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Research Article

Sensory Acceptability and Microbiological Quality of Protein-Rich Malted Cereal Flakes Produced from Bambara Groundnut, Soybean and Wheat

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Abstract

Nutritional improvement of cereal foods must be accompanied by acceptable sensory characteristics and satisfactory microbiological quality. Cereal-legume combinations can increase protein contribution, although increasing legume incorporation may influence taste, aroma, texture and consumer acceptance. This study evaluated the sensory acceptability and microbiological quality of protein-rich malted cereal flakes produced from Bambara groundnut, soybean and wheat and fortified with ginger, clove and date. Five formulations were developed: sample A contained 100% malted wheat and served as the control, whereas samples B-E contained 35% malted wheat with progressively increasing proportions of malted soybean and decreasing proportions of malted Bambara groundnut, together with 2% ginger, 2% date and 1% clove. The flour blends were hydrated, kneaded, spread, oven-roasted at 180°C for 20 min and formed into flakes. Sensory evaluation was conducted using a nine-point hedonic scale, while microbiological quality was assessed using liquid and powdered preparations inoculated onto nutrient agar, blood agar, chocolate agar and MacConkey agar and examined after inoculation, 24 h and 48 h. Sample D generally recorded comparatively high sensory scores, with overall acceptability values of 5.43 ± 1.76, 5.43 ± 2.36, 5.90 ± 1.77, 6.77 ± 1.57 and 5.30 ± 1.56 for samples A-E, respectively. Sample D was significantly more acceptable than samples A, B and E, whereas sample C was statistically intermediate. Aftertaste was also highest in sample D (6.10 ± 2.12). No detectable microbial growth was observed in samples A-E after 48 h on any of the culture media evaluated for either liquid or powdered preparations, and the diluent controls remained negative. The formulation containing 40% soybean, 20% Bambara groundnut and 35% wheat, together with ginger, date and clove, therefore produced the most acceptable cereal formulation. Although sample E had the highest protein content, its lower sensory score demonstrates that maximizing protein incorporation does not necessarily produce the most acceptable product. Overall, the findings indicate that appropriate cereal-legume formulation can improve nutritional characteristics while maintaining consumer acceptability, although the absence of detectable microbial growth under the specified culture conditions should not be interpreted as proof of sterility.

Keywords

Bambara Groundnut, Breakfast Cereal, Malted Cereal, Microbiological Quality, Sensory Evaluation, Soybean, Wheat

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1. Introduction

Breakfast cereals represent a convenient vehicle for delivering energy and nutrients. However, cereal products based predominantly on wheat or other grains may have relatively limited protein density compared with cereal-legume combinations. Incorporating legumes such as soybean and Bambara groundnut provides an opportunity to improve protein contribution while maintaining a cereal-based food format.

Bambara groundnut is an underutilized African legume with considerable nutritional potential. Its use in composite foods may support food diversification and value addition [1]. Soybean is similarly important because of its high protein content and good protein quality [2]. Studies of cereal-legume products have shown that changing ingredient proportions can influence nutritional composition as well as functional and sensory characteristics [3, 4].

Sensory acceptability is particularly important in the development of functional foods. A product can possess high nutritional value but fail commercially if consumers reject its appearance, aroma, flavour or texture. This consideration is important for legume-containing foods because increasing legume flour can alter colour, flavour, mouthfeel and texture.

The present study therefore developed five malted cereal formulations containing different proportions of wheat, soybean and Bambara groundnut, with ginger, clove and date incorporated into formulations B-E. The study specifically examined consumer sensory response and microbiological quality.

2. Materials and Methods

2.1. Formulation

Five formulations were produced using malted wheat, malted soybean and malted Bambara groundnut. Sample A consisted of 100% malted wheat. Samples B-E contained 35% wheat, while soybean increased from 30 to 45% and Bambara groundnut decreased from 30 to 15%. Each composite formulation contained 2% ginger, 2% date and 1% clove [5].

2.2. Processing

Bambara groundnut was steeped for 12 h and germinated for 72 h. Soybean was germinated for 48 h, while wheat was germinated for 72 h. The malted materials were dried, milled and sieved. Date and clove were separately processed into powders.

The composite flours were mixed and hydrated with approximately 35-40% water. The dough was kneaded, spread to approximately 5 mm thickness, and roasted at 180 ℃ for 20 min. After cooling, the roasted sheets were broken into flakes and packaged [5].

2.3. Sensory Evaluation

Sensory evaluation was performed using a nine-point hedonic scale ranging from 1 = dislike extremely to 9 = like extremely. The attributes assessed included appearance/colour, aroma, texture/crispness, taste, mouthfeel, sweetness, flavour, aftertaste and overall acceptability.

The project reports 150 observations for most sensory attributes, with flavour having a different sample size because Sample A had no recorded flavour observations. Statistical differences were evaluated at $p < 0.05$.

2.4. Microbiological Analysis

Microbiological quality was assessed using both liquid and powdered preparations. Samples were inoculated onto nutrient agar, blood agar, chocolate agar and MacConkey agar and incubated at 37 ℃ for 48 h. Plates were examined after inoculation, 24 h and 48 h.

Nutrient agar served as a general cultivation medium, blood agar provided an enriched medium for bacterial growth and haemolysis observation, chocolate agar supported more fastidious organisms, while MacConkey agar provided selective and differential screening for Gram-negative organisms [6-8].

