.07*A^2	Water activity = +0.41 − 0.11*A − 0.17*B − 0.013*C	a* = −0.45 + 0.12*A + 0.18*B − 0.15*C + 0.22*A*B	b* = +11.90 + 0.30*A + 0.81*B − 0.93*C

NA: not analyzed; a^*: green to red; b^*: blue to yellow. Statically significant differences if $^*p \le 0.05$, $^{**}p \le 0.01$, $^{***}p \le 0.001$.

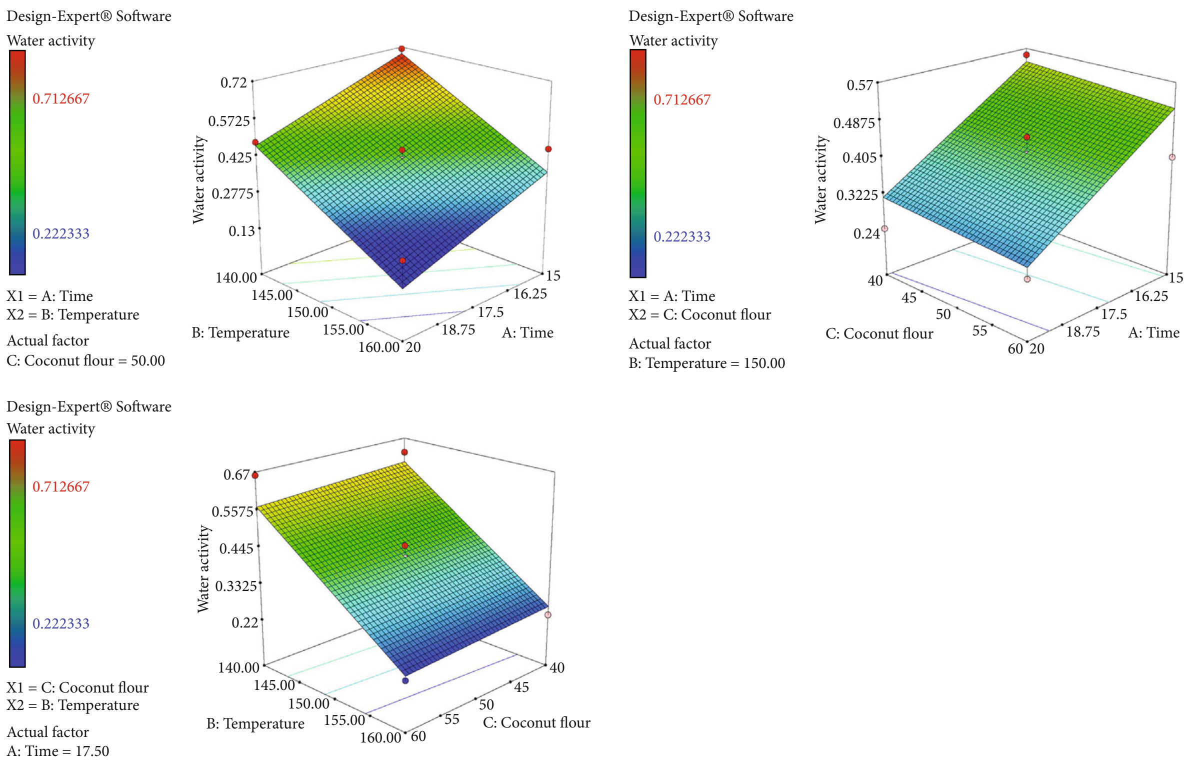

Figure 1: Contour plots of water activity. Water activity equation:$+0.41 - 0.11^{*}A - 0.17^{*}B - 0.013^{*}C$.

