Vol. 20, No. 3(2021) Alim2433
Revista Mexicana de Ingeniería Química
Ingeniería de alimentos

Design of lattice simplex mixtures as a statistical tool for the inclusion of cowpea bean flour (*Vigna unguiculata*) in a cheese stick formulation

Diseño de mezclas lattice simplex como herramienta estadística para la inclusión de harina de frijol caupí (*Vigna unguiculata*) en una formulación de palitos de queso

J.C. Mendoza-Combatt[1], L. Fuentes-Medina[2], M. Mendoza-Combatt[3]*

[1]*School of Basic Sciences, Technology and Engineering, National Open and Distance University, Cartagena, Bolivar, Colombia.*
[2]*Department of Chemistry, University of Cordoba, Monteria, Cordoba, Colombia.*
[3]*Department of Food Science and Technology, Federal University of Viçosa, Viçosa, Minas Gerais, Brazil.*

Received: April 6, 2021; Accepted: August 9, 2021

Abstract

The cowpea bean, recognized as Cowpea (*Vigna unguiculata* L. Walp.), is an important crop in low-income populations due to its nutritional properties. A mixture analysis was used to obtain the formulation of dough for frozen products, type cheese sticks, including cowpea bean flour (*Vigna unguiculata*). The frozen sensory evaluation was carried out using an acceptance test with a 7-point hedonic scale with 91 untrained panelists of both genders of variable age between 17 and 62 years. Of the treatments studied, the evaluating panel showed the greatest preference, for which the largest fraction of cowpea flour constituted it. The addition of cowpea flour in a higher proportion has a significant effect on the product's nutritional and sensory properties. Cowpea flour is indicated to partially replace wheat flour in frozen cheese sticks because it improves its flavor, color, texture, and overall impression, providing a more nutritious product made with native raw materials.

Keywords: sensory analysis, nutritional quality, cowpea (*Vigna unguiculata* L. Walp).

Resumen

El fríjol caupí reconocido como Cowpea (*Vigna unguiculata* L. Walp.), es un cultivo importante en poblaciones de baja renta por sus propiedades nutricionales. Se utilizó un análisis de mezclas para obtener la formulación de una masa para productos congelados, tipo palitos de queso, incluyendo la harina del frijol caupí (*Vigna unguiculata*). La evaluación sensorial de los congelados fue ejecutada mediante un test de aceptación con escala hedónica de 7 puntos con 91 panelistas no entrenados de ambos sexos de edad variable entre 17 a 62 años. De los tratamientos estudiados, el panel evaluador mostró mayor preferencia, por el que estuvo constituido por la mayor fracción de harina de caupí. La adición de harina de caupí en mayor proporción otorga un efecto significativo en las propiedades nutricionales y sensoriales del producto. La harina de caupí es indicada para sustituir parcialmente la harina de trigo en los congelados tipo palitos de queso, debido a que mejora su sabor, color, textura e impresión global, brindando un producto más nutritivo elaborado con materia prima autóctona.

Palabras clave: análisis sensorial, calidad nutricional, cowpea (*Vigna unguiculata* L. Walp).

* *Corresponding author. E-mail*: maripauli18@hotmail.com
https://doi.org/10.24275/rmiq/Alim2433
ISSN:1665-2738, *issn-e*: 2395-8472

1 Introduction

The cowpea bean, worldwide recognized as Cowpea (*Vigna unguiculata* L. Walp.), is a grain legume from West Africa and inserted in India during the Neolithic (Ehlers & Hall, 1997). Cowpea was brought to America in the 17th century by the Spanish and is currently widely cultivated in various regions of the United States, the Caribbean, and Brazil (Ngalamu *et al*., 2015). Data from 2013 show that approximately 12 million hectares were harvested in the world, while in Colombia, the cultivated area was 14 thousand hectares, mainly in small areas of the Colombian Caribbean region (Araméndiz *et al*., 2016).

Cowpea beans are characterized by its reniform seeds with beige to white smooth cover and brown hilum (De Oliveira *et al*., 2018); it is an important crop, especially in low-income populations, due to their nutritional properties. The grain contains between 23 to 25% protein; also, it has a low amount of fat, an average of 2% (Frota *et al*., 2008). It also contains minerals such as potassium (1977 mg/100g), phosphorus (2607 mg/100g), and iron (13.8 mg /100g) (Vargas *et al*., 2012). The grain has a high content of total polyphenols. An increase in antioxidant activity has also been found after bean digestion, indicating the potential health benefits it brings to consumers (Mtolo *et al*., 2017). Cowpea is one of the bean varieties widely cultivated in the Colombian Caribbean in small areas in the Córdoba State. In addition to this, there are investigations in the region aimed at the species' genetic improvement, focusing on the grain's biofortification at a nutritional level (Araméndiz *et al*., 2016).

The consumption of cowpea in different food formulations is a healthy alternative due to the bean´s nutritional properties, especially its protein contains (Bezerra *et al*., 2019), in addition to allowance the differentiation and sophistication of conventional preparations foods, thus contribuiding at the sustainability goals (SDGs) on food security and nutrition, helping to Figth against "hidden hunger" and the high levels of different forms of malnutrition. The latest report on the state of food security and nutrition worldwide reports that the number of undernourished people increased to 820 million: around one in nine people worldwide. Coupled with this, almost 149 million children under the age of five, or more than 22%, were affected by stunting (FAO *et al*., 2020). The report on the panorama of food and nutrition security for Latin America and the Caribbean shows how the region is moving away from the goal of zero hunger. The stunting of boys and girls continues to trend downward. On the contrary, child overweight continues to increase and affects 7.3% of the population under five years of age (FAO *et al*., 2018).

