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Sensory analysis of pancakes made with sorghum flour, xanthan gum and microbial transglutaminase enzyme

Análisis sensorial de panqués elaborados con harina de sorgo, goma xantana y enzima transglutaminasa microbiana

Avaliação sensorial de panquecas elaboradas com farinha de sorgo, goma xantana e enzima microbiana transglutaminase

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Abstract

Sorghum is a cereal used as fodder, mainly. Despite being a beneficial product for human health, its consumption is little or null in Mexico. The food industry could be an alternative to diversify this cereal in products compatible with celiac people. The study was focused on the consumer's characterization and the sensory assessment of pancakes elaborated with various proportions of xanthan gum (GX) and the microbial transglutaminase (MTG) enzyme in two cities from the central and northeastern regions of Mexico. A survey, designed and validated previously, was given to 58 consumers where the demographic characteristics of participants and the sensory analysis of nine pancakes (P) were explored. The latter were prepared with the following proportions of GX/MTG: P1 (0/0 %), P2 (0/0.25 %), P3 (0/0.5 %), P4 (0.25/0 %), P5 (0.25/0.25 %), P6 (0.25/0.5 %), P7 (0.5/0 %), P8 (0.5/0.25 %), P9 (0.5/0.5 %) and a commercial pancake (control). The study revealed that the majority of the participants were women (77.5 %). The predominant age was between 20 and 29 years (51.7 %) with a university academic level (30.2 %) and postgraduate degree (38 %), and income $\geq$ \$20,000 MXN (53.6 %). The most preferred and accepted pancakes were P9 and P7 followed by the control, P5 and P8. However, the most accepted pancake was the control followed by P7 and P9. It is concluded that sorghum pancakes represent an alternative with health benefits for people with celiac disease.

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Resumen

El sorgo es un cereal utilizado como forraje, principalmente. A pesar de ser un producto benéfico para la salud humana, su consumo es poco o nulo en México. La industria alimentaria podría ser una alternativa para diversificar este cereal en productos compatibles con personas celíacas. El estudio se enfocó en la caracterización de consumidores y la evaluación sensorial de panqués elaborados con diferentes proporciones de goma xantana (GX) y la enzima transglutaminasa microbiana (MTG) en dos ciudades de la región centro y noreste de México. Un cuestionario, previamente diseñado y validado, fue administrado a 58 consumidores donde se exploraron las características demográficas de los participantes y el análisis sensorial de nueve panqués (P). Estos últimos fueron preparados con las siguientes proporciones de GX/MTG: P1 (0/0 %), P2 (0/0,25 %), P3 (0/0,5 %), P4 (0,25/0 %), P5 (0,25/0,25 %), P6 (0,25/0,5 %), P7 (0,5/0 %), P8 (0,5/0,25 %), P9 (0,5/0,5 %) y un panqué comercial (testigo). El estudio reveló que, de los participantes, la mayoría eran mujeres (77,5 %). La edad predominante fue entre 20 y 29 años (51,7 %) con un nivel académico universitario (30,2 %) y de postgrado (38 %) e ingresos ≥ $ 20, 000 MXN (53,6 %). Los panqués de mayor preferencia y aceptación fueron el P9 y P7 seguido por el testigo, P5 y P8. Sin embargo, el panqué de mayor aceptación fue el testigo seguido por el P7 y P9. Se concluye que los panqués de sorgo representan una alternativa con beneficios para la salud de personas celíacas.

Palabras clave: segmentación de consumidores, goma xantana, transglutaminasa microbiana, aceptación y preferencia, pacientes celíacos.