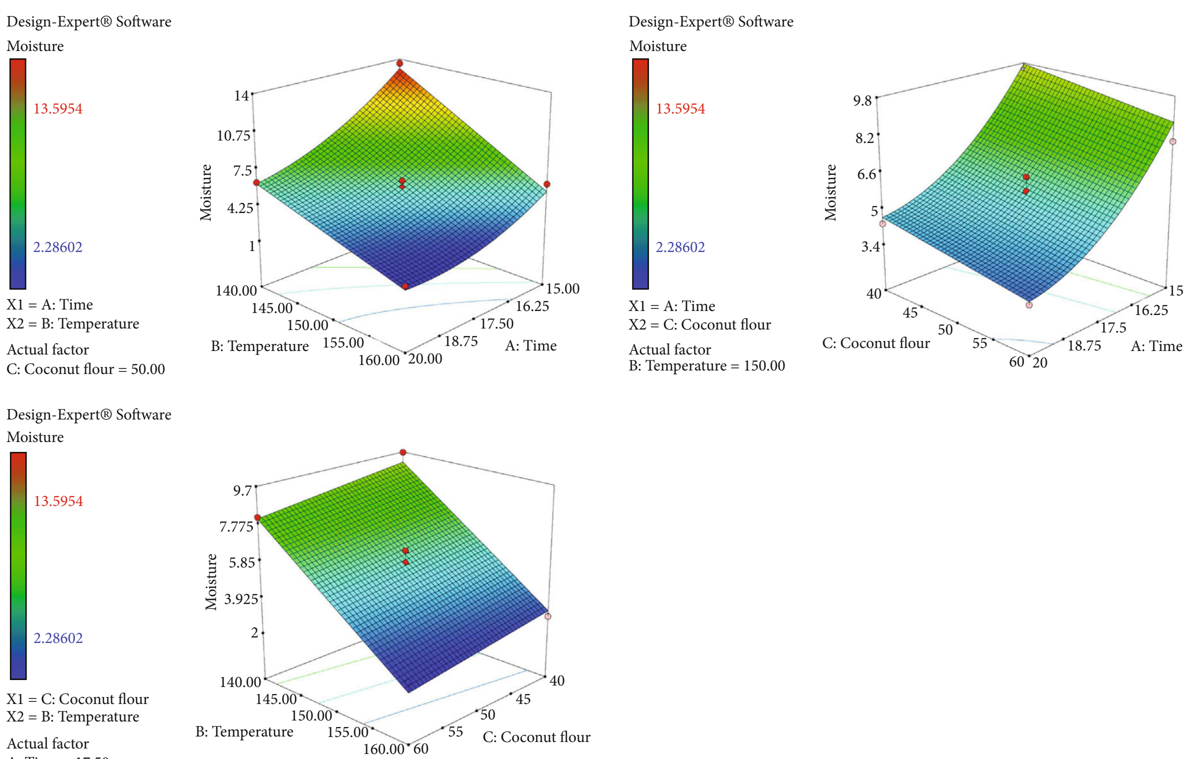

Figure 2: Contour plots of moisture. Moisture equation:$+5.59 - 2.57^{*}A - 3.00^{*}B - 0.53^{*}C + 0.90^{*}A^{*}B + 1.07^{*}A^{2}$.

A value of *aw* of 0.95 or above is sufficient for bacterial, yeast, and mold growth. With low *aw* levels, the growth of microorganisms is less, and other deterioration reactions in the food are lowered [43]. Additionally, if the aim is to elaborate on a low or reduced sodium product, it is essential to consider another mechanism to guarantee food safety.

These two factors not only affect the microbial quality of the food but also have been reported that the physical characteristics and the acceptance by consumers are dependent on them. For example, an adequate value of water activity and moisture content can provide the crispiness characteristic of salty snacks expected by consumers [44].

3.2.2. Effect over a^* and b^* Parameters. The snack color parameters a^* and b^* were affected by temperature, time, and coconut flour amount (Figures 3 and 4 and Table 4). Regarding the a^* value, a positive significant linear effect of time and temperature and a negative effect of coconut flour amount was observed. Additionally, there was a positive interaction between time and temperature. For the b^* value, only temperature had a positive linear effect, and coconut flour amount had a negative linear effect.