In the food industry, healthy alternatives are being studied to replace or complement common formulations, bringing nutritional and techno-functional improvements that do not affect or improve the sensory perception of the final product. (Gómez *et al*., 2021; Rodriguez *et al*., 2020). The use of legume flours with high protein content to enrich other food products that are already on the market is a trend that provides the opportunity to diversify food intake (Carreño, 2017; Elías, 1996; Ponce *et al*., 2018). However, the use of different types of flours for frozen foods that improve their nutritional and sensory characteristics is an innovative matter. Recent studies recommend the use of cowpea bean flour as it is a low-cost and readily available source of protein to improve nutritional quality in combined food products that are thawed for consumption (Akosua *et al*., 2015; Naiker *et al*., 2019), making it a promising crop for development of regional agribusiness that contributes to the opening of markets for cowpeas (De Oliveira *et al*., 2018; Freire, 2011).Coupled with the above, the success of a new food product on the market depends on its commitment to consumer opinion. The determination of acceptance is essential in developing new products and improving existing products (Reis *et al*., 2009).

The reticular simplex design (lattice-simplex) is a statistical methodology used to solve problems of experiments with mixtures. With this design, it is not a matter of arriving at formulations by simple trial and error, but applying a planning methodology that ensures obtaining a projected and clear goal (Gutiérrez & De la Vara, 2012). The design of mixtures has been little used to evaluate sensory acceptance, being that it offers several advantages (Grosso *et al*., 2015; Los *et al*., 2020; Ramos *et al*., 2019).

This work's objective was to use the design of lattice simplex mixtures to obtain the formulation of dough for frozen products, including a cowpea bean flour (*Vigna unguiculata*) that would increase the nutritional content of the dough; besides, evaluate the sensory acceptability of the final food product.

2 Materials and methods

2.1 *Location, period, and type of study*

The practical part was developed in the kitchen and bakery environment of the Center for Commerce, Industry and Tourism (CCIT) of the National Learning Service (SENA) and in the process research laboratories of the vegetable agribusiness of the University of Cordoba in an execution period of six months. The sensory analysis of preference and acceptance of this experiment was carried out at the CCIT, in the SENA Monteria kitchen and gastronomy room. The study was an exploratory quantitative experimental type.

2.2 *Selection and preparation of raw materials*

Cowpea beans were used for being one of the bean varieties widely cultivated in the Colombian Caribbean in small areas in the State of Córdoba. In addition to this, there are investigations in the region aimed at the species' genetic improvement, focusing on the grain's biofortification at a nutritional level (Araméndiz *et al*., 2016).

The treated beans had a homogeneous beige color, and it was also observed that the hilum and the germ of the bean were between dark brown and black, a characteristic sign of said variety, the beans that did not meet this characteristic were removed. Also, stones were found between the raw material, which is why this stage was necessary. The other raw materials were verified for the expiration date and adequate condition (wheat flour, sugar, and salt), and the fat was verified that did not have a rancid odor or unusual coloring.

The beans were purchased in a local market in the city of Montería. Cowpea flour was obtained through a process adapted from Vargas & Villamil, 2012. The doughs' preparation ingredients (wheat flour, fat, additives) were obtained in a local warehouse.

2.3 *Method of obtaining bean flour*

Figure 1 describes the flow chart of obtaining bean flour until its vacuum packing, to be later used in the mixture to make frozen cheese sticks.

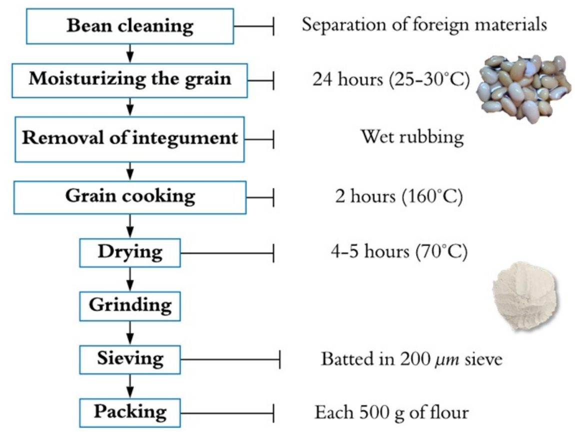

Fig 1. Process of obtaining cowpea flour (*Vigna unguiculata*).

2.3.1 *First stage - bean cleaning*

Once the beans were obtained, they were distributed on a contrasting color surface to facilitate the cleaning and separation of foreign materials. The grains were subjected to washing and soaking. This process was carried out in stainless steel containers of 5 liters in volume. A ratio of 1 kg of grains to 2 kg of water (1: 2) was used.

2.3.2 *Second stage - moisturizing the grain*

The seed was hydrated in a container with a lid, using twice the weight of the legume material in drinking water, for a period of 24 hours at a temperature of 25-30°C, obtaining grain hydration of 60%. This stage facilitated the removal of the bean integument and also helped in the removal of the antinutritional factors of said legume such as trypsin inhibitor, protease inhibitor, phytic acid, among others (Abbas & Ahmad, 2018; Bezerra *et al*., 2019; Brigide *et al*., 2019).