Resumo

O sorgo e um cereal utilizado como forragem, principalmente. Ainda de ser um produto benéfico para a saúde humana, seu consumo é pouco o nulo no México. A indústria alimentaria pode ser uma alternativa para diversificar esta cereal em produtos compatíveis com pessoas celíacas. O estúdio centrou-se na caracterização de consumidores e avaliação sensorial de panquecas elaboradas com diferentes proporções de goma xantana (GX) e a enzima microbiana transglutaminase (MTG) em duas cidades na região central e nordeste do México. Foi aplicado um questionário, previamente desenhado e validado, foi administrado a 58 consumidores onde foram exploradas as características demográficas dos participantes e a avaliação sensorial de nove panquecas (P). Estes foram preparados com as seguintes proporções de GX/MTG P1 (0/0 %), P2 (0/0,25 %), P3 (0/0,5 %), P4 (0,25/0 %), P5 (0,25/0,25 %), P6 (0,25/0,5 %), P7 (0,5/0 %), P8 (0,5/0,25 %), P9 (0,5/0,5 %) e uma panqueca comercial (testemunha). O estúdio revelou que, dos participantes, a maioria eram mulheres (77,5%). A idade predominante tinha entre 20 e 29 anos (51,7 %) com um nível académico universitário (30,2 %) com post-grado (38 %) e renda ≥ $ 20.000 MXN (53,6 %). A panquecas de maior preferência e aceitação foram o P9 e P7 seguido por a testemunha, P5 e P8. Porém, a panqueca de maior aceitação foi a testemunha seguida por o P7 e P9. Conclui-se que as panquecas de sorgo representam uma alternativa alternativa com benefícios para a saúde de pessoas com doença celíaca.

Palavras chave: segmentação de consumidores, goma xantana, enzima microbiana transglutaminase, aceitação e preferência, pacientes celíacos.

Introduction

The Organization for Economic Cooperation and Development ranked Mexico in second place among the nations with the highest rate of obesity, whose trend begins at an early age (Organization for Economic Cooperation and Development [OECD], 2022). On the other hand, 75 % of the Mexican population aged 20 and older is overweight or obese; while 35 % of school-age children and 38 % of adolescents suffer from this chronic-degenerative disease (National Health and Nutrition Survey [ENSANUT], 2018). This condition increased during social distancing due to the SARS-CoV-2 (COVID-19) pandemic.

The Pan American Health Organization (PAHO) indicated that Mexico is one of the main Latin American countries in the consumption of ultra-processed foods, whose average annual *per capita* consumption is 214 kg (Pan American Health Organization [PAHO], 2022). The latter has resulted in 1 % suffering from wheat allergy among the Mexican population; while non-gluten sensitivity varies between 1 and 25 % in specific populations (Cobos-Quevedo *et al.,* 2017).

Sorghum is a cereal rich in protein (between 10.9 and 12.0 %) that can help the gluten-intolerant population (Marchini *et al.,* 2021). In addition, different studies have proven that sorghum contains high levels of phenolic compounds (Awika *et al.*, 2005) between 0.46 and 20 mg per g gallic acid equivalents (Li *et al.*, 2021) and, therefore, rich in antioxidant properties (Awika *et al.,* 2005). It contains fatty acids such as linoleic (35.7 %), oleic (37.6 %), palmitic (18.6 %), and 2.1 % linolenic acid (Pontieri *et al.,* 2022). This is associated with protective effects against several chronic-degenerative diseases (Wu *et al.,* 2018; Slavin, 2004). It has also been shown that its consumption reduces cholesterol and triglyceride levels up to 50 % when this cereal is ingested by patients with hypercholesterolemia (Treviño-Salinas *et al.,* 2021).

The importance of sorghum in Mexico lies in the area destined for cultivation, which amounts to 1,621,971.88 ha and generated a production of 4,370.064 t (Agri-Food and Fisheries Information Service [SIAP], 2022). Worldwide, Mexico accounts for 10 % of sorghum production (Food and Agriculture Organization of the United Nations [FAOSTAT], 2020). However, the production was mainly destined for animal consumption (Cuevas *et al.,* 2020). For the above, generating added value through sorghum flour offers a window of opportunity with the purpose of developing gluten-free foods as an option for a particular consumer niche. However, gluten removal has unpleasant effects such as poor texture, taste, aroma, color and short shelf life of processed products (Motahar *et al.,* 2021). Thus, the production of gluten-free bread, with acceptable quality, has become a great challenge in the food chain. Consequently, this research is not only presented with a new pancake product based on sorghum flour, but also presents an analysis of preference and acceptance of potential consumers of this product. Therefore, the study was focused on the characterization of consumers and sensory evaluation of pancakes made with different proportions of xanthan gum (GX) and the microbial transglutaminase enzyme (MTG) in two cities in the central and northeastern regions of Mexico.