Interestingly, the coconut flour addition reduces both the a^* and b^* parameters, while temperature increases them. The a^* value seems to be an effect of time, so it can be expected that redness may be enhanced if the baking time is increased.

These two variables were used to calculate BI via Equation (2). Therefore, the incorporation of coconut flour into the snack formulation reduced yellowness and redness and affected BI. This result is interesting because the value of a^* tended to rise due to temperature. This effect was identified in the roasting process of rapeseed powder: as time passed, the a^* value increased and b^* remained stable [45]. Additionally, in carob powder, the increase in BI as temperature and time increased was very clear [46].

3.3. Optimization. The regression equation for each response variable was used to optimize the process variables of coconut flour amount, time, and temperature for snack elaboration. The range explored for the time was 16-20 min, that for temperature was 150-160°C, and that for coconut flour amount was 40-60% (values established in the preliminary experiments). For the goal of response values, *aw* and moisture were established as critical points (5 values of relevance), with the goal of minimizing both of them. The b^* parameter (a value of 3 of relevance) and a^* (a value of 1 of relevance) were expected to be between the minimum and maximum.

After elaborating on the optimized version of the snack, its proximate composition, water activity, and color were analyzed. As seen in Table 2, compared to the raw materials, the values of the proximate composition of the optimized snack were significantly different ($p < 0.05$). We expected this result because of the composition and the amount of the two flours used to elaborate the snack. For example, comparing the flour (coconut and corn) with the snack product, for the proximate composition, coconut flour was higher in fat, protein, and ash, and nixtamalized corn flour was higher in moisture and total carbohydrates.

The amino acid content of the protein fractions (albumin, globulin, prolamine, glutelin-1, and glutelin-2) of the coconut cake contains an important amount of essential amino acids. Among the nonessential amino acids, glutamic acid and arginine are the most abundant [47]. This is of relevance because the coconut flour after oil extraction contains important protein values (22.71%). Therefore, incorporating this byproduct into a food product can improve its nutritional characteristics.

Meanwhile, extra fat is not incorporated into the formulation of baked snacks, guaranteeing that all the lipid content of the product is provided by its ingredients. In this case, coconut flour is the primary donor of crude fat, and the principal component of this fat is lauric acid, a saturated medium-chain fatty acid [48]. Additionally, as saturated fat, the product can present resistance to rancidness [49].

As seen in Table 5, nearly 90% of the fat of coconut flour is saturated fatty acids, and lauric acid represents 43.81% of them. This tendency prevails in the optimized snack, where almost all of the fat is provided by the coconut flour, not the nixtamalized corn flour. Additionally, the principal fatty acid continues to be lauric acid. Other fatty acids present in the byproduct and in the snack are caproic, caprylic, capric, and myristic acid, all of which are saturated.

Lauric acid is the principal component of VCO, and ingestion of this oil seemed to have an antioxidant effect and a protective cardiovascular effect on a healthy group of rats [16]. Additionally, an investigation by Padmakumaran Nair et al. [50] showed that the hypocholesterolemic effect seems to be enhanced when endosperm or protein is added to the coconut oil being fed to a group of rats. Those researchers reported that this effect is due to the protein content of the coconut, which may explain why populations that usually consume the coconut with all its protein have relatively normal plasma cholesterol levels.

The effect of MCFAs on blood lipids may be associated with their absorption mechanisms and their use as an energy source. These fatty acids are absorbed and transported into the liver to be used in energy production. Therefore, most of MCFAs are stored in the liver and not in other body tissues [51].

Nixtamalized corn flour has mono- and polyunsaturated oleic acid, but in the snack, the presence of unsaturated fatty acids is significantly inferior ($p < 0.05$). This is related to the fact that nearly 90% of the fat of the snack comes from coconut flour (according to the results of the proximate analysis). Of the fat of the coconut flour, as observed in Table 5, 93.14% are saturated fatty acids. For that, the amount of saturated fatty acids in the final snack is associated with the quantity of fat provided by the coconut flour.

