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Production and Sensory Evaluation of Mixed Cereal Flour: An Experimental Study on Somali Flatbread

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Abstract

Bread is one of the most widely consumed food products globally, with wheat as the primary ingredient. Due to rising wheat prices, partly driven by the ongoing crisis in Ukraine, there is an urgent need to explore alternative grains and reduce reliance on wheat. This study aimed to evaluate the sensory quality and nutritional enhancement of flatbreads made from mixed cereal flours: rice, maize, and sorghum, incorporated with banana peels (*Musa acuminata* L.). Using a Randomized Complete Design (RCD), the study assessed the organoleptic properties and overall acceptability of flatbreads formulated as follows: RMS (43% rice, 26% maize, 26% sorghum, 5% banana peel), MSR (43% maize, 26% rice, 26% sorghum, 5% banana peel), SMR (43% sorghum, 26% maize, 26% rice, 5% banana peel), and WCTRL (100% wheat flour as control). Sensory evaluation showed significant differences ($p < 0.05$) in color, aroma, flavor, and overall acceptability among the formulations. The MSR formulation demonstrated the highest scores for flavor and overall acceptability, outperforming all others in these attributes. Although WCTRL scored higher in color and aroma, it fell short of MSR in both flavor and overall acceptability. The inclusion of banana peel likely influenced color perception. In conclusion, the MSR formulation presents a promising wheat flour alternative, offering comparable or superior sensory qualities, aside from color. Based on these findings, the study recommends establishing flour mills dedicated to high-quality mixed cereal flours, reducing dependency on wheat imports, encouraging the use of maize, sorghum, and rice in food production, and increasing government support for local farmers to ensure sustainable grain supply chains.

Subject Areas

Food Science and Technology

Keywords

Cereal Flour, Somali Flatbread, Gluten-Free, Dietary Fiber

1. Introduction

Cereal grains are the most common sources of calories, carbs, and plant proteins worldwide. Reference [1] emphasizes that staple cereals remain a key source of dietary energy and supply essential macro- and micronutrients, underscoring their vital role in human nutrition. Cereals serve as the main staple in all regions, providing a significant portion of the dietary energy supply (DES). Wheat and maize are produced in the largest quantities annually (766 and 1148 million metric tonnes, respectively), followed by rice (755 million metric tonnes). Rice is the most popular cereal worldwide, followed by wheat and maize. Sorghum, millet, barley, rye, and oats are also used globally for human consumption [2]. Recent FAO forecasts further highlight the central role of cereals, projecting global production in 2025 to reach a record 2961 million tonnes, driven mainly by coarse grains, especially maize. Wheat production is expected to reach 804.9 million tonnes and rice 555.5 million tonnes (milled basis), marking record highs for global availability [3]. Compared to major legume crops, the yields of the three main cereal crops are quite large—for example, soybeans and peas (231 and 9.8 million tons, respectively). Between 2005 and 2015, the share of cereals in the global diet slightly declined, from about 51% in 1970 to around 46% in 2010, reflecting increased diversification of food sources. Besides their nutritional importance, recent research highlights the potential of underutilized by-products such as banana peel flour [4]. According [5] explored adding banana peel flour to wheat flour for biscuit production, finding that it increases dietary fiber and carbohydrate content. Sensory evaluations indicated that blends with 5% - 15% banana peel flour were acceptable, while higher levels reduced acceptability due to changes in color and texture. Other studies emphasize banana peel flour's functional properties, including water retention, antioxidant activity, and improved nutritional content in bread, cookies, and gluten-free products [6] [7]. Cereal grains—such as wheat, rice, maize, barley, sorghum, rye, and oats—contain starch and protein as major components, with minor constituents including vitamins, phytic acid, lipids, non-starch carbohydrates, and minerals. These crops comprise about one-third to half of Somalia's diet by calories and are among the most important locally produced food crops. Maize and sorghum are the primary staples of Somalia's cereal production [8]. Over the past two decades, eating habits have changed, with consumers showing increased interest in healthy eating and new food products. In Somalia, baked foods are gaining popularity among a large portion of the population. The most common baked foods in households include bread (Injera/Canjeelo) or flatbread, made from wheat flour high in gluten, which can cause issues for gluten-intolerant individuals, such as celiac disease, leading to diarrhea, abdominal pain, and bloating. Despite high local wheat consumption, Somalia is a non-wheat-producing country. The country produces cereals like maize, sorghum, and rice, but many associate these with poverty and illiteracy, consuming them either whole or processed as products like Soor porridge. During the COVID-19 pandemic, wheat prices soared rapidly, complicating imports, especially amid the ongoing Ukraine war. Additionally, most imported flour is refined white flour. As a result, many countries are exploring ways to boost local production to enhance food security. Some are seeking alternatives or complete replacements for wheat in bread-making. It is therefore crucial for Somalia to utilize its major crops either as staple foods or incorporate them into the most popular products to reduce reliance on imports. This research aims to encourage local production and reduce wheat imports by developing a product made from mixed cereal flour enriched with banana peel powder. Banana peels, often discarded carelessly, have negative environmental, economic, and social impacts. However, they are rich in antioxidants, antibacterial and antibiotic properties, dietary fiber, and phenolic compounds. Incorporating banana peel into bread could provide nutritional, environmental, and food security benefits. This study could also help decrease wheat imports, lowering dependence on foreign products. It could boost demand for local cereal grains, potentially increasing production and creating numerous job opportunities for young graduates and farmers alike. The main objectives include assessing the sensory qualities of flatbread made from mixed cereal flour and developing a fortified version with banana peel. The study focuses on processing methods for the mixed cereal flour, from manufacturing to sensory evaluation, data analysis, and interpretation. Overall, the goal is to create a nutritious, locally-sourced flour blend from maize, sorghum, and rice, enriched with banana peel.

