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Acceptability, shelf life, and microbial analysis of glutinous corn (*Zea mays*) bar as functional food

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Abstract

This study aimed to develop and evaluate the acceptability of an energy bar made from glutinous corn (Zea mays L.). Specifically, it sought to assess the sensory qualities (appearance, aroma, color, taste, and texture) as evaluated by experts and consumers, determine significant differences among formulations, and evaluate the shelf life and microbial safety of the best treatment. The study employed an experimental Completely Randomized Design with three treatments varying only in the amount of glutinous corn: Treatment A (200 g), Treatment B (175 g), and Treatment C (150 g). A panel of ten experts evaluated the products over three replications, followed by 100 consumer respondents. Data were analyzed using mean, one-way ANOVA, and LSD post hoc tests. Results showed that Treatment B consistently received the highest ratings from both experts and consumers, being described as "Extremely Appealing," "Extremely Pleasant," "Extremely Authentic," "Extremely Delicious," and "Extremely Firm." Significant differences ($p < .01$) were found among treatments for all sensory qualities, with Treatment B being significantly superior. The product had a shelf life of 72 hours at room temperature and 360 hours under chilling temperature without mold formation. Microbial analysis confirmed that the glutinous corn energy bar met BFAD safety standards. The study concludes that glutinous corn can be effectively used to produce an acceptable, safe, and commercially promising energy bar.

Keywords: Glutinous Corn; Energy Bar; Sensory Evaluation; Acceptability; Shelf Life; Microbial Analysis; Food Product Development

1. Introduction

In today's fast-paced world, the increasing demand for convenient and ready-to-eat food products has led to the widespread popularity of energy bars. These products, initially developed for athletes (Norajit et al., 2011), have become a common snack among working individuals and those with limited time for meal preparation due to their ability to provide essential nutrients such as carbohydrates, proteins, fats, vitamins, and minerals (Wyatt, 2011; Ryland et al., 2010; Drayer, 2017). Their growing market appeal is further driven by their image as healthy and convenient food options, reinforced through product labeling and advertising strategies (Bower and Whitten, 2010). However, despite these perceived benefits, many commercially available energy bars contain high levels of sugar and saturated fats, making them comparable to confectionery products rather than genuinely nutritious alternatives (Drayer, 2017). This situation highlights a significant concern regarding the actual health value of these products and underscores the need for improved, more nutritious formulations.

Several efforts have been made to enhance the nutritional quality of energy bars through the use of alternative ingredients such as cereals, fruits, and legumes (Sun-Waterhouse et al., 2010). While these initiatives have contributed to product innovation, many existing formulations still rely on expensive or imported raw materials, limiting their accessibility and affordability. In addition, some products prioritize nutritional enhancement without adequately

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addressing sensory qualities such as taste, aroma, and texture, which are essential for consumer acceptance. These limitations suggest the need for a more sustainable and locally adaptable approach in developing energy bars.

In the Province of Capiz, glutinous corn (Zea mays L.) is an abundant agricultural resource with promising potential as a food ingredient. Its starch composition, consisting almost entirely of amylopectin (Moncel, 2018), classifies it as a slow-digesting carbohydrate that supports sustained energy release and efficient glycogen replenishment (Ai and Jane, 2016; Jozsi et al., 2010). Furthermore, its availability and low cost make it a practical and economical source of carbohydrates (Sands et al., 2009). Despite these advantages, glutinous corn remains underutilized in the development of value-added food products.

In response to these gaps, this study proposes the development of a glutinous corn energy bar as a functional food product. The uniqueness of this study lies in its utilization of a locally abundant crop to produce a nutritious, affordable, and sensory-acceptable energy bar, thereby addressing both health concerns and economic sustainability.

This study aims to determine the level of acceptability of glutinous corn energy bars in terms of appearance, aroma, color, taste, and texture. It also seeks to identify the most preferred formulation based on varying proportions of glutinous corn and to evaluate the shelf life and microbial safety of the developed product. Ultimately, this study intends to contribute to the development of a healthier alternative to commercial energy bars while promoting the utilization of local agricultural resources.