2.3.3 *Third stage - removal of integument or shell*

The integument's removal was carried out manually employing a wet rubbing process, using abundant water and friction of grain against the grain using the hands. This process allowed obtaining a clean grain, without hilum, germ, or integument, the density of the material led to adequate separation in a humid environment.

2.3.4 *Fourth stage - grain cooking*

A cooking process was carried out in 10-liter stainless steel containers, using 20% more of the volume

Fig 2. A. Wheat flour; B. Cowpea flour.

of water per grain quantity. The cooking process was carried out at 160°C for 2 hours until the beans were soft, allowing the starch's gelatinization in the pearl grain (Varela *et al*., 2017). After this period, the beans were removed from the cooking container and placed in an aluminum tray for subsequent drying.

2.3.5 *Fifth stage - drying*

The beans were dried in a VWR brand vacuum oven, stainless steel model 19087 with time and temperature control of 70°C for 4-5 hours to facilitate grinding and obtaining flour. The dried and rested beans were vacuum packed and preserved for no more than 2 weeks until grinding.

2.3.6 *Sixth stage - grinding*

The dry beans were ground, subsequently sieved with a sieve specification of 200 μm, the process was carried out by batting of 500 g. Cowpea bean flour of beige or pearl color was obtained, similar to wheat flour used to prepare the dough for the different treatments (Figure 2). Each 500 g of flour obtained was vacuum packed until later use.

2.4 *Experimental design*

Initially, trials were developed to formulate frozen dough using wheat flour, fat, sugar, salt, and water (data not shown). The standardization of said mass is described in Table 1.

Once the dough formulation was established, pre-tests were carried out, making progressive wheat flour modifications by bean flour considering the dough's technological characteristics such as elasticity, cohesion, cut, and shine. Table 2 shows the different mixtures between flours made in the pre-test. The proportions of fat (17%), sugar (3%), salt (1%), and water (23%) were kept constant.

Table 1. Standard formulation used to make the dough.

Ingredient	**Percentage ratio (m/m)**
Wheat flour	55%
Fat	17%
Sugar	3%
Salt	1%
Water	23%
Total	100%

Table 2. Pre-tests used to define the maximum accepted proportion of bean flour over the total mass.

Ingredients	**Pre-tests 1**	**Pre-tests 2**	**Pre-tests 3**
Wheat flour	44%	27,5%	11%
Bean flour	11%	27,5%	44%

Table 3. Percentage proportion on flour of the tests carried out according to the lattice simplex model.

Treatment	Fraction of the type of flour	
	Wheat flour	Bean flour
T1	0,35	0,65
T2	0,51	0,49
T3	0,67	0,33
T4	0,84	0,16
*Tc	1	0

*Tc: control treatment.

Once the maximum percentage proportion that the dough formulation allowed was found, an experiment was designed for binary mixtures to evaluate the influence of the proportion of bean flour on the final product's sensory characteristics. The experiment was carried out using a lattice simplex model for two components: bean flour and wheat flour. The sensory characteristics analyzed were color, flavor, texture, and global impression of the product. The treatments that show the percentage proportion over the total flour are presented in Table 3.

2.5 *Preparation of the doughs and frozen cheese sticks*

Figure 3 shows the flow chart of a typical process for preparing the doughs and the cheese sticks.

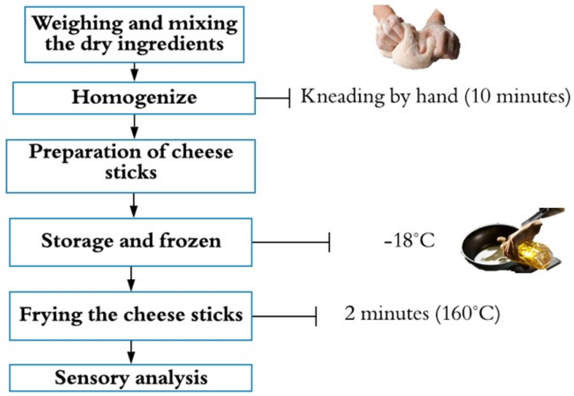

Fig 3. Process of preparation of the doughs and frozen cheese sticks.

2.5.1 *First stage - Weighing and mixing the ingredients*

The necessary proportions of the dry ingredients were weighed. Wheat flour, bean flour, sugar, salt, and fat for each of the treatments. The wheat flour and bean flour and the salt and sugar were homogenized, and then the fat was added, mixing the powdered components according to the treatment of the experimental design. The water was progressively added to the mixture of dry ingredients until a homogeneous integration was achieved, followed by process of kneading by hand for 10 minutes for each treatment until the portioning point.

2.5.2 *Second stage - Preparation of frozen type "cheese sticks."*

After a resting period of 30 minutes, the dough was portioned in 12 g units, and the local curd-type cheese was portioned in 3 g units, forming approximately 15 g cheese-filled sticks. The latter were stored and frozen at -18°C until the moment of frying.

2.5.3 *Third stage - Frying the cheese sticks*

Each treatment's frozen products were fried in soybean vegetable oil at 160 ° C for 2 minutes and kept in heating in a convection oven at 70 ° C until the moment of their consumption in the sensory analysis.