Concerning physical parameters, it was observed that in most of the characteristics of the snack, the values were in or near the predicted limits. The exception was the color parameter of a^*, which was inferior to the prediction (Table 6). Considering that the optimization was performed using *aw* and moisture as the most critical parameters and a^* and b^* as secondary factors, especially a^* with a value of relevance of 1, this result was not unexpected. In addition, as mentioned above, the coconut flour had a detrimental effect on a^* and b^* values, so it is important to consider that the snack contains over 50% coconut flour in its formulation.

3.4. Color Change and Browning Index. We obtained the BI and the ΔE of some of the versions of the Box–Behnken experimental design and the optimized snack (Table 7).

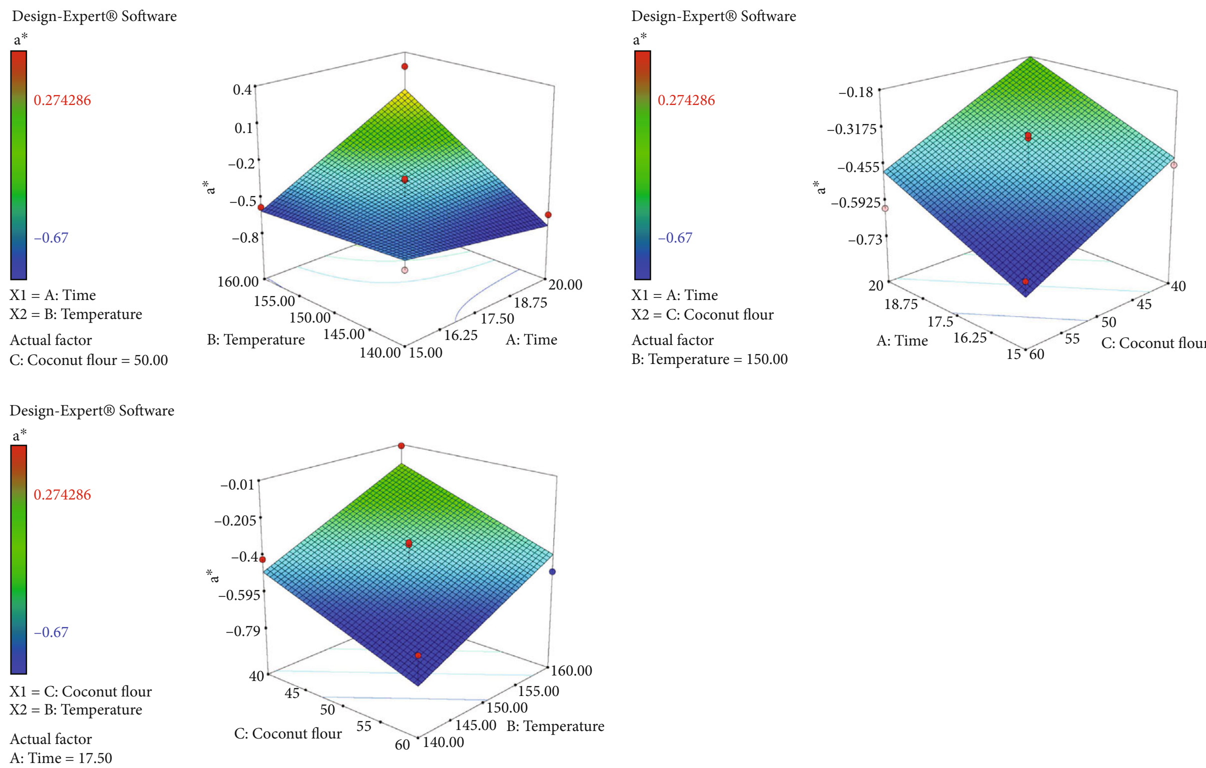

Figure 3: Contour plots of a^*. a^* equation: $-0.45 + 0.12^*A + 0.18^*B - 0.15^*C + 0.22^*A^*B$.