Materials and methods

Sample selection

The information was obtained through a convenience survey prepared in person to consumers who visited shopping centers in

the city of Querétaro, Querétaro (Center), and Reynosa, Tamaulipas (Northeast) of Mexico in January 2014. Simple random sampling was selected for an infinite population with age-proportional fixation (people over 20 years old) and consumption habits of some type of flour. An error of 10 % was established, a confidence level of 95 % (Sánchez-Toledano *et al.,* 2013), and with this, the number of surveys to be applied was estimated (*n* = 58). The survey included 15 closed questions, which were validated with 15 consumers to correct errors. The questions were segmented into 1) demographic characteristics of the participants and 2) sensory analysis without information on the elaboration of the product (Malhotra, 2008).

Development of prototypes of pancake made with sorghum flour

The variety of sorghum used for the development of the product was 'RB Paloma' produced in Tamaulipas, Mexico, and provided by the Río Bravo Experimental Station, belonging to the National Institute of Forestry, Agricultural and Livestock Research. First, the grain was cleaned, washed with drinking water, and immediately dried in a stove (Drying oven DHG-9145[a]) at 30 ± 2 °C until it reached a humidity between 12-13 %. Subsequently, the grain was pulverized in a hammer mill (Azteca No. 6, Type GP 100) with a 0.4 mm screen and sieved in a mesh number 80 (Manufacturers of Industrial and Commercial Supplies). Later, the sorghum flour obtained was vacuum packed in plastic bags and stored at 5 °C until use.

The elaboration of the prototypes of pancakes was carried out according to Figueroa-González *et al.* (2015) with some modifications. The first step was to weigh the ingredients separately. Subsequently, the vegetable oil (10 g) was mixed with sugar (10 g) for two minutes, the egg yolk (5 g) was added and mixed for one minute, and then the sorghum flour (50 g) was added. Sodium bicarbonate (1.3 g), ascorbic acid (1.3 g), and salt (0.1 g) were added to the mixture to mix again for one minute. Subsequently, 23 mL of whole cow's milk at 50 °C, vanilla (0.6 mL), xanthan gum (GX), and microbial transglutaminase (MTG) were added and mixed for one minute to later add the egg white (5 g). Separately, the mold was greased with vegetable oil (1 g) and covered with sorghum flour (1.0 g) to prevent adhesion of the dough on the walls of this during baking. The mixture was emptied into the mold and baked in a homemade stove (Acros gas stove AF3600B) at 250 °C for 45 minutes. The pancakes were left to rest in the oven for 30 minutes, unmolded, and packed in cellophane bags for sensory analysis. The prototype pancakes had the following GX/MTG ratios: prototype 1 (0/0 %), prototype 2 (0/0.25 %), prototype 3 (0/0.5 %), prototype 4 (0.25/0 %), prototype 5 (0.25/0.25 %), prototype 6 (0.25/0.5 %), prototype 7 (0.5/0 %), prototype 8 (0.5/0.25 %) and prototype 9 (0.5/0.5 %). The control consisted of a commercial pancake.

GX is an extracellular polysaccharide produced by the bacterium *Xanthomonas campestris*. GX imitates the rheological properties of gluten, conferring high viscosity and strength to bread dough due to its interaction with proteins (Burešová *et al.,* 2016). Commercial enzymes, especially microbial transglutaminase (MTG) are widely used in fermented wheat flour-based products as conditioners to promote protein networks and improve product quality attributes (Gao *et al.,* 2021).

Sensory evaluation of the pancake made with sorghum flour and the control

The sensory evaluation was done the day after the elaboration of the different prototypes of pancakes together with the control pancake. The control pancake was made with 100 % wheat flour and is widely sold in commercial establishments distributed in the cities where the study was carried out. The pancakes were sliced into cubes of 4 × 4 x 1 cm. Consumers assessed, in a blind condition, the preference of pancakes made with sorghum flour and commercial bread made with wheat. The preference of panelists for different pancake samples was assessed based on smell (aroma), sight (color), touch (softness), and taste (bitter aftertaste, moisture, and adhesiveness). The samples were presented monodically (Di Monaco *et al.,* 2004) and water was offered between each sample. The panelists rated the acceptance of the prototypes with the Hedonic scale (1 = I dislike it extremely, 2 = I dislike it a lot, 3 = I dislike it moderately, 4 = I dislike it a little, 5 = I do not like or dislike it, 6 = I like it little, 7 = I like it moderately, 8 = I like it a lot, 9 = I like it extremely) (Abdelghafor *et al.,* 2011).