2. Materials and Instruments

The materials used in the preparation of the glutinous corn energy bar included glutinous corn, glucose, brown sugar, glutinous corn stock, powdered milk, honey, powdered brown rice (toasted), skinned nuts (toasted and chopped), pinipig (toasted), chopped raisins, and dried fruits (pineapple). All ingredients were obtained from local markets and grocery stores.

The instruments and equipment utilized in the study consisted of a gas range oven, blender, measuring spoons, measuring cups, nonstick pan, mixing bowl, ladle, rolling pin, colander, utility tray, paring knife, working table, Pyrex baking pan, scissors, mortar and pestle, and weighing scale.

Table 1 Experimental treatments used in the study.

Ingredients	**Treatment**		
	A	**B**	**C**
Glutinous Corn (Boiled)	200 grams	175 grams	150 grams
Glucose	1 tsp.	1 tsp.	1tsp.
Brown Sugar	50 grams	50 grams	50 grams
Glutinous Corn Stock	2 tbsp.	2 tbsp.	2 tbsp.
Powdered Milk	50 grams	50 grams	50 grams
Honey	2 tbsp.	2 tbsp.	2 tbsp.
Powdered Brown Rice (toasted)	100 grams	100 grams	100 grams
Skinned Nuts (toasted, chopped)	50 grams	50 grams	50 grams
Pinipig (toasted)	50 grams	50 grams	50 grams
Chopped Raisins	25 grams	25 grams	25 grams
Chopped Dried fruits(pineapple)	50 grams	50 grams	50 grams

2.1. Experimental Procedures

The study employed an experimental research design using a Completely Randomized Design (CRD) with three treatments and three replications. The treatments varied only in the amount of glutinous corn used: Treatment A (200 g), Treatment B (175 g), and Treatment C (150 g), while all other ingredients and procedures were kept constant.

For the preparation, glutinous corn kernels were removed from the cob, washed, and boiled for 30 minutes. The cooked kernels were cooled, mashed, and measured according to the required treatment proportions. The wet ingredients (powdered milk, corn stock, honey, and glucose) were mixed separately. The mashed glutinous corn and brown sugar were combined, followed by the addition of the wet mixture. The resulting batter was spread evenly in a greased baking pan and baked at 350°F for 15–20 minutes. The product was then cooled and cut into uniform portions.

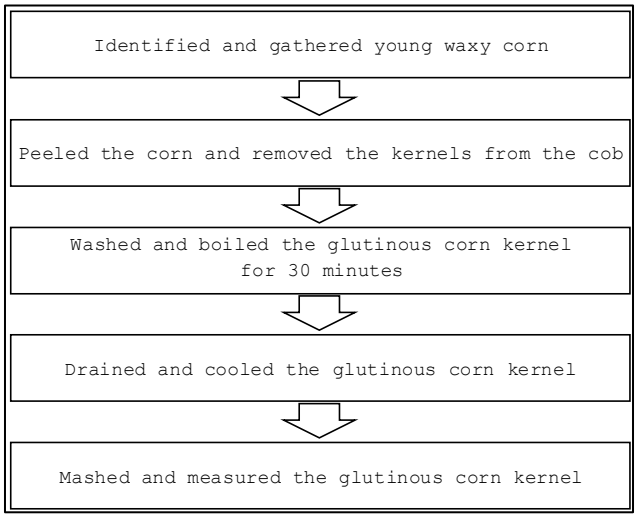

Figure 1 Process showing the preparation of glutinous corn.

