# Sensory profile analysis of spice extruded cereal formulated with rice bran and banana flour using Quantitative Descriptive Analysis (QDA)

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**Abstract.** This study aims to analyse the sensory profile of spice breakfast cereal (SBC). The SBC is developed with local material, including rice bran, unripe banana flour, brown palm sugar, and a blend of ginger, cinnamon, and lemongrass powder. Evaluation sensory profile applied with QDA to characterize the sensory profile of the formulated sample and commercial spice cereal. Ten trained panellists identified key sensory attributes, and PCA revealed that the first two principal components explained 86.28% of the total variance. The analysis demonstrated that the formulated samples (F1-F3) successfully developed a complex sensory profile dominated by spiced, sweet, and bitter flavors, effectively masking undesirable branny notes present in the control. While the methodology provided a comprehensive sensory map, the study was limited to a descriptive profile and did not assess consumer liking or preference for the identified attributes. Therefore, to directly inform product development, future research should integrate QDA with consumer acceptance testing to bridge the gap between sensory characterization and market preference.

## 1 Introduction

The development of functional, health-oriented breakfast cereals and snacks has accelerated in response to consumer demand for products with enhanced nutritional profiles and novel sensory experiences. Rice bran (RB) and unripe banana flour (UBF) are increasingly recognized as valuable ingredients for such innovations due to their high dietary fiber, antioxidant content, and unique functional properties.

Rice bran, a nutrient-dense byproduct of rice milling comprising approximately 10% of the total grain weight, has emerged as a particularly promising functional ingredient for cereal applications. RB is compositionally rich in dietary fiber (15%), protein (15%), essential fatty acids (20%), and bioactive phytochemicals including γ-oryzanol, tocopherols, and tocotrienols [1]. Similarly, banana flour, particularly when derived from unripe bananas, represents an exceptional source of resistant starch and dietary fiber. Unripe banana flour contains remarkably high total dietary fiber content, with resistant starch comprising up to 48.99 g/100 g [2]. The RS content can range from 30-74% depending on processing conditions, positioning banana flour as one of the richest natural sources of RS among unprocessed foods. This high RS content functions as fermentable dietary fiber, supporting gut health, modulating postprandial glucose response, and promoting satiety [3].

The incorporation of rice bran and banana flour into extruded breakfast cereals presents substantial technological challenges. The hydrophilic nature of dietary fiber disrupts starch gelatinization and bubble formation during extrusion, resulting in products with reduced crispness, increased hardness, and compromised sensory acceptability [4]. Furthermore, the lipid content in rice bran can cause extruder barrel slippage, while the distinct flavour profiles of both ingredients earthy notes from banana flour and potential rancidity from rice bran pose additional sensory challenges [5]. These processing and sensory limitations underscore the critical need for comprehensive sensory characterization to guide formulation optimization.

Quantitative Descriptive Analysis (QDA) is a well-established approach for detailed sensory profiling of food products. QDA employs trained panelists to systematically quantify complex sensory attributes including appearance, aroma, flavour, texture, and aftertaste using standardized terminology and calibrated rating scales [6]. Unlike hedonic testing that measures overall liking, QDA provides precise, objective measurements of individual sensory characteristics that can be statistically analyzed to determine significant product differences ([7]. The integration of culinary spices into functional breakfast cereals represents an innovative approach to simultaneously enhance both nutritional value and sensory appeal. Spices such as ginger (*Zingiber officinale*), cinnamon (*Cinnamomum* spp.), and lemongrass (*Cymbopogon citratus*) have gained recognition not only as flavour modulators but also as potent sources of bioactive compounds that complement the health benefits of functional ingredients [8]. The incorporation of these aromatic spices into extruded cereals can offers effectively mask potential

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off-flavours associated with high-fiber ingredients, improving overall palatability and consumer acceptance [9,10]. Spices contribute minimal calories while adding complexity to the flavour profile, allowing manufacturers to reduce added sugars without compromising taste appeal a critical consideration given current dietary guideline. This research, aimed to determine profile sensory of extruded breakfast cereal through incorporating ginger, cinnamon, and lemongrass, which could provide consumers with various functional benefits.