The survey was validated and approved by an ethics committee of the social sciences and carried out according to the principles established in the Declaration of Helsinki with special attention to the protection of personal information, according to Mexican standards.

Statistical analysis

Before analyzing the information, the hedonic scores of consumers were standardized to normalize the data. The information was analized in a completely randomized model and internal preference mapping (MDPREF) was obtained. Subsequently, the multivariate technique of correspondence analysis (CA) was applied to determine the possible simultaneous association between the pancake prototypes including the commercial control with the evaluated attributes (Hair *et al.,* 1998).

The information was analyzed in the SPSS 27.0 software program for Windows (IBM, 2022) and in the statistical analysis system (SAS ver. 9.4 2002-2010) (Ferrán-Aranaz, 2001).

Results and discussion

Establishing the demographic characterization of the participants contributes to knowing the socioeconomic level of consumers who would potentially be willing to include a new product in their diets. Therefore, the analysis of the information indicated that the sample of participants consisted of 22.4 % men and 77.6 % women. The highest proportion was concentrated in consumers between 20 and 29 years old (51.7 %), followed by consumers over 60 years old (31.2 %). The sample in terms of age and gender was comparable with the official population statistics (INEGI, 2020) (table 1).

Table 1. Sociodemographic characteristics.

Characteristics of the sampled population	Sample (*n*=58)* (%)	Total population of the Mexican Republic** (%)
Gender		
Female	77.5	51.4
Male	22.5	48.6
Age (years)		
20-29	51.7	25.6
30-40	3.4	14.4
41-60	13.7	21.8
>60	31.2	10.5
Educational level		
Primary	7.0	31.2
Secondary school	10.0	27.9
High school	9.8	21.7
University	35.2	18.6
Post-university	38.0	8.0

Table 1. Sociodemographic characteristics. (Continuación).

Characteristics of the sampled population	Sample (*n*=58)* (%)	Total population of the Mexican Republic** (%)
Income (MXN)		
Less than 5,000	6.2	29.0
5,001-10,000	10.1	32.0
10,001-15,000	12.9	34.0
15,001-20,000	17.2	3.1
20,001-30,000	25.1	1.0
Over 30,000	28.5	0.9

*Own elaboration; **Source INEGI (2022).

In education and income, the sample included a higher proportion of people with greater academic preparation than that detected at the population level (INEGI, 2020). This discrepancy may have been due, in part, to sampling sites. The states of Querétaro and Tamaulipas have grown economically and developed capacities to attract talent and investment in terms of gross domestic product (GDP) *per capita* (INEGI, 2022).

Consumer preference and acceptance of the pancake

In sensory experience, the most important attributes for the consumer panel were color, aroma, and sweetness, whose mean values on the hedonic scale were 6.8, 6.7, and 6.7, respectively. While attributes such as bitter aftertaste (6.2) and adhesiveness (6.0) liked moderately. In contrast, the mean values of humidity (5.5) and softness of the product (5.8) tended to taste slightly (figure 1).
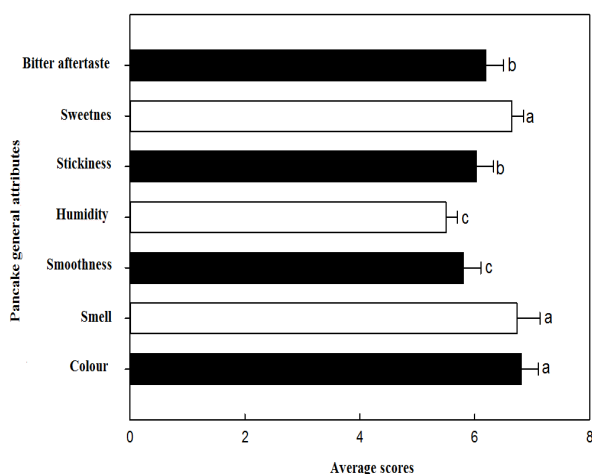

Figure 1. Mean hedonic scores of the sorghum flour pancake attributes. † 1 = I dislike it extremely, 2 = I dislike it a lot, 3 = I dislike it moderately, 4 = I dislike it a little, 5 = I don't like it or dislike it, 6 = I like it little, 7 = I like it moderately, 8 = I like it a lot, 9 = I like it extremely. [a, b, c] Statistical differences between different consumer groups at 95 % (Tukey).