2. Materials and Methods

2.1. Materials

The research was conducted as an experimental study to assess the production and sensory evaluation of flat bread made from different mixed cereal flours, using randomly selected panelists to evaluate color, flavor, taste, aroma, and overall acceptability. The experiment on the mixed flour production process was carried out at the Somali National University Lab, Gahayr Campus, Faculty of Agriculture and Environmental Sciences. The study took place from October 2024 to February 2025. Raw materials included the edible parts of grains such as maize, rice, and sorghum, which were purchased from local markets. Banana peels were collected from restaurants. The samples were prepared immediately upon arrival at the university, so no raw material storage was involved. A standard commercial procedure was followed to produce the mixed or composite flour. Grains were ground finely with a grinder for approximately 30 seconds. The products were categorized into four types: product A (100% wheat flour) served as the control; product B (MRS, 43% maize flour, 26% rice flour, 26% sorghum flour); product C (RMS, 43% rice flour, 26% maize flour, 26% sorghum flour); and product D (SMR, 43%

sorghum flour, 26% maize flour, 26% rice flour), with 5% banana peel powder added to each sample. The banana peels, from *Musa acuminata* fruits, were separated from the flesh. The peels were washed with tap water, blanched for 20 minutes using blanching agents to remove color, then dried, crushed using a manual plate mill (mincer), and sieved (See Figures 1-3).

Figure 1. Equipment used in the study.

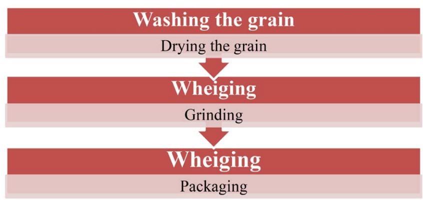

Figure 2. Milling process of flour.

Figure 3. Flow chart preparation of banana peel powder.

2.2. Research Design

The study used a Completely Randomized Design (CRD). Each panelist evaluated all four flour formulations (three composite blends and one 100% wheat control) across sensory attributes: color, aroma, flavor, and overall acceptability. This was conducted in three separate sensory sessions, one day apart, to determine whether time significantly affected the flour's quality attributes at different intervals. Each session served as a replicate, and the presentation order was randomized for each panelist to minimize bias. Sensory evaluation was performed through acceptance tests. The 30 panelists were selected based on the guidelines of the Institute of Food Technologists (IFT, 1981), which state that there is no specific minimum number for preference, acceptance, or opinion tests; however, a minimum of about 24 panelists is generally sufficient. Panelists were chosen for their willingness and commitment to participate in the sensory evaluation. All participants provided informed consent, and the study received approval from the faculty academic committee. They were neither trained nor informed about the ingredients used in preparing the samples. Panelists rated each sample on a five-point hedonic scale (1 = dislike a lot, 5 = like a lot). If a panelist did not understand a certain attribute, an explanation was provided. The sensory evaluation was repeated in three sessions to ensure reliable results. Data analysis was performed using Minitab V 18.1 with one-way ANOVA, with flour formulation as the treatment factor. All evaluations across the three sessions—each spaced one day apart—were treated as three replicates in the analysis, with the same panelists assessing all four formulations each time. The pooled session data were subjected to one-way ANOVA, using flour formulation as the treatment factor.