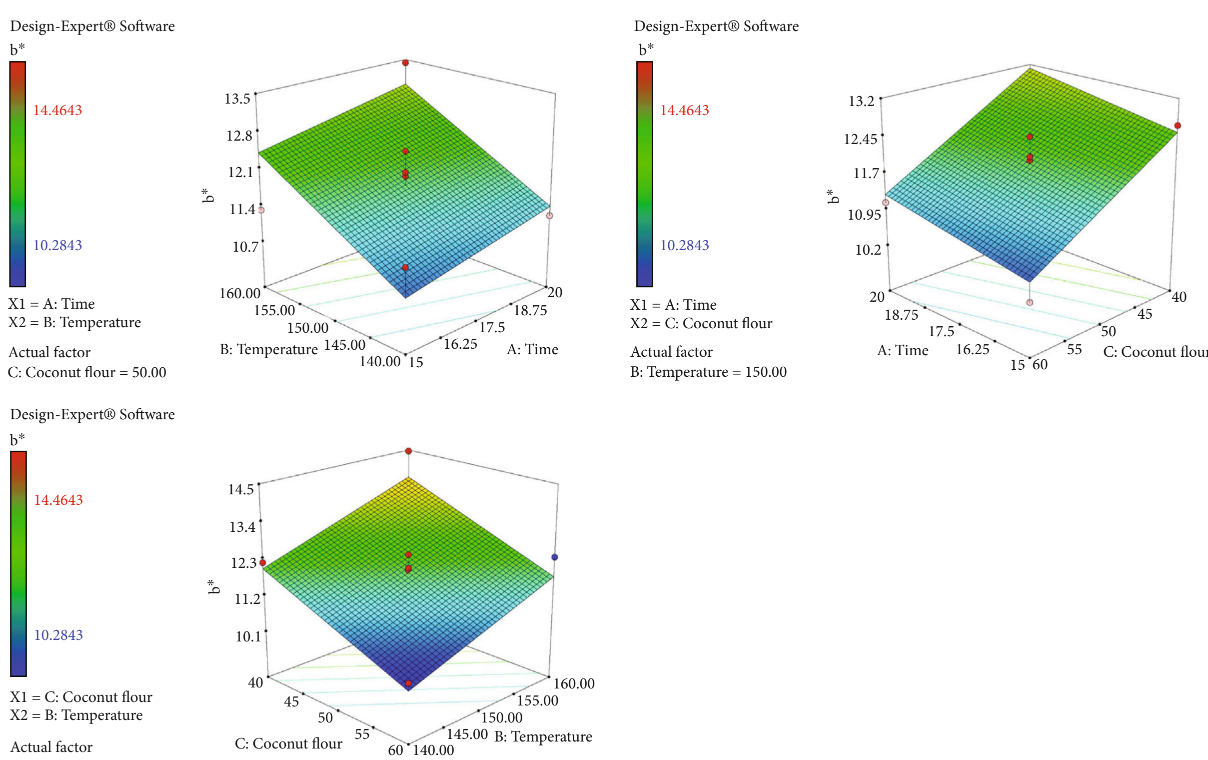

Figure 4: Contour plots of b^*. b^* equation: $+11.90 + 0.30^*A + 0.81^*B - 0.93^*C$.

Table 5: Fatty acid profile of nixtamalized corn flour, coconut flour, and optimized snack.