Likewise, the prototypes with the best preference and acceptance by consumers were the control (commercial) and prototypes 5 (0.25/0.25 %), 7 (0.5/0 %), 8 (0.5/0.25 %) and 9 (0.5/0.5 %). In contrast, the lowest scores were given to prototypes 1 (0/0 %), 2 (0/0.25 %), and 3 (0/0.5 %) (table 2).

Table 2. Consumer preference and acceptance towards prototype pancakes made with sorghum flour and different proportions of xanthan gum and microbial transglutaminase.

Prototypes of Pancakes	*n**	Preference†	Consumer acceptance (%)		
			I like it extremely	Neither likes it nor dislikes it	Dislike it
P1	58	2.96 b	84.48	3.45	12.07
P2	58	2.94 c	68.97	10.34	20.69
P3	58	3.00 b	77.59	3.45	18.96
P4	58	3.04 b	79.31	5.17	15.52
P5	58	3.14 c	84.48	1.73	13.79
P6	58	3.00 b	74.14	12.07	13.79
P7	58	3.23 a	89.66	3.44	6.90
P8	58	3.12 a	77.59	12.07	10.34
P9	58	3.24 a	86.21	5.17	8.62
Control	58	3.14 a	91.38	3.45	5.17

*Sample Size
† 1 = I dislike it, 2 = I don't like or dislike it, 3= I like it.
[a, b, c] Statistical differences between different consumer groups at 95 % (Tukey).

This can be attributed to a low consistency of the pancake due to the absence of GX; in addition, this is indicative that MTG, by itself, does not provide the characteristics of dough and volume to be preferred by consumers. Then, the incorporation of GX and MTG is done in gluten-free bread in order to improve the rheology, texture, nutritional, and even sensory properties. In this regard, Jaros *et al.* (2006) indicated that MTG is one of the most widely used enzymes in the baking industry because it catalyzes the crosslinking reactions between glutamine and lysine/glutamine or glutamine and water. On the other hand, Castillejos *et al.* (2018) stated that adding of MTG to bread made with quinoa flour and sorghum improved the values of chewability, gumminess, and cohesion decreasing the hardness of the product. Thus, adding of these proteins positively affects the nutritional composition and texture properties of breads.

The MDPREF confirmed the heterogeneity of consumers in the face of the various prototypes and quality attributes minimally required. In this way, differentiated business strategies can be applied, which will allow producers to adopt technological innovation (pancake) to obtain better profits.

Figure 2 presents the internal preference mapping of the prototypes, the control, and the consumers. The first two factors accounted for approximately 90.2 % of the explained variance (74.6 % and 15.6 % for the first and second axis, respectively).

The results showed that consumers were not evenly distributed across the quadrants of the map, reflecting the existence of heterogeneous preferences. However, the majority (60 %) of consumers are positioned on the right side of the map (Quadrant I, figure 2), in the direction of prototypes 5, 7, 8, and 9 where intrinsic and extrinsic attributes are best valued.
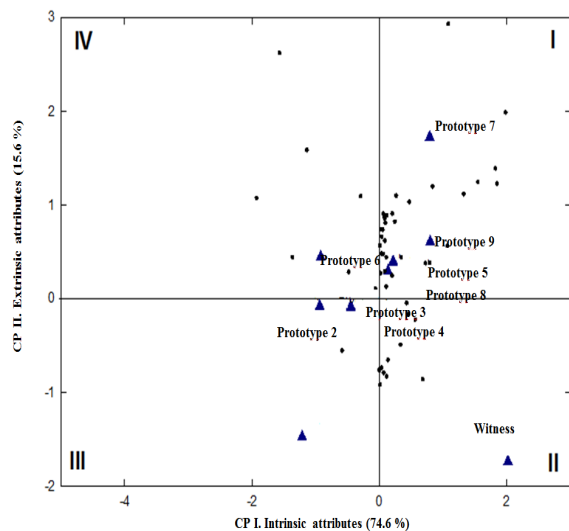
Figure 2. Internal preference mapping based on nine prototypes of pancakes made with sorghum flour and a commercial pancake as a control.

So, the elaboration of gluten-free pancake with better organoleptic characteristics, as well as functional properties, using innovative ingredients and better prices, is a challenge for the bakery industry (Molina-Rosell, 2013).