3. Results and Discussion

3.1. Organoleptic Characteristics of Mixed Cereal Flours

The table below, Table 1, shows the organoleptic characteristics of mixed cereal flours and compares flatbreads made from different cereal flour blends. Sensory analysis revealed significant differences (at a p-value of less than 0.05) among the various flatbreads in terms of color, aroma, flavor, and overall acceptability. The flatbread made with MSR flour, followed by WCTRL flour, was rated as the most palatable by panelists. When compared to breads made with other formulations, such as SMR and RMS, the MSR flatbread was noticeably superior in flavor and overall acceptability. In fact, the MSR bread performed even better than the control bread, which was made from wheat alone. This may be because flatbreads made solely from wheat tend to be more elastic than those with maize. Flatbreads from MSR also outperformed other formulations in aroma and color. As a result, MSR may have surpassed the control in all test parameters except color. The superior performance of MSR bread, which earned the highest scores, could be related to the fact that most Somali people regularly use maize in dough for flatbread, and maize is also consumed as milled maize (Soor), traditional baked dough from milled maize (Mufo), and in other forms. Therefore, any flour formulation with a higher percentage of maize is likely to have flavor, color, and aroma profiles that are more familiar and acceptable to the Somalis compared to cereal grains used in other formulations. Consequently, bread with a higher maize content will have organoleptic characteristics more familiar to the community than those containing rice or sorghum as primary ingredients. Reference [9] investigated using sweet potato flour as a substitute for maize flour and found similar results, including increased preference and acceptability among consumers. They argued that maize flour's higher protein, moisture, crude fiber, starch, and fat contents directly affect the acceptability of flour and its products, explaining why maize flour is more widely used than sweet potato flour.

Table 1. Organoleptic characteristics of mixed cereal flours.

Products	Color	Flavor	Aroma	Overall
MSR	3.67 ± 1.27^{ef}	4.70 ± 0.70^{a}	4.30 ± 0.92^{abcd}	4.47 ± 0.97^{ab}
WCTRL	4.43 ± 1.10^{abc}	4.30 ± 0.95^{abcd}	3.90 ± 1.09^{cde}	4.03 ± 1.03^{bcde}
SMR	3.00 ± 1.29^{g}	4.03 ± 1.19^{bcde}	4.07 ± 1.08^{bcde}	3.73 ± 1.39^{ef}
RMS	3.33 ± 1.24^{fg}	3.90 ± 1.09^{cde}	4.00 ± 0.87^{bcde}	3.77 ± 1.28^{def}

MSR maize, sorghum & rice flour, with maize is the highest proportion. **WCTRL** = Wheat flour as a control. **SMR** = addition of sorghum, maize & rice flour, with sorghum having the highest proportion. **RMS** = addition of rice, maize & sorghum flour, with rice having the highest proportion.

3.1.1. Overall Acceptability

The study's findings (Table 1) indicate that the maize, sorghum, and rice flour blend with maize as the most significant proportion (MSR) is generally preferred across all sensory qualities when compared to the other flour blends and wheat control. This suggests that maize is important in improving the sensory appeal of flour mixes, making MSR the preferred alternative to standard wheat flour in terms of color, flavor, scent, and overall acceptability. Maize-rich composites commonly score well in acceptability trials because maize contributes familiar taste, softer texture, and better mouthfeel compared with higher proportions of sorghum [10]. Work on extruded composite flours similarly found that formulations with higher maize content had superior sensory scores and consumer acceptance than formulations dominated by sorghum [11]. Recent product development studies also report that maize-based composite porridges and instant flours achieve high acceptability when maize is the major component, while enrichment with other ingredients (e.g., roots, leaves, or minor cereals) is used to improve nutrition without large sensory qualities [12].