2.6 *Analysis of nutritional components of the dough*

Obtained the mass to prepare the frozen ones, the physicochemical analyzes were carried out to obtain the nutritional information of the same, the analyzes carried out to each treatment were made considering the international methods of the Association of Official Analytical Chemists - AOAC- for its acronym in English (AOAC, 2019): acid number; proteins by Kjeldah method (AOAC 976.05), fat determination by Soxhelt extraction method (AOAC 969.24); moisture by gravimetric method (AOAC 950.01), ash by muffle at 550°C (AOAC 942.05).

2.7 *Sensory analysis*

The sensory evaluation of the frozen was carried out through an acceptance test with a 7-point hedonic scale (ranging from "I liked a lot" with a score of 7 to "I disliked a lot" with a score of 1) with 91 untrained panelists of both genders of variable age between 17 to 62 years. The samples were presented separately in disposable plastic plates, coded, and randomized under white light. Between each sample, a glass of water at room temperature was offered to cleanse the palate. The MINITAB® 18 software was used to construct the statistical models (Minitab 18, 2010).

3 Results and discussion

3.1 *Analysis of nutritional components of the dough*

Figure 4 shows the dough's physicochemical analyses' results as the proportion of bean flour used increases.

A progressive increase in acidity is observed with the increase in bean flour (Figure 4 A), characteristics of this type of dough due to the content of amino acids and proteins present. There is a record of the presence of glutamic acid and aspartic acid in cowpea bean seeds, which are found in a higher proportion concerning other amino acids also found in this grain (Baptista *et al*., 2016; Gonçalves *et al*., 2016).

The ash and fat values did not show a trend regarding the increase in the proportion of bean flour (Figure 4 B and C). Other studies have reported that there is a reduction in the content of these components after cooking (Bezerra *et al*., 2019), highlighting the low-fat content compared to other grains, a characteristic that makes it striking for application in diets of weight restriction (Gonçalves *et al*., 2016).

The humidity of the dough increased proportionally with the increase of bean flour in the formulation (Figure 4D). A model is presented that describes the humidity of the dough explained by the variation of the proportion of wheat flour (T) and bean (F) used (Equation 1). It is observed that the model is significant at a confidence level of 5% (p-value = 0.023). Additionally, the value for the high coefficient of determination of R^2 = 86% shows a good fit for the data.

$$H = 32.38T + 46.99F \tag{1}$$

The dough's maximum moisture value can reach when using exclusively wheat flour is 32.38% for the formulation used. As the proportion of bean flour increases, the dough's humidity increases, the maximum tolerable humidity condition is 42%, a result achieved for treatment 1 (65% bean flour and 35% wheat flour).

It is of interest in the baking and confectionery industry to include moisture-retaining flours in their recipes because this characteristic is conducive to obtaining fully cooked snacks inside and conferring desirable sensory properties (Espinosa, 2007; Torres *et al*., 2017). Researchers have justified cowpea starch's relevance as a thickening agent and texture modifier in food formulation due to its high water retention capacity (Ratnaningsih *et al*., 2016). The increase in water absorption when incorporating bean flour into the dough is due to the higher fiber content since it retains water inside its fibrous matrix's cell spaces. In this legume, the fiber value ranges between 5.4% and 8.1%, while in wheat, it is 2.4 and 2.8% (De Paula *et al*., 2018; Espitia & Petro, 2016; Vargas & Villamil, 2012).

It is evidenced the increase in the values for the percentage of protein present in the food mass as the proportion of cowpea flour increases (Figure 4E). Wheat does not have all the essential amino acids necessary for proper development; due to the deficiency of amino acids such as lysine, for nutritional improvement, mixtures of cereals and legumes can be used to achieve acceptable protein contents (León & Rosell, 2007). Cowpea bean flour is a promising protein supplement to wheat flour, characterized by high amounts of lysine and other essential amino acids (Baptista *et al*., 2016; Frota *et al*., 2008; Gonçalves *et al*., 2016). Recent studies recommend using cowpea flour to develop bakery products, cookies, and pasta due to its ability to increase the amount of protein and due to its technological and microbiological potential (Frota *et al*., 2008; Rios *et al*., 2018).

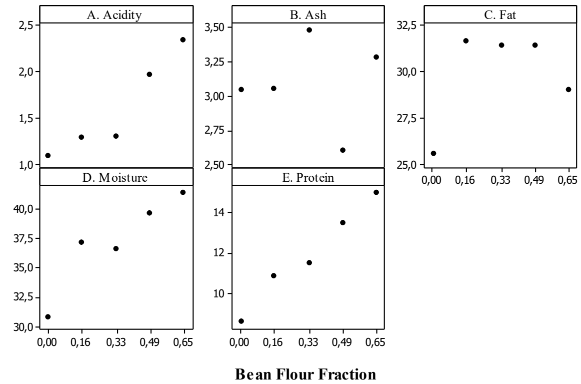

Fig 4. Data from the physicochemical analysis of the formulations made for the mass of frozen products.

3.2 *Analysis of nutritional components of the dough*

In the pre-tests carried out to evaluate the proportion of bean flour that the dough supported without losing the technological characteristics necessary for its preparation, it was found that the maximum proportion of bean flour was 36% of the total ingredients (65% on flour).

The estimated mean values obtained for the four sensory characteristics studied according to each treatment proposed by the lattice simplex design are show (Table 4).