## 2 Materials and Methods

In this study, the characteristic of five spiced breakfast cereals (R, F1, F2, F3, F4) were evaluated and analyzed. Three formulas were developed with formulated rice bran, unripe banana flour, skimmed milk, brown palm sugar, ginger powder, cinnamon powder, and lemongrass powder. The characteristic spiced formula was compared to control (without spice) and the similar commercial spice breakfast cereal from the market (R).

The QDA was initiated through a Focus Group Discussion (FGD) involving ten trained sensory panelists from Measure Hub Laboratory, Faculty of Agricultural Engineering and Technology, IPB University, were selected for this study based on their expertise in descriptive analysis and prior experience with cereal products. To familiarize the panelists with the product category and support attribute development, a commercial spiced breakfast cereal was provided as a reference during an initial orientation session. The sensory evaluation protocol consisted of a FGD followed by QDA, conducted over 20 hours on weekdays, with a two-day break between phases to maintain panelist focus and reduce sensory fatigue. During the evaluation, panelists assessed three randomly coded formulations by rating the intensity of each agreed-upon breakfast cereal attribute using reference standards. A 15-cm unstructured line scale was employed, with anchor points positioned 1.5 cm from both ends. The sensory evaluations were conducted in four separate sessions on different days, with a total evaluation duration of 100 hours. After each assessment, the distance from the left anchor point (0, representing the absence of the attribute) to the right anchor point (10, representing very strong intensity) was measured and recorded. The descriptor development process aimed to establish a structured sensory lexicon for the product. During the 60-minute FGD session, the researcher facilitated discussions to characterize the spice-enriched extruded cereal, encompassing both base product attributes and representative condiment-related descriptors. The FGD was conducted with ten regular consumers of extruded cereal, using a modified QDA procedure adapted from [10,11].

Described attributes of spiced breakfast cereal (SBC) was measure with their intensity values. The QDA data was analyzed using XLSTAT-Student 2025.1.3.1431 software. The menu used to analyze the principal component analysis (PCA) and intensity attributes was visualized with radar chat.

## 3 Result and Discussion

QDA stands as a dependable technique for evaluating and measuring sensory characteristics through the expertise of trained assessors. This methodology enables comprehensive sensory profiling and proves valuable for enhancing products and gaining deeper insights into their sensory features [12]. Applied spices to extruded cereals, QDA enables precise identification and measurement of distinct flavour components and their strength levels contributed by various spices. The QDA process begins with a focus group discussion (FGD). Panellists are given five cereal samples which one commercial spice cereal and four cereal formulas. Panellists are asked to identify the attributes in the samples. The expert panellists then discuss and determine the sensory attributes that represent the five cereal samples provided. The list selected attributes summarized on **Table 1.** and visualized on wheel sensory lexicon shown in **Figure 1.**

**Table 1.** Sensory descriptors of SBC

| Descriptor | Definition |
|---|---|
| **Color** | |
| Cream | Creamy color like hazelnut gelato |
| **Aroma** | |
| Earthy | Aroma associated with the smell of earth after rain |
| Ginger | Aroma reminiscent of fresh ginger |
| Sweet | Aroma associated with cane sugar |
| Spicy | Aroma associated with pepper |
| Starchy | Aroma associated with flour and bread dough |
| Toasted | Aroma associated with toast |
| Branny | Aroma associated with cereals |
| Cinnamon | Aroma reminiscent of cinnamon |
| Musty | Aroma associated with a damp environment |
| Milky | Aroma associated with fresh milk |
| **Taste** | |
| Salty | Taste associated with salt |
| Bitter | Taste associated with coffee caffeine, burnt bread, spring water |
| Sweet | Taste associated with granulated sugar |
| Spicy | Taste associated with spices |
| Ginger | Taste associated with gingerbread |
| Umami | Taste associated with monosodium glutamate (MSG) |
| **Texture** | |
| Crunchy | Produces a crunchy sound intensity when chewed |
| Brittle | Provides a brittle/fragile intensity to the teeth when chewed |
| Solubility | Provides a soft intensity when chewed |
| Tooth packing | Provides a sticky intensity on the teeth when chewed |
| **Aftertaste** | |
| Bitter | Intensity of bitter taste that remains after swallowing |

| | |
|---|---|
| Spicy | Intensity of spicy sensation that remains after swallowing |
| Warmth | Intensity of warm sensation that remains after swallowing |
| Salty | Intensity of salty taste that remains after swallowing |
| Sweet | Intensity of sweet taste that remains after swallowing |