On the contrary, prototype 1 is positioned on the left side (Quadrant III, figure 2), where the density of consumers decreased considerably. The aforementioned is attributed to the fact that the hydrocolloids used have a sensory impact on the attributes of the pancake. Gluten-free breads are characterized by the use of specific additives to enhance them, among which are starches, proteins, fibers, fats, hydrocolloids, and specific enzymes (Turkut *et al.,* 2016). However, to prototype 1, no additives were added to improve both dough development and gas retention through increased viscosity, thus producing bread with low baking properties and quality.

On the other hand, the control pancake was positioned in quadrant II (figure 2) where consumers associate it with favorable intrinsic attributes, but extrinsic attributes have a negative value. The color of the commercial pancake was dull and brown; while pancakes made with sorghum flour were characterized by having a bright yellow crust and a crunchy texture, so this attribute attracted consumers. Product appearance induces an increase or decrease in repeat purchases of the product. Studies indicate that the factors that influence the choice of a product are taste, quality, and appearance (García *et al.,* 2019). Consequently, pancake consumers seek, regardless of price, a product that looks good, low in fat, high in protein, and with medium durability (Meyerding *et al.,* 2018). However, these last parameters were not evaluated in this study.

Multiple correspondence analysis indicated dependence (χ^2 = 232.4; p <0.0001) between the prototypes and the intrinsic and extrinsic attributes of the pancake made with sorghum flour. This analysis indicated that the first two dimensions accumulated 79.2 % of the total inertia (Figure 3).

Aroma and sweetness tended to be better associated with prototype 3 (Quadrants III and IV); while attributes such as softness and adhesiveness did not seem to be associated with any prototype (Quadrant I). Instead, color and humidity tended to be associated with prototypes 2, 5, 6, and 7 (Quadrant II). Prototypes 9 (Quadrant I), 4 (Quadrant (III), 8 (Quadrant IV), and the control (positioned at the midpoint) do not seem to be associated with any of the attributes included in this study (figure 3).
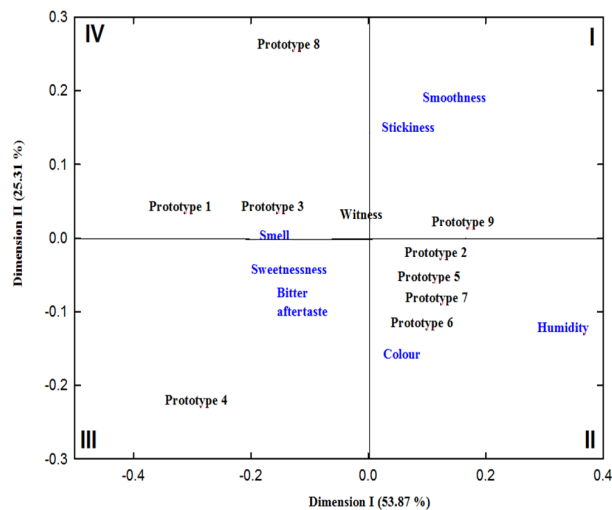

Figure 3. Mean two-dimensional positioning of attributes and prototypes qualified by the consumer panel.

Consumers are increasingly moving towards preferring healthy, nutritious, fat-free, low-salt, wholemeal and local bread, which is often obtained from cereals other than wheat or pseudo cereals (Annett *et al.,* 2008). In this study, participants had no information on the health benefits of using sorghum flour, so they were guided, perhaps, by hedonic aspects. In this sense, Vermeir and Verbeke (2008) mentioned that the process of food choice is the result of a complex set of interrelated subjective and environmental factors, which is related to many conscious aspects and also to individual, automatic, habitual, and subconscious motivations. The first ones are related to the sensory characteristics, health properties, and cost of bread, as well as consumer characteristics such as social and economic status. These last are linked to motivational, cognitive, and affective processes.

Conclusions

The sensory analysis of the composition of the pancake made with sorghum indicated, on average, that the most important attributes that determine the purchase preferences of the pancake were color, aroma, and sweetness. From the business point of view, these results generate an area of opportunity for this product with these attributes.

The study showed that the prototypes of pancakes with market potential were 7, 9, 5, and 8 with GX and MTG proportions of (0.5/0 %), (0.5/0.5 %), (0.25/0.25 %) and (0.5/0.25 %), respectively. For this reason, the different marketing strategies (promotion, place, and price) must be analyzed in order to position them in the market.

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