The analysis of variance for the four attributes studied; flavor (S), texture (Tex), Color (C), and global impression (GI) are presented in picture 1. The input variables studied are represented by the wheat flour fraction (T) and the bean flour fraction (F).

Table 4. Mean values of the sensory characteristics evaluated using the hedonic scale.

Treatment	Flavor	Texture	Color	Overall impression
T1	5,84	5,67	5,58	5,59
T2	4,86	5,3	5,32	4,91
T3	4,68	4,66	5,15	4,73
T4	4,67	4,84	5,07	4,71
*Tc	5,91	5,05	5,31	5,56

*Tc: control treatment.

A. Anova for taste (S)					
Source	**Sum of square**	**DF**	**Midle square**	**F**	**P**
Quadratic Model	1,51826	2	0,75913	24,48	0,039
Residual error	0,06202	2	0,03101		
Total	1,58028	4			
R^2 = 96,08% R^2adj = 92,15% Standard error = 0,176101					

B. Anova for texture (Tex)					
Source	**Sum of square**	**DF**	**Midle square**	**F**	**P**
Quadratic Model	0,569029	2	0,284514	9,56	0,095
Residual error	0,059491	2	0,029746		
Total	0,62852	4			
R^2 = 90,53% R^2adj = 81,07% Standard error = 0,172469					

C. Anova for color (C)					
Source	**Sum of square**	**DF**	**Midle square**	**F**	**P**
Quadratic Model	0,147274	2	0,073637	24,36	0,039
Residual error	0,006046	2	0,003023		
Total	0,15332	4			
R^2 = 96,06% R^2 adj = 92,11% Standard error = 0,0549805					

D. Anova for global impresión (GI)					
Source	**Sum of square**	**DF**	**Midle square**	**F**	**P**
Quadratic Model	0,74736	2	0,37368	25,39	0,038
Residual error	0,02944	2	0,01472		
Total	0,7768	4			
R^2 = 96,21% R^2 adj = 92,42% Standard error = 0,121326					

Picture 1. ANOVAS for quadratic models of the sensory characteristics evaluated.

The analysis of variance for the four attributes studied; flavor (S), texture (Tex), Color (C), and global impression (GI) are presented in picture 1. The input variables studied are represented by the wheat flour fraction (T) and the bean flour fraction (F).

For the flavor attribute, it is observed that the model is significant at a confidence level of 5% (p-value = 0.039). Additionally, for selecting the model, the determination coefficient was considered (R^2 = 96 %), which indicates that the quadratic model explains the response variable by more than 90% (Picture 1A). The coefficients of the quadratic model are given by Equation (2). From the magnitude of the linear terms, it can be inferred that when the proportion of bean flour is higher, the higher value for the flavor characteristic is achieved. In this way, to maximize the output variable, the highest proportion of bean flour must be placed to preserve the dough's technological characteristics; this is 65% of the total flour.

$$S = 5.84057T + 10.2358F - 12.47TF \qquad (2)$$

In the analysis of variance for the food texture model, a p-value of 0.092 is observed, whose magnitude is greater than 0.05 but less than 0.1, it is decided to admit the model at a confidence level of 10%. Furthermore, the coefficient of determination of 90% (R^2= 90%) indicates that the model explains the answer satisfactorily (Picture 1.B). The coefficients of the quadratic model are given by Equation (3). From the texture model, the greater magnitude of the linear term's coefficient for the proportion of beans (F) must be considered since, as the latter increases, there will be a consequent increase in the variable studied.

$$Tex = 5.04686T + 7.96757F - 5.35587TF \qquad (3)$$

The proportional increase in humidity with the increase in the proportion of bean flour maintains the smooth texture of products made with flours from cereal-legume mixtures. On the other hand, fiber and protein play an important role when it comes to maintaining the humidity of food, as well as in bakery products (Aguilera, 2009).

Another factor involved in the resulting texture for the elaborated product is the high granulometric uniformity that cowpea flour has associated with the homogeneous absorption of water, promoting uniform cooking in it (Dussán *et al.*, 2019). In the present work, the cowpea bean flour that was prepared had its particles retained on a 200 μm mesh sieve. Rios *et al.* (2018) maintain that cowpea flour is indicated to totally or partially replace wheat flour in food, based on the particles' diameter that composes it. His study was close to 250 μm, being in the interval established by the Brazilian legislation of granulometry (<250 μm), and thus managing to conclude that foods produced with cowpea bean flour tend to present a texture similar to those made with wheat flour (Rios *et al*., 2018).

For the color model, it is observed that the model is significant at a confidence level of 5% (p-value = 0.039). The criterion of the determination coefficient (R^2= 96%) is also considered, which indicates that the quadratic model explains the response variable (Picture 1.C). The coefficients of the quadratic model are given by Equation (4). The magnitude of the coefficient for the proportion of bean flour continues to be higher when compared to the coefficient for wheat flour, and the interaction term continues to be negative, denoting antagonism. The recommendation is the same as for the other sensory characteristics, keep the highest possible proportion of bean flour in the dough (F = 0.65) to increase acceptance at the color level.

$$C = 5.28371T + 6.80182F - 2.94844TF \quad (4)$$

The visual acceptance of the cheese stick preparations with cowpea flour is attributed to the similarity of the light color of the flour resulting from the mixture when compared to wheat flour, which consequently produces a straightforward dough for the frozen ones so that the color of the cheese stick is not strange to the final consumer. Niker *et al*. (2019) and Rengadu *et al*. (2020) highlight the capacity of different species of cowpea to produce light flours. These investigations coincide on the importance of color analysis for applying cowpea bean flour in food since a difference in color in the flour can affect the final color of food products and consequently their acceptability (Naiker *et al*., 2019; Rengadu *et al*., 2020).