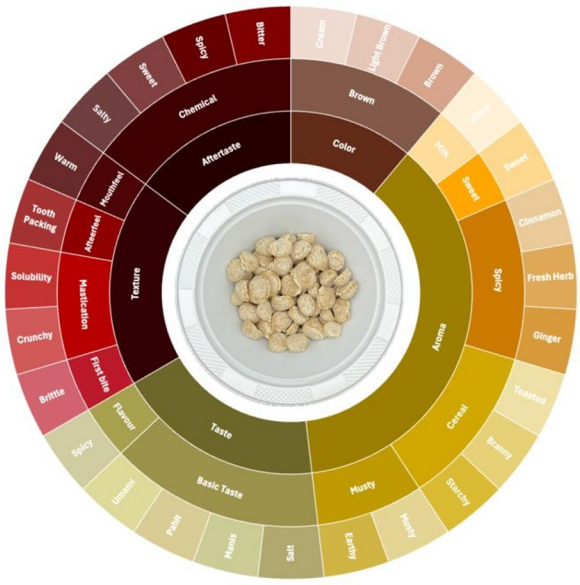


**Figure 1.** Wheel of sensory SBC

The sensory profile of spiced cereal is presented in the form of a principal component analysis (PCA) biplot graph shown in **Figure 2**, which illustrates the correlation between samples and sensory attributes. The biplot reveals a clear sensory map, the control and commercial reference (R) samples cluster in the left quadrants, strongly associated with attributes like grainy, earthy, and hardness. This profile aligns with the known sensory contributions of the rice bran lipid and fiber components can impart earthy notes, while the particulate nature of unripe banana flour resistant starch contributes to a grainy texture. In contrast, the formulated samples F1-F3 are positioned in the right quadrants, closely correlated with spicy, cinnamon aroma, sweet, and toasted notes. This spatial separation visually confirms that the strategic blend of ginger, cinnamon, and lemongrass was successful in masking the inherent heavy notes of the RB-UBF matrix. The vector for bitter aftertaste also loads in this region, suggesting this may be a characteristic imprint of the spice blend itself, particularly from bioactive compounds in ginger and cinnamon. The common sufficiency criterion in PCA, where approximately 70-80% of the variance should be, was comfortably satisfied explained with the first two principal components explaining a combined 86.28% of the variation. The biplot of each sample is divided into four quadrants. [13]. with the first two principal components explaining a combined 86.28% of the variation.

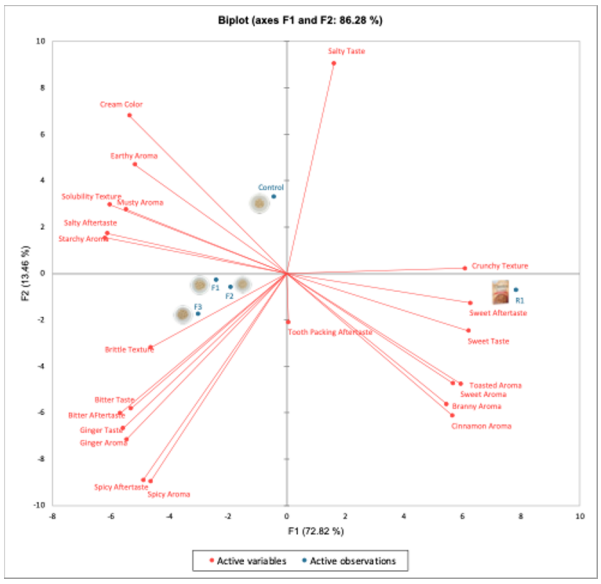


**Figure 2.** Biplot QDA SBC

All sensory attributes demonstrate a positive loading on the first principal component (F1). Conversely, a group of attributes comprising texture and visual properties are negatively loaded on the second principal component (F2). Visual appearance is often the primary criterion humans use to assess food quality. According [14], foods with higher visual textural complexity such as a combination of porous, crispy, and crunchy structures inherent to extruded products are perceived as more appetizing and stimulating, leading to a higher preference over simple, homogenous alternatives. Appearance such as color of the final extruded breakfast cereal influenced by chemical reactions in ingredients, combination raw material defined shade of the final product [15, 16].