2.5. Statistical Analysis

Sensory data were analysed using one-way analysis of variance. Results were expressed as mean ± standard deviation, with statistical significance assessed at $p < 0.05$.

3. Results and Discussion

3.1. Sensory Characteristics

The sensory evaluation demonstrated differences among formulations. Appearance/colour scores ranged from 4.63 in E to 5.47 in D; aroma ranged from 4.67 to 5.63; texture/crispness ranged from 4.67 to 5.30; taste ranged from 4.53 to 5.80; mouthfeel ranged from 4.83 to 5.50; and sweetness ranged from 4.77 to 5.70. Sample D generally recorded comparatively high values across these attributes.

Overall acceptability was 5.43 ±1.76 for A, 5.43 ±2.36 for B, 5.90 ±1.77 for C, 6.77 ±1.57 for D and 5.30 ±1.56 for E. Sample D had the highest overall acceptability and was significantly more acceptable than A, B and E, while C was statistically intermediate.

The superiority of D is important because it demonstrates that the formulation with the highest protein content was not necessarily the formulation most preferred by consumers. Sample E contained 13.30% protein but recorded the lowest overall acceptability (5.30 ±1.56), whereas D contained 10.85% protein but achieved an overall acceptability score of 6.77 ±

1.57.

This finding highlights the need to balance nutritional enhancement with sensory quality. Increasing soybean and reducing Bambara groundnut may improve protein density, but higher legume incorporation can influence flavour, aroma, texture and mouthfeel. Previous studies have similarly shown that cereal-legume flour ratios can influence the sensory characteristics of breakfast cereals [3, 4].

3.2. Aftertaste and Contribution of Fortifying Ingredients

Sample D recorded the highest aftertaste score (6.10 ±2.12), while B recorded the lowest (4.70 ±2.02). The significant difference suggests that formulation influenced the persistence of flavour after consumption.

Ginger, clove and date are likely to have contributed to the sensory characteristics of the formulations. Ginger contains pungent compounds such as gingerols and shogaols, while clove contains aromatic phenolic compounds, particularly eugenol [9, 10]. Date contributes naturally occurring sugars and may provide sweetness that moderates stronger spice characteristics [11].

The comparatively favourable response to D may therefore reflect an interaction among cereal-legume ratio, spice intensity, sweetness and texture rather than the effect of any single ingredient.

3.3. Microbiological Quality

No detectable microbial growth was observed in samples A-E after inoculation, 24 h or 48 h on nutrient agar, blood agar, chocolate agar or MacConkey agar for either liquid or powdered preparations. The diluent controls also remained negative.

The negative culture findings are encouraging for a dry cereal product. The products had low moisture contents ranging from 4.15 to 7.28%, which may limit microbial multiplication. However, low moisture does not mean that a food is sterile, because some microorganisms can survive in low-water-activity foods without actively multiplying.

The absence of growth on MacConkey agar indicates that Gram-negative organisms capable of growing under the particular test conditions were not detected. It should not, however, be interpreted as absolute evidence that all enteric pathogens were absent. The same caution applies to the negative findings on nutrient, blood and chocolate agars.

Low-moisture cereal products can remain important vehicles for foodborne pathogens because organisms such as *Salmonella* may survive for extended periods without multiplying. Consequently, hygienic raw-material handling, adequate processing, environmental sanitation and appropriate storage remain necessary even where culture-based testing produces no detectable growth [12-14].

3.4. Relationship Between Formulation and Product Quality

The results demonstrate a useful distinction between nutritional optimization and consumer optimization. Increasing soybean concentration produced the highest protein value in E, whereas the intermediate formulation D achieved the highest sensory acceptance. This indicates that the formulation containing the greatest proportion of a protein-rich ingredient may not necessarily be optimal from a product-development perspective.

The findings are consistent with previous research on cereal-legume breakfast foods. Okoye et al. [3] demonstrated that changes in cereal-legume formulation affected nutritional, functional, microbiological and sensory characteristics. Igwego et al. [4] similarly reported differences in nutritional and organoleptic properties of breakfast cereals containing Bambara groundnut.

The present findings therefore suggest that an intermediate legume ratio may provide a more favourable balance between nutritional improvement and sensory quality than simply maximizing soybean incorporation.

4. Conclusion

Protein-rich malted cereal flakes were successfully produced from Bambara groundnut, soybean and wheat with ginger, clove, and date. The formulations differed in sensory performance, with sample D achieving the highest overall acceptability score of 6.77 ±1.57.

Although sample E had the highest protein content, its lower sensory score demonstrates that nutritional superiority does not necessarily translate into greater consumer acceptance. Sample D therefore represents the most promising formulation when sensory acceptability is prioritized.

No detectable microbial growth occurred in any formulation under the culture conditions employed. The results indicate satisfactory microbiological quality of the tested products, although the findings should be interpreted as absence of detectable growth under the specified conditions rather than proof of sterility.

The study supports the development of cereal-legume breakfast products using Bambara groundnut and soybean and demonstrates the importance of optimizing ingredient ratios to achieve an appropriate balance between nutritional value and consumer acceptability.

Abbreviations

ANOVA	Analysis of Variance
SD	Standard Deviation

Author Contributions

Simcha Chinyere Okeyahweh: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing

Conflicts of Interest

The author declares no conflicts of interest.

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