For the global impression model. It is observed that the model is significant at a confidence level of 5% (p-value = 0.038). It is also considered the criterion of the coefficient of determination (R^2= 96%), which indicates that the quadratic model satisfactorily explains the variable answer (Picture 1.D). The coefficients of the quadratic model are given by Equation (5). The models' results for the sensory variables separately and the global impression variable showed agreement in the greater magnitude of the bean flour fraction's coefficient. This last premise shows that even though the panelists were not trained, there was consistency in their evaluations regarding the sensory characteristics evaluated since the greater acceptance of the food product was always evidenced, as bean flour was added in a higher proportion.

$$IG = 5.50800T + 8.71652F - 8.71006TF \quad (5)$$

Regarding the acceptability of the final product, treatment 1, which consisted of 65% bean flour and 35% wheat flour, showed greater preference by the panelists. This indicates that cowpea flour's addition to wheat flour in this proportion has a significant effect on the elaborated cheese stick's physical-functional and sensory properties, improving its appearance and making it more attractive to the final consumer. This work corroborates and justifies the use that many people have given to cowpea flour as an ingredient in fried products and ground meat products, such as *Akara*, which is a typical traditional dish of African cuisine (Amadou, 2017). Espitia and Petro (2016), in their study of obtaining fritters using bean flour, reported that none of the prepared formulations entered the displeasure scale in the sensory evaluation carried out, and one of them was placed in hedonic terms of "nor I do not like it or dislike it" and "I like it slightly" (Espitia & Petro, 2016). Together with the above, recent studies affirm that cowpea starch has a low-fat retention capacity (Ratnaningsih *et al*., 2016), which makes it more appropriate to add it to fried recipes without the sensation of saturation of oil in the final product.

Conclusions

The design of lattice simplex mixtures allowed to obtain the formulation of dough for frozen products, including cowpea bean flour (*Vigna unguiculata*) which increased the dough's nutritional content and the sensory characteristics of the final food product.

The dough's proportional increase in the humidity with the cowpea bean flour fraction makes the cereal-legume mixture an advantageous option for the baking and pastry industry, which seeks to include moisture-retaining flours in its recipes. This characteristic is conducive to obtaining fully cooked snacks and gives desirable sensory properties to the final product. On the other hand, aiming to meet the sustainability objectives (SDG) on food security and nutrition, cowpea bean flour is an alternative that emerges as a promising protein supplement to wheat flour for frozen cheese sticks due to its content of lysine and other essential amino acids.

Regarding the sensory part, the evaluating panel showed a greater preference in the four attributes studied for treatment 1, which consisted of the highest fraction of cowpea flour. This indicates that the latter's addition in this proportion significantly affects the physical-functional and sensory properties of the processed cheese stick, making it more attractive to the final consumer. Cowpea flour is indicated to partially replace wheat flour in frozen cheese sticks because it improves its flavor, color, texture, and overall impression, providing a more nutritious product made with native raw materials.

Acknowledgements

SENA National Learning Service. To SENNOVA, Research, Technological Development, and Innovation System and the Tecnoparque Biotechnology and Nanotechnology Laboratory - SENA Bogotá.

References

Abbas, Y., & Ahmad, A. (2018). Impact of processing on nutritional and antinutritional factors of legumes: a review. *Food Science and Technology 19(2)*, 199-215. http://www.afst.valahia.ro/images/documente/2018/issue2/I.4_Abbas.pdf

Aguilera, Y. (2009). Harinas de leguminosas deshidratadas: Caracterización nutricional y valoración de sus propiedades Tecno-funcionales. Tesis de Doctorado en química agrícola. Universidad Autonoma de Madrid, España. http://hdl.handle.net/10251/89419

Akosua, A., Mawunyo, K., Courage, D., & Christopher, M. (2015). Development and assessment of conformance of cowpea flour for cake production. *International Journal of Nutrition and Food Sciences 4(3)*, 320-325. https://doi.org/10.11648/j.ijnfs.20150403.19

Amadou, I. (2017). Physico-functional and sensory properties of cowpea flour based recipes (*Akara*) and enriched with sweet potato. *Journal of Nutritional Health & Food Engineering 7(4)*, 243-248. https://doi.org/10.15406/jnhfe.2017.07.00243

AOAC. (2019). *Official Methods of Analysis* (21st ed.). AOAC international. USA.