Profile sensory attributes can be differentiated by intensity on radar chart and it shown in **Figure 3.** The control and commercial reference (R) samples exhibited an intense textural and grainy profile. In contrast, the formulated samples (F1-F3) successfully reduced the intensity of these base aromas and established a new, intense profile dominated by spiced, sweet, and bitter flavours, effectively masking the beany notes and creating a more complex product. This shift was achieved by combining ginger with cinnamon and lemongrass for enhanced synergistic effects. The perceived increase in sweetness likely results from a complex interaction where spices like cinnamon modulate sweetness perception [17,18], potentially counteracting the masking effect that the fibrous matrix has on the sweetness from brown palm sugar. Furthermore, the toasted note detected in F1-F3 could be attributed to the Maillard reaction between amino acids present in skimmed milk and rice bran and the reducing sugars in brown palm sugar during extrusion. The aromatic products of this reaction became detectable precisely because the dominant spice profile had masked the competing earthy notes from the base ingredients.

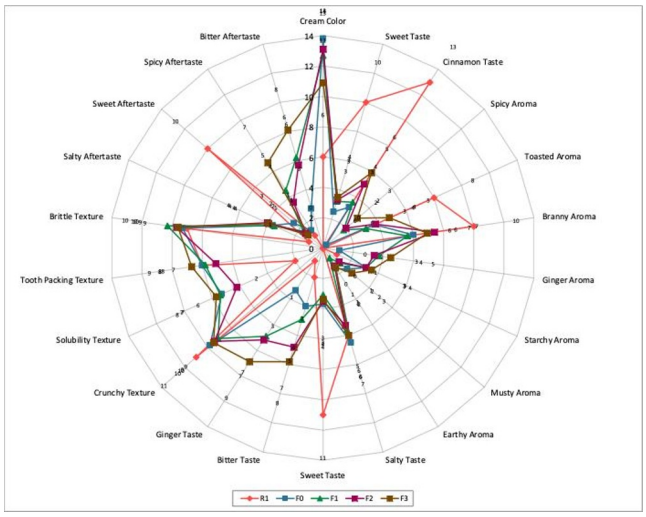


**Figure 3.** Radar chart SBC by expert panel (n=10)

## 4 Conclusion

The Quantitative Descriptive Analysis (QDA) of spice-enhanced extruded breakfast cereals demonstrates that strategic spice formulation effectively transforms the sensory profile of spiced breakfast cereals. Principal component analysis demonstrated robust discrimination with 86.28% total variance explained by the first two components, exceeding acceptable thresholds for sensory studies.

Strategic spice formulation effectively masked undesirable beany notes while creating complex flavour profiles. Formulated samples (F1-F3) exhibited desirable characteristics including cinnamon aroma, toasted notes, and enhanced sweetness, clearly differentiating them from control samples. The synergistic combination of ginger, cinnamon, and lemongrass proved particularly effective, though careful balance is required to preserve palm sugar's subtle sweetness. Appropriate spice integration not only improves palatability but also enhances visual and textural appeal critical factors in consumer preference.

However, this study focused on sensory characterization by trained panelists and does not provide insights into consumer preferences regarding specific sensory attributes. Since understanding consumer liking and disliking patterns is crucial for successful product development, future research should integrate with consumer preference testing of optimized formulations to ensure commercial viability.