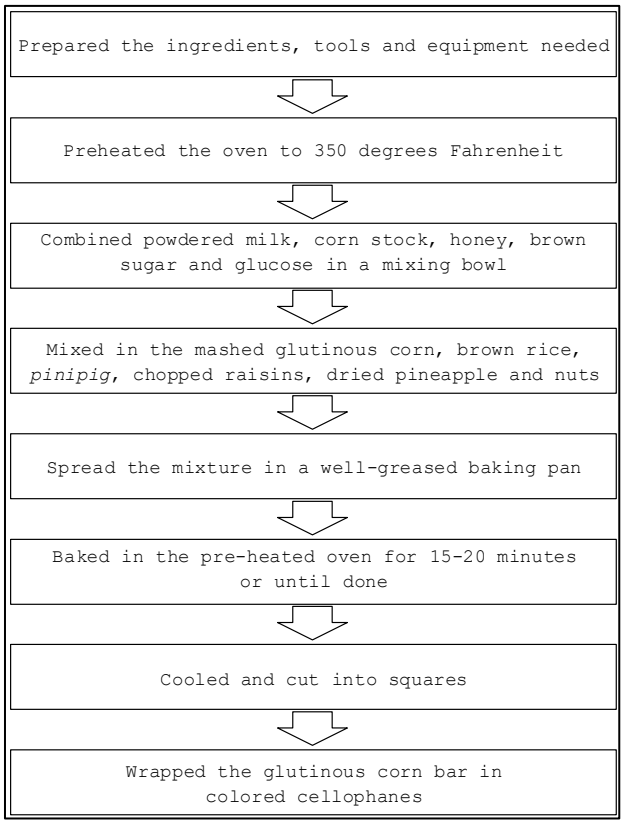

Figure 2 Procedure in making the glutinous corn energy bar

2.2. Data Collection and Evaluation

Sensory evaluation was conducted using a nine-point hedonic scale to assess appearance, aroma, color, taste, and texture. The evaluation was carried out in two phases: first by a panel of ten expert evaluators in three replications, and second by 100 consumer respondents composed of teachers, students, bakers, and housewives.

2.3. Ethical Considerations

This study involved human participants for sensory evaluation. Prior to participation, all respondents were informed about the purpose of the study and were asked to voluntarily participate. Informed consent was obtained from all participants. The procedures conducted posed minimal risk, as the study only involved food tasting and evaluation.

No animal subjects were involved in this study. Formal institutional ethical committee approval was not required; however, the study adhered to ethical standards in ensuring voluntary participation, confidentiality, and safety of all respondents.

3. Results and Discussion

Sensory Qualities as Evaluated by

3.1. Experts in Three Replications

The data on the evaluation of the sensory qualities of glutinous corn energy bar by a panel of experts in three replications are shown in Table 2.

In terms of appearance, Treatment B was the most liked by the panel of experts as it got the highest mean of 8.37 which is interpreted as “Extremely Appealing”. Both treatments C and A were found to be “Very Much Appealing” with means of 8.03 and 7.77 consecutively. This clearly shows that among the three replications, Treatment B was the most attractive in terms of its appearance to the panel of experts.

Table 2 Overall sensory qualities of glutinous corn energy bar among three treatments.

Sensory Qualities	**Overall Evaluation of Experts**					
	TA	AD	TB	AD	TC	AD
Appearance	7.77	VMA	8.37	EA	8.03	VMA
Aroma	7.87	VMP	8.37	EP	8.00	VME
Color	7.80	VMAu	8.53	EAu	8.03	VMAu
Taste	7.63	VMD	8.47	ED	7.77	VMD
Texture	7.70	VMF	8.60	EF	8.13	EF

Legend: AD – Adjectival Description; VMA – Very Much Appealing; EA – Extremely Appealing; VMP – Very Much Pleasant; EP – Extremely Pleasant; VMAu– Very Much Authentic; Eau– Extremely Authentic; VMD – Very Much Delicious; ED – Extremely Delicious ; VMF – Very Much Firm; EF – Extremely Firm; MA - Moderately Appealing

As to the aroma of glutinous corn energy bar, Treatment B still was rated at “Extremely Pleasant” with a mean of 8.37.

This was followed by Treatments C and A which were described to be “Very Much Appealing” with means of 8.00 and 7.87 respectively. The results imply that Treatment B smelled the best as compared to the other two treatments as perceived by the panel of experts.

For the color of the product, it can be seen from the table that Treatment B was considered to be “Extremely Authentic” in its color as it was given the mean of 8.53. The other two treatments were described to be “Very Much Authentic” with means of 8.03 for Treatment C and 7.80 for Treatment A. This indicates that in terms of the color of the glutinous corn energy bar, Treatment B was the most preferred by the experts as it was observed to be pleasant and authentic in its color.

As to the its taste, the panel of experts identified Treatment B to be “Extremely Delicious” with a mean of 8.47. It was followed by Treatment C with 7.77 and Treatment A with 7.63. Both were interpreted as “Very Much Delicious”. The

data simply shows that for the sensory quality in terms of taste, Treatment B was very much superior among the three treatments and that it indicates a good possibility of being commercialized or sold to the market as it was very pleasing to the taste buds of the experts.