Fatty acid	% of fatty acid of the total crude fat		
	Nixtamalized corn flour	Coconut flour	Optimized snack
C6:0	0.00 ± 0.00^{c}	6.06 ± 0.42^{b}	9.36 ± 0.18^{a}
C8:0	0.00 ± 0.00^{b}	4.85 ± 0.17^{a}	4.36 ± 0.18^{a}
C10:0	0.00 ± 0.00^{c}	4.66 ± 0.11^{a}	4.15 ± 0.11^{b}
C11:0	0.00 ± 0.00^{b}	0.02 ± 0.00^{a}	0.02 ± 0.00^{a}
C12:0	0.00 ± 0.00^{c}	43.81 ± 0.45^{a}	38.95 ± 0.40^{b}
C13:0	0.00 ± 0.00^{b}	0.04 ± 0.00^{a}	0.03 ± 0.00^{a}
C14:0	0.08 ± 0.03^{c}	19.88 ± 0.03^{a}	17.75 ± 0.09^{b}
C16:0	14.19 ± 0.04^{a}	9.90 ± 0.11^{b}	9.86 ± 0.17^{b}
C17:0	0.09 ± 0.00^{a}	0.00 ± 0.00^{c}	0.02 ± 0.01^{b}
C18:0	2.58 ± 0.03^{b}	3.81 ± 0.07^{a}	3.62 ± 0.09^{a}
C20:0	0.50 ± 0.01^{a}	0.10 ± 0.01^{b}	0.12 ± 0.01^{b}
C24:0	0.22 ± 0.01^{a}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}
Σ saturated	17.66 ± 0.09^{c}	93.14 ± 0.11^{a}	88.24 ± 0.18^{b}
C16:1	0.11 ± 0.00^{a}	0.02 ± 0.00^{b}	0.04 ± 0.00^{b}
C18:1 *cis*	29.00 ± 0.05^{a}	5.83 ± 0.09^{c}	7.14 ± 0.13^{b}
C20:1 *n9*	0.26 ± 0.02^{a}	0.03 ± 0.01^{b}	0.06 ± 0.01^{b}
C22:1	0.16 ± 0.05^{a}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}
Σ monounsaturated	29.52 ± 0.11^{a}	5.88 ± 0.10^{c}	7.24 ± 0.14^{b}
C18:2 *cis*	51.96 ± 0.19^{a}	0.97 ± 0.01^{c}	4.45 ± 0.04^{b}
C18:3 *n3*	0.85 ± 0.01^{a}	0.00 ± 0.00^{c}	0.07 ± 0.00^{b}
Σ polyunsaturated	52.81 ± 0.20^{a}	0.97 ± 0.01^{c}	4.52 ± 0.04^{b}

Data is shown in percentages of the total of the fat detected in mean ± standard deviation. Total measures: 2 replicates. Different letters in the same line are significantly different ($p \leq 0.05$) with one-way analysis of variance and a post hoc Tukey–Kramer test.

Table 6: Values predicted by the optimization model and real values obtained.

Parameter	Minimum	Maximum	Real values
aw	0.065	0.240	0.186 ± 0.012
Moisture (%)	1.07	3.64	1.84 ± 0.120
L^*	40.02	42.66	42.30 ± 1.00
a^*	−0.28	0.15	−0.66 ± 0.14
b^*	11.65	13.10	11.46 ± 0.64
C^*	11.79	13.72	11.47 ± 0.63
h^*	86.05	91.55	93.28 ± 0.76

Data is shown in mean ± standard deviation. Total measures (L^*, a^*, b^*, C^*, h^*): 7 replicates. aw and moisture: 3 replicates. *aw*: water activity; L^*: luminosity; a^*: red to green; b^*: blue to yellow; C^*: Chroma; h^*: hue.

Table 7: Scores of browning index and ΔE.

BI	*ΔE*
29.58 (optimized)	—
41.35	3.78
51.43	5.42
24.70	1.39
31.07	1.25

ΔE: color change; BI: browning index.

The values of ΔE indicate that the optimized version can be differentiated at a glance from the two versions with higher BI. For the other two products, close observation is necessary to distinguish the differences in color from the optimized snack. As expected, the snack with a higher BI was also the snack with the highest *ΔE*. The variations in the process of elaboration and the BI observed were, for the two versions with higher BI, the baking temperature of 160°C. Between these two versions, the one with the highest BI, although it was baked for less time, contained more coconut flour (60%).

In contrast, the two snacks with lower BI were baked at a lower temperature (150°C), but in this case, the coconut flour had a reducing effect on BI. Therefore, the version with more coconut flour was also the one with a lower BI.