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## References

1. S. Sapwarobol, J. Astina, and W. Saphyakhajorn, Biological functions and activities of rice bran as a functional ingredient: a review. Nutr Metab Insights **14**, 11786388211058559 (2021). https://doi.org/10.1177/11786388211058559
2. E. W. Menezes, C. C. Tadini, T. B. Tribess, A. Zuleta, J. Binaghi, N. Pak, G. Vera, M. Cara, T. Dan, A. C. Bertolini, B. R. Cordenunsi, and F. M. Lajolo, Chemical composition and nutritional value of unripe banana flour (*Musa acuminata, var. Nanicão*). Plant Foods Hum Nutr **16**, 231 (2011). https://doi.org/10.1007/s11130-011-0238-0
3. H. Munir, H. Alam, M. T. Nadeem, R. S. Almaliki, M.S. Arshad, H. A. R. Suleria, Green banana resistant starch: A promising potential as functional ingredient against certain maladies. Food Sci Nutr **12**, 3787 (2024). https://doi.org/10.1002/fsn3.4063
4. O. Santala, A. Kiran, N. Sozer, K. Poutanen, and E. Nordlund, Enzymatic modification and particle size reduction of wheat bran improves the mechanical properties and structure of bran-enriched expanded extrudates. J Cereal Sci **60**, 448 (2014). https://doi.org/10.1016/j.jcs.2014.04.003
5. V. Offiah, V. Kontogiorgos, and K. O. Falade, Extrusion processing of raw food materials and by-products: A review. Crit Rev Food Sci Nutr **59**, 8398 (2018). https://doi.org/10.1080/10408398.2018.1480007
6. H. Stone, R. N. Bleibaum, and H. A. Thomas, *Sensory Evaluation Practices*, 5th ed. (Academic Press, Cambridge, 2021)
7. R. Puri, K. Khamrui, Y. Khetra, and R. Malhotra, Quantitative descriptive analysis and principal component analysis for sensory characterization of Indian milk product cham-cham. J Food Sci Technol **53**, 1238 (2016). https://doi.org/10.1007/s13197-015-2089-4
8. M. Serafini and I. Peluso, Functional foods for health: the interrelated antioxidant and anti-inflammatory role of fruits, vegetables, herbs, spices and cocoa in humans. **22**, 6701 (2016). https://doi.org/10.2174/1381612823666161123094235
9. G. Das, J. K. Patra, S. Gonçalves, A. Romano, E. P. Gutiérrez-grijalva, J. B. Heredia, A. Das, and S. Shome, Galangal, the multipotent super spices : A comprehensive review. Trends Food Sci Technol **101**, 50 (2020). https://doi.org/10.1016/j.tifs.2020.04.032
10. J. Yuan, F. Qin, Z. He, M. Zeng, Z. Wang, and J. Chen, Influences of spices on the flavor of meat analogs and their potential pathways. Foods **12**, 1650 (2023). https://doi.org/10.3390/foods12081650
11. D.R Adawiyah, D. Hunaefi, B. Nurtama. 2024. Evaluasi Sensori Produk Pangan. Jakarta (ID): Bumi Aksara.
12. M. Ng, J. B. Lawlor, S. Chandra, C. Chaya, L. Hewson, and J. Hort, Using quantitative descriptive analysis and temporal dominance of

sensations analysis as complementary methods for profiling commercial blackcurrant squashes. Food Qual Prefer **25**, 121 (2012). https://doi.org/10.1016/j.foodqual.2012.02.004
13. N. Salem and S. Hussein, Data dimensional reduction and principal components analysis. Procedia Comput Sci **163**, 292 (2019). https://doi.org/10.1016/j.procs.2019.12.111
14. T. Otterbring, K. Gidlöf, K. Rolschau, and P. Shams, Cereal deal: how the physical appearance of others affects attention to healthy foods. Perspect Behav Sci **43**, 451 (2020). https://doi.org/10.1007/s40614-020-00242-2
15. T. Krahl, H. Fuhrmann, and S. Dimassi, Coloration of Cereal-Based Products (Elsevier Ltd, Amsterdam, 2016)
16. C. Nitikornwarakul, R. Wangpradid, C. Sirimuangmoon, S. Lekjing, A. Nishioka, and T. Koda, Nutritious elderly diet: Pigmented rice-porridge from shear-heat milling process. Ital. J. Food Sci. **34**, 25 (2022). http://dx.doi.org/10.15586/ijfs.v34i3.2241
17. Aminullah, A. Moulidia, and M. F. Kurniawan, Potency of Indonesia native spices as unpleasant sensory remover in high protein and fiber okara-based snack bar. Carp. J. Food Sci. and Tec. **16**, 40 (2024). https://doi.org/10.34302/crpjfst/2024.16.4.4
18. E. Puspitojati, Waluyo, N. A. Rahayu, H. P. Saputra, Ginger, lemongrass, and stevia tea: antioxidant activity, alpha-glucosidase inhibitory, and sensory quality. Food Research **9**, 217 (2025). https://doi.org/10.26656/fr.2017.9(1).070