Lastly, for the texture of the products, it was found out that in the three replications conducted, Treatments B and C were observed to be "Extremely Firm" with means of 8.6 and 8.13 respectively, while Treatment A was rated to be "Very Much Delicious" with a mean of 7.7. This denotes that for the texture of the product, experts found that Treatments B and C have more than satisfactorily passed their standards in terms of the firmness of the product.

3.2. Acceptability of Glutinous Corn Energy

3.2.1. Bar as Evaluated by Consumers

The results on the evaluation conducted by consumers on the level of acceptability of glutinous corn energy bar are shown in Table 3. The 100 consumers who evaluated the end products were composed of TLE teachers, Grade 12 cookery students, bakers and housewives. They evaluated the product in terms of its sensory qualities such as appearance, aroma, color, taste and texture.

Table 3 Consumers' general acceptability of glutinous corn energy bar.

Sensory Qualities	**Treatment A**		**Treatment B**		**Treatment C**	
	Mean	**QD**	**Mean**	**QD**	**Mean**	**QD**
Appearance	7.41	LVM	8.07	LVM	7.35	LVM
Aroma	7.37	LVM	7.90	LVM	7.52	LVM
Color	7.56	LVM	8.06	LVM	7.65	LVM
Taste	7.02	LM	8.02	LVM	7.37	LVM
Texture	7.30	LVM	7.89	LVM	7.47	LVM
General Acceptability	**7.33**	**LVM**	**7.99**	**LVM**	**7.47**	**LVM**

Legend: LVM – Liked Very Much; LM – Like Moderately; QD – Qualitative Description

It can be observed that all three treatments have been described by the consumers as "Liked Very Much". This was evident in their acceptability mean for each treatment, where Treatment B got the highest mean of 7.99, followed by Treatment C with 7.47 and Treatment A with a mean of 7.33. With these means, it can be inferred that Treatment B was the most preferred product by the consumers in all the facets of its sensory qualities.

This is also in consonance with the results of the evaluation of experts, where it was found out that Treatment B generally was the most favored among the three treatments according to its sensory qualities, while Treatment A was the least liked product of the three.

From the findings of the consumer evaluation, the ratio of the glutinous corn in the Treatment B was the most acceptable and may have a strong marketability if ever the product would be sold to the market.

3.3. Difference in the Sensory Qualities of Glutinous Corn Energy Bar

Table 4 presents the analysis of variance (ANOVA) results on the sensory qualities of the glutinous corn energy bar as evaluated by experts. The findings revealed that there were significant differences among the three treatments in all sensory attributes, including appearance, aroma, color, taste, and texture.

For appearance, a significant difference was observed ($F(2,27) = 6.158$, $p = .006$), indicating that the variation in the amount of glutinous corn significantly affected the visual appeal of the product. The null hypothesis was therefore rejected. Post hoc analysis showed that Treatment B was significantly better than Treatment A, while no significant differences were found between Treatments B and C and between A and C. This suggests that Treatment B exhibited a more desirable appearance.

In terms of aroma, a significant difference was also found ($F(2,27) = 6.463$, $p = .005$). This indicates that the proportion of glutinous corn influenced the aroma of the product. The null hypothesis was rejected. Further analysis using LSD

revealed that Treatment B significantly differed from Treatments A and C, indicating that it had the most preferred aroma.

Table 4 Mean difference in the sensory qualities of glutinous corn energy bar**.**

Source of Variance	Sum of Squares	df	MS	F-value	p-value	Remarks
Appearance	1.819	2	0.909	6.158	0.006	s
	3.987	27	0.148			
	5.806	29				
Aroma	1.347	2	0.674	6.463	0.005	s
	2.814	27	0.104			
	4.161	29				
Color	2.797	2	1.399	9.527	0.001	s
	3.964	27	0.147			
	6.761	29				
Taste	4.008	2	2.004	15.495	0.000	s
	3.492	27	.129			
	7.500	29				
Texture	4.079	2	2.040	23.668	0.000	s
	2.327	27	0.086			
	6.406	29				

Legend: s – significant at .01 level of significance

For color, the results showed a significant difference (F (2,27) =9.527, p=.001), suggesting that varying the amount of glutinous corn contributed to noticeable differences in the color of the energy bars. The null hypothesis was rejected. Post hoc results indicated that Treatment B was significantly superior to both Treatments A and C in terms of color.