Araméndiz, H., Cardona, C. E., & Combatt, E. M. (2016). Contenido nutricional de líneas de fríjol caupí (*Vigna unguiculata* L. Walp.) seleccionadas de una población criolla. *Información Tecnológica 27(2)*, 53-60. https://doi.org/10.4067/S0718-07642016000200007

Baptista, A., Pinho, O., Pinto, E., Casal, S., Mota, C., & Ferreira, I. M. P. L. V. O. (2016). Characterization of protein and fat composition of seeds from common beans (Phaseolus vulgaris L.), cowpea (*Vigna unguiculata* L. Walp) and bambara groundnuts (*Vigna subterranea* L. Verdc) from Mozambique. *Journal of Food Measurement and Characterization 2(11)*, 442-450. https://doi.org/10.1007/s11694-016-9412-2

Bezerra, J. M., Marlene, M., Ferreira, A., Farias, R., Lopes, M. F., & Souza, S. (2019). Composição química de oito cultivares de feijão-caupi Chemical composition of eight cultivars of cowpea. *Revista Verde de Agroecologia e Desenvolvimento Sustentável 24(1)*, 41-47. https://doi.org/10.18378/rvads.v14i1.6683

Brigide, P., De Toledo, N. M. V., López-Nicolás, R., Ros, G., Frontela Saseta, C., & De Carvalho, R. V. (2019). Fe and Zn: *In vitro* bioavailability in relation to antinutritional factors in biofortified beans subjected to different processes. *Food and Function 10(8)*, 4802-4810. https://doi.org/10.1039/c9fo00199a

Carreño, M. (2017). Sustitución de harina de trigo refinada por harinas más nutritivas y libres de gluten en magdalenas. Tesis de Maestría en Ciencia e Ingeniería de Alimentos. Universitat Politécnica de Valéncia, España. http://hdl.handle.net/10251/89419

De Oliveira, G., Pallaoro, D., Camili, E., & Dalmolin, Â. (2018). Physical and bromatological characteristics of cowpea varieties preferred by *Callosobruchus maculatus* (Coleoptera: Bruchidae). *Revista Caatinga 31(2)*, 515-522. https://doi.org/10.1590/1983-21252018v31n229rc

De Paula, C. D., Jarma Arroyo, S., & Aramendiz Tatis, H. (2018). Caracterización nutricional y determinación de ácido fítico como factor antinutricional del frijol caupí. *Agronomía Mesoamericana 29(1)*, 29-40. https://doi.org/10.15517/ma.v29i1.27941

Dussán, S., Hurtado, D., & Camacho, J. (2019). Granulometría, propiedades funcionales y propiedades de color de las harinas de quinua y chontaduro. *Informacion Tecnologica 30(5)*, 3-10. https://doi.org/10.4067/S0718-07642019000500003

Ehlers, J. D., & Hall, A. E. (1997). Cowpea (*Vigna unguiculata* L. Walp.). *Methods in Molecular Biology 53(1-3)*, 187-204. https://doi.org/10.1007/978-1-4939-1695-5_20

Elías, L. (1996). Concepto y tecnologías para la elaboración y uso de harinas compuestas. *Boletín de La Oficina Sanitaria Panamericana (OSP) 121(2)*, 1-3. https://iris.paho.org/handle/10665.2/15443

Espinosa, J. (2007). Evaluacion sensorial de los alimentos. In *Editorial Universitaria*. Cuba.

Espitia, C., & Petro, M. (2016). Obtención de buñuelos por medio de freído por inmersión empleando harina de frijol caupí (*Vigna unguiculata*). Trabajo de grado en Ingeniería de Alimentos. Universidad de Córdoba, Colombia. https://repositorio.unicordoba.edu.co/handle/ucordoba/1035

FAO, FIDA, OMS, PMA, & UNICEF. (2020). El estado de la seguridad alimentaria y la nutrición en el mundo. Transformación de los sistemas alimentarios para que promuevan dietas asequibles y saludables. 44. https:/doi.org/10.4060/ca9699es

FAO, OPS, WFP, & UNICEF. (2018). Panorama de la seguridad alimentaria y nutricional en américa latina y el caribe, desigualdad y sistemas alimentarios. 133. http://www.fao.org/3/CA2127ES/ca2127es.pdf

Freire, F. (2011). *Feijão Caupi no Brasil: Produção, Melhoramento Genético, Avanços e Desafios* (1 Ed). Embrapa Meio-Norte-Livro científico (ALICE), Brasil.

Frota, K., Soares, R., & Arêas, J. (2008). Composição química do feijão caupi (*Vigna unguiculata* L. Walp), cultivar BRS-Milênio. *Ciência e Tecnologia de Alimentos, 28(2)*, 470-476. https://doi.org/10.1590/S0101-20612008000200031

Gómez, A., Faccinetto, P., Orozco, N., Carrillo, E., Santacruz, A., & Jacobo, D. (2021). Physicochemical properties and sensory acceptability of sugar-free dark chocolate formulations added with probiotics. *Revista Mexicana de Ingeniería Química 20(2)*, 697-709. https://doi.org/10.24275/rmiq/Alim2131

Gonçalves, A., Goufo, P., Barros, A., Domínguez-Perles, R., Trindade, H., Rosa, E., Ferreira, L., & Rodrigues, M. (2016). Cowpea (*Vigna unguiculata* L. Walp), a renewed multipurpose crop for a more sustainable agri-food system: Nutritional advantages and constraints. *Journal of the Science of Food and Agriculture 96(9)*, 2941-2951. https://doi.org/10.1002/jsfa.7644

Grosso, G., Reyes, L., Osorio, M., & Rodríguez, N. (2015). Diseño experimental de mezclas como herramienta para la optimización de cremolácteos de mango. *Revista Colombiana de Investigaciones Agroindustriales 2(1)*, 16-24. https://doi.org/10.23850/24220582.166

Gutiérrez, H., & De la Vara, R. (2012). *Análisis y Diseño de Experimentos* (2da ed.). Mc Graw Hill, México.