When the coconut is heated to a temperature over 150°C, the characteristic sweet, fruity taste changes to a roasted nut-like taste. This flavor is also passed to the oil extracted by heating the coconut. Regarding defatted coconut, browning and the burnt odor indicate a decrease in the solubility of proteins or their denaturalization. Additionally, in this process of browning by the Maillard reaction in coconut, glucose, fructose, and free amino acids, such as lysine, glycine, and tryptophan, were found to contribute significantly [52–54].

The ΔE of coconut flour and the optimized snack indicate differences at a glance. However, the familiarity of the consumer can generate a like or dislike for a product. The BI associated with the snacks may be perceived as a good effect in this case. However, due to the characteristics of the coconut and its characteristic white color, this expectation may be altered. The level of L^* of fresh coconut was 67.92 ± 4.13, indicating a high level of luminosity, so products made with coconut flour may also be expected to have certain levels of whiteness.

The color of fruits may be associated with the maturity state and with the cooking process in cooked food. These learned expectations may potentially alter the perceived sensorial stimuli and hence the qualification of the product (Delwiche, 2012).

It is important to consider the factors associated with color change and the expectation of the consumers since approximately 98% of the participants reported eating salty snacks, with diversity in the frequency of consumption.

In this case, 24.5% reported eating salty snacks one time a week and 24.5% reported eating salty snacks two times per week, followed by 19.6% who ate salty snacks three times a month. In the case of parameters that they considered most important to select a salty snack to eat, 20.6% of the participants referred to the flavor as the most important factor, followed by a combination of flavor cost with 15.7% and that the snacks were healthy with 10.8%. The color aspect was included in a group of factors (flavor, odor, color, cost, and that they are healthy), with 6.9% of the answers.

According to the answers provided by the participants, color is not one of the most relevant factors when selecting a salty snack for consumption. Nevertheless, this characteristic is not only associated with the consumer's preference, as BI was found to be associated with nonenzymatic browning reactions, such as the Maillard reaction. Additionally, it is well known that food selection is highly influenced by its aspect, and visually, color is one of the most important parameters [24].

Although the participants did not select color as a principal factor for choosing a snack, in other reports, yellow or orange shades favored the scores in the sensorial color analysis of snacks [30, 55].

As can be seen, the modifications in time, temperature, and coconut flour amount reacted differently in color aspects. Therefore, this information may be of interest if a snack including coconut is going to be elaborated but is necessary to analyze all the sensorial aspects of the product to obtain more data.

4. Conclusions

According to the results of this study, it was possible to incorporate a percentage of coconut flour above 50% into the snack. Therefore, this may be a new use for this byproduct, enhancing the possible uses of coconut.

In obtaining a snack version optimized as regards physical factors, it is essential to highlight that *aw*, moisture, a^*, and b^* were variables with sufficient relevance to modify all other components. This is because, considering these variables as the ones with more relevance to the optimization process, the time and temperature of the bake and the coconut flour were modified to adjust to them. On the other hand, modifications in protein, fat, and carbohydrate contents were observed to be derived from the addition of coconut flour. Additionally, the fatty acid profiles of the coconut byproduct and the optimized snack indicate that the principal components are saturated, with lauric acid being predominant. The characteristics of the content of the fatty acids of the snack seem to be related to the addition of coconut flour because it is the principal donor of fat to the snack.

Coconut flour amount affected the color parameters, while modifying the baking time and temperature changed *aw* and moisture. However, it seems that the browning of the product may be related to reactions such as the Maillard reaction, and in this case, the coconut flour altered the browning level.

The participants did not consider the color as the most important factor in choosing a snack for consumption, but rather, they considered this to taste. Therefore, characteristics such as BI that can generate taste modifications may be considered. Although coconut flour was viable for the elaboration of a salty snack, its sensorial characteristics and other physical properties of this coconut oil byproduct must be explored further to allow it to be included in other types of foods.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors report there are no competing interests to declare.

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