With regard to taste, a highly significant difference was observed (F (2,27) =15.495, p=.000). This implies that the variation in glutinous corn proportion significantly influenced the flavor of the product. The null hypothesis was rejected. LSD analysis further revealed that Treatment B obtained the highest rating and was significantly better than the other treatments.

Similarly, texture showed a significant difference among treatments (F (2,27) =23.668, p=.000), indicating that the amount of glutinous corn had a strong effect on the firmness of the energy bars. The null hypothesis was rejected. Post hoc analysis showed that Treatment B was significantly better than Treatments A and C, suggesting that it had the most desirable texture.

3.4. Difference in the General Acceptability of Glutinous Corn Energy Bar

The mean difference in the general acceptability of glutinous corn energy bar as evaluated by consumers is presented in Table 5.

The data revealed that there exists a significant difference (F (2,297) =27.601, p=.000) among the treatments in the study. This implies that the modification done on the proportion of glutinous corn per treatment resulted to a substantial difference on the acceptability of the treatment among the consumers.

Post hoc tests using LSD further showed that Treatment B was significantly preferred by consumers, while Treatments A and C were received similarly by the consumers. In light with the foregoing results of the study, the null hypothesis of the study, which states that there is no significant difference on the level of acceptability of glutinous corn energy bar as evaluated by consumers is rejected.

Table 5 Mean difference in the general acceptability of glutinous corn energy bar among consumers**.**

Source of Variance	Sum of Squares	df	MS	F-value	p-value	Remarks
Glutinous Corn Energy Bar Treatments	23.873	2	11.937	27.601	0.000	s
	128.445	297	0.432			
	152.318	299				

Legend: s – significant at .01 level of significance

The results simply imply that among the three treatments utilized in the study, the proportion of glutinous corn in Treatment B was the most enjoyed by the consumers and was able to satisfy their standards, which means that that particular treatment has potential market value.

3.5. Shelf Life of Glutinous Corn Energy Bar

The results on the shelf life of glutinous corn energy bar at room temperature is presented in Table 6. When the glutinous corn energy bar was stored at room temperature for 72 hours, it was noticed that during a twelve-hour observation interval, there were no molds that formed on the surface of the glutinous corn energy bar.

Table 6 Shelf life of glutinous corn energy bar at room temperature.

Treatments	Observation Interval					
	0-12 Hours	13-24 Hours	21-36 Hours	37-48 Hours	49-60 Hours	61-72 Hours
A	-	-	-	-	-	-
B	-	-	-	-	-	-
C	-	-	-	-	-	-

Legend: (-) – Negative, no mold formation

On the other hand, Table 7 presents the shelf life of the glutinous energy corn bars when stored at chilling temperature. It was notable that no molds were found on the glutinous energy corn energy bar for up to 360 hours with a 120-hour observation interval.

This can be attributed to the fact that the ingredients as well as the procedures used in the preparation of the energy bar has removed a lot of moisture from the raw materials. Therefore, the low moisture content of the product may have contributed to the slow formation of molds.

Thus, based on the observation conducted, it can be inferred that the glutinous corn energy bar is safe to be stored for up to 72 hours without refrigeration and 360 hours at most when placed inside the refrigerator at 5 degrees Celsius.

Table 7 Shelf life of glutinous corn energy bar at chilling temperature.

Treatments	Observation Interval		
	0-120 Hours	121-240 Hours	241-360 Hours
A	-	-	-
B	-	-	-
C	-	-	-

Legend: (-) – Negative, no mold formation

3.6. Microbial Analysis of Glutinous Corn Energy Bar

Table 8 presents the microbial analysis of glutinous corn energy bar made by the DOST Regional Standard and Testing Laboratory, Iloilo City. Test Service Request No. R6-012019-MIC-0091-0136 was submitted on January 28, 2019 and was analyzed from January 28 to February 4, 2019, which was attached in Appendix I.