León, A., & Rosell, C. (2007). *De Tales Harinas, Tales Panes: Granos, Harinas y Productos de Panificación en Iberoamérica* (1a ed.). ISEKI-Food, Argentina.

Los, P. R., Marson, G. V., Dutcosky, S. D., Nogueira, A., Marinho, M. T., Rosana, D., & Simões, S. (2020). Optimization of beef patties produced with vegetable oils: a mixture design approach and sensory evaluation. *Food Science and Technology 40*, 1-9. https://doi.org/10.1590/fst.22518

Minitab 18 Statistical software (2010). [Computer sofware]. State College, PA:Minitab, Inc. https://www.minitab.com

Mtolo, M., Gerrano, A., & Mellem, J. (2017). Efecto de la digestión gastrointestinal estimulada en el contenido de compuestos fenólicos y la capacidad antioxidante in-vitro de cultivos de judía de careta procesada (*V. unguiculata*). *CYTA - Journal of Food 15(3)*, 391-399. https://doi.org/10.1080/19476337.2017.1285816

Naiker, T. S., Gerrano, A., & Mellem, J. (2019). Physicochemical properties of flour produced from different cowpea (*Vigna unguiculata*) cultivars of Southern African origin. *Journal of Food Science and Technology 56(3)*, 1541-1550. https://doi.org/10.1007/s13197-019-03649-1

Ngalamu, T., Odra, J., & Tongun, N. (2015). *Cowpea Production Handbook*. IFS/AGRA, Sudán del Sur.

Ponce, M., Navarrete, D., & Vernaza, M. G. (2018). Sustitución parcial de harina de trigo por harina de lupino (*Lupinus mutabilis* sweet) en la producción de pasta larga. *Información Tecnológica 29(2)*, 195-204. https://doi.org/10.4067/S0718-07642018000200195

Ramos, M., Jordán, O., Silva, M., & Salvá, B. (2019). Optimización de la formulación de cabanossi con carne de llama (*Lama glama*) y papa (*Solanum tuberosum*) mediante el diseño de mezclas. *Revista de Investigaciones Altoandinas 21(1)*, 15-28. https://doi.org/10.18271/ria.2019.442

Ratnaningsih, N., Suparmo, Harmayani, E., & Marsono, Y. (2016). Composition, microstructure, and physicochemical properties of starches from Indonesian cowpea (*Vigna unguiculata*) varieties. *International Food Research Journal 23(5)*, 2041-2049. https://www.researchgate.net/publication/323691599

Reis, R. C., Minim, V. P. R., Dias, B. R. P., Chaves, J. B. P., & Minim, L. A. (2009). Impacto da utilização de diferentes edulcorantes na aceitabilidade de iogurte "light" sabor morango. *Alimentos e Nutrição Araraquara 20(1)*, 53-60. http://200.145.71.150/seer/index.php/alimentos/article/viewArticle/965

Rengadu, D., Gerrano, A. S., & Mellem, J. J. (2020). Physicochemical and structural characterization of resistant starch isolated from *Vigna unguiculata*. *International Journal of Biological Macromolecules 147*, 268-275. https://doi.org/10.1016/j.ijbiomac.2020.01.043

Rios, M., Damasceno-Silva, K., Moreira-Araújo, R., Figueiredo, E., Rocha, M., & Hashimoto, J. (2018). Chemical, granulometric and technological characteristics of whole flours from commercial cultivars of cowpea. *Revista Caatinga 31(1)*, 217-224. https://doi.org/10.1590/1983-21252018v31n125rc

Rodriguez, M., Ciro, H., Salcedo, J., & Serna, T. (2020). Development and characterization of a dehydrated mixture based on pumpkin flour (*Cucurbita maxima*) incorporating modified starch of yam (*D. alata* cv. Diamante 22) with potential application for instantaneous soups. *Revista Mexicana de Ingeniera Quimica 19(3)*, 1011-1025. https://doi.org/10.24275/rmiq/Alim1031

Torres, J. D., Acevedo, D., & Montero, P. M. (2017). Efectos de la fritura al vacío en los atributos de calidad de arepa con huevo. *Informacion Tecnologica 28(1)*, 99-108. https://doi.org/10.4067/S0718-07642017000100010

Varela, G., Ávila, J., Valero, T., Ruíz, E., Rodríguez, P., & Enjamio, L. (2017). *Informe sobre Legumbres, Nutrición y Salud*. Fundación Española de la Nutrición (FEN), España.

Vargas, Y., & Villamil, O. (2012). Caracterización fisicoquímica y nutricional de la harina de frijol caupí (*Vigna unguiculata* L.) cultivado en el departamento del Tolima. Trabajo de Grado en Ingeniería Agroindustrial. Universidad del Tolima, Colombia. http://repository.ut.edu.co/handle/001/1251

Vargas, Y., Villamil, O., Murillo, E., Walter, M., & Solanilla, J. (2012). Caracterización fisicoquímica y nutricional de la harina de frijol caupí *Vigna unguiculata* L. cultivado en Colombia. *Vitae 19(1)*, S320-S321. https://www.redalyc.org/pdf/1698/169823914099.pdf