The samples submitted for microbial analysis was Treatment B with 175 grams of glutinous corn, consisting of 5 pieces at around 25 grams each. These were subjected to Aerobic Plate Count using pour plate method at 35 degrees Celsius for 48 hours (PCA, USFDA BAM Online, 2001), Coliform Count using multiple tube fermentation technique (USFDA BAM Online, 2017), and Mold and Yeast Count using pour plate method at 25 degrees Celsius for 5 to 7 days (PDA, USFDA BAM Online, 2001).

Table 8 Microbial analysis of glutinous corn energy bar.

Sample Description	**Parameter**	**Result**
Glutinous Corn Energy Bar (5 pcs @ 25 g/pc MFD: 01/28/2019)	Aerobic Plate Count	320cfu/g sample
	Escherichia coli Count	< 1.8 MPN/g sample
	Molds and Yeast Count	2 400 cfu/g sample

Microbial analysis showed that the glutinous corn energy bar with 175 grams of glutinous corn attained an Aerobic Plate Count of 320 cfu/g sample. While the Escherichia coli Count of the product was < 1.8 MPN/g sample, and its Molds and Yeast Count obtained the result of 2 400 cfu/g sample. The results given in the said report were those obtained at the time of examination and referred only to that particular sample.

Further, the comparative value of DOST and BFAD microbial analysis of glutinous corn energy bar is shown in Table 9. Since there is no specific reference product for glutinous corn energy bar in the BFAD Reference Criteria, the values for Baked Goods (microbiologically sensitive types, e.g. containing eggs & dairy products) was used for the said comparison.

Table 9 Comparative value of DOST and BFAD microbial analysis of glutinous corn energy bar.

	BFAD Reference Criteria Baked Goods (microbiologically sensitive types, e.g. containing eggs & dairy products)				
Parameter	Allowable Level c	Acceptable Level m	Level of Rejection M	Results	Remarks
Aerobic Plate Count	2	10^4	10^6	320 cfu/g sample	Acceptable
Escherichia coli Count	2	50	10^3	< 1.8MPN/g sample	Acceptable
Molds and Yeast Count	2	10^2	10^4	2 400cfu/g sample	Acceptable

Legend: m - acceptable level of microorganism determined by a specified method; the values are generally based on levels that are achievable under GMP; M – level which when exceeded in one or more samples would cause the lot to be rejected as this indicates potential help hazard or imminent spoilage; c – maximum allowable number of defective or marginally acceptable units (FDA Circular, 2013)

In terms of the Aerobic Plate Count, the product was found to be acceptable as the Aerobic Plate Count of the glutinous corn energy bar, which is 320 cfu/g sample, was below the level of rejection of 106 cfu/g sample. On the other hand, Escherichia coli Count of the product registered the value of < 1.8 MPN/g sample that is below the maximum value of 103 MPN/g sample. Thus, the product was deemed acceptable in terms of Escherichia coli Count. Moreover, for Molds and Yeast Count of the product, the product was considered to be acceptable as a value of 2 400 cfu/g sample was determined from the glutinous corn energy bar, which was lower that the level of rejection of 104 cfu/g sample.

The comparison of the microbial analysis results of glutinous corn energy bar with that of the Revised Guidelines for the Assessment of Microbiological Quality of Processed Foods, revealed that the product was acceptable and safe for human consumption.

4. Conclusion

The study demonstrated that glutinous corn can be effectively used to produce an energy bar with satisfactory sensory qualities. Among the three treatments, Treatment B, containing 175 grams of glutinous corn, was found to be superior in appearance, aroma, color, taste, and texture, consistently receiving the highest ratings from both expert panels and

consumers. The amount of glutinous corn significantly influenced the sensory characteristics and overall acceptability of the product, indicating that formulation levels directly affect product quality. All three treatments were well-received by consumers, demonstrating strong market potential, with Treatment B being the most preferred and most marketable.

Due to its low moisture content, the product exhibited a practical shelf life of three days at room temperature and fifteen days under chilling conditions without mold development. Furthermore, microbial analysis confirmed that the glutinous corn energy bar complied with established food safety standards, making it safe for human consumption. Overall, the study demonstrated that glutinous corn energy bar is not only sensorially acceptable but also safe and commercially promising.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The author declares that there are no financial or non-financial conflicts of interest regarding the publication of this paper.

Statement of ethical approval

The present research work does not contain any studies performed on animals by the author. The study involved minimal risk procedures limited to food product evaluation.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study prior to their participation in the sensory evaluation.

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