The (WCRL) flour, however, came in second place in terms of acceptability, largely because most Somalis are familiar with its distinctive flavor. It also has physicochemical properties that make it suitable for flatbread production. According to [13], the viscoelastic characteristics of wheat flour's storage protein are what set it apart from other flours. When wheat flour is mixed with water and kneaded, the seed-storage proteins, predominantly glutenins and gliadins, assemble into a viscoelastic gluten network that gives dough both strength and extensibility and allows it to trap and retain gas bubbles during fermentation and baking. This unique combination of elasticity and extensibility is what differentiates wheat flour from other cereal flours and underpins the wide array of leavened products [14]. These functional qualities of wheat, particularly its gluten network and the interaction of starch and protein, permit its use in a wide range of products, from breads and pasta to more delicate baked goods like cakes, cookies, and pastries, which require weaker gluten development and finer crumb structure [15].

SMR and RMS: Scored lower for overall acceptability, with SMR at 3.73 ± 1.39ef and RMS at 3.77 ± 1.28def, indicating that blends with sorghum and rice as the highest proportion are less preferred overall compared to the maize-dominant blend and wheat flour. Due to its crumbly, poor taste, and poor baking qualities, the SMR and RMS flour scored the lowest. This might be explained by the fact that even in ground conditions, sorghum is rigid and hard. Our findings were consistent with other studies showing that increasing the proportion of sorghum in wheat breads reduces softness, specific volume, and overall sensory scores. Early work reported clear declines in bread mouthfeel and acceptability as sorghum reached and exceeded about 20% substitution, with decorticated sorghum performing better than whole grain. More recent studies confirm that higher sorghum levels adversely affect dough rheology and bread texture [16]-[18].

3.1.2. Color

According to **Table 1**, the WCTRL performed significantly better in terms of color than the other formulation results. The WCTRL had the highest mean score of 4.43 points, followed by MSR with a score of 3.6 points, RMS with 3.3 points, and SMR flour having the lowest score in terms of color, with a mean of 3.0 points. This indicates that the panelists preferred WCTRL flour's color more than other mixed cereal flours. This is because the flour that is made from wheat flour is daily consumed and accepted by the majority of local households in their routine daily foods like bread, flat bread, and other essential flour-formulated products. Additionally, the milling procedure is another factor that gives WCTRL flour its white color, which is more accepted due to its widespread use. Hence, the outer layer or the bran, which has a brown color, is removed, and the whiteness is polished to become more and more appealing. A study by [19], which had findings and justifications similar to those of the current research, was cited as having similar results. SMR flour received the lowest color score, with a mean of 3. The study's use of sorghum, whose endosperm and bran were darker than those of the cereals, may have contributed to the lower score because more darkly colored flour was produced from it than from the other grains. Similarly, [20] reported findings regarding the acceptance of brown-colored sorghum varieties and noted that, when comparing sorghum varieties, white sorghum varieties fared better in terms of acceptance in flour formulations.

3.1.3. Flavor

The results of the ANOVA analysis in Table 1 showed that MSR cereal flour performed significantly better than the studied formulations, except the WCTRL, in terms of flavor. According to the panelists in the current study from MSR, WCTRL, SMR, and RMS flours scored 4.70, 4.30, 4.03, and 3.9, respectively, in terms of flavor. It follows that MSR produced the best-tasting products, while RMS produced those with the least desirable flavors. The panelists, however, gave the products made with various flour formulations high marks for flavor acceptability, suggesting that all of the formulations under consideration would result in breads with palatable flavor attributes. The main ingredient in this formulation is maize, which is added to wheat flour when making the commonly used flatbread to increase fermentation and improve porosity. This increases the absorption rate, which improves the quality of the final flatbread and may account for the higher score of MSR in terms of flavor. Therefore, MSR was related to high water absorption and oil holding capacity due to its larger pores related to the introduction of the maize in the formula. In addition, the majority of Somalis prefer to consume their flatbread with a lot of tea or stew. In terms of maize's contribution to the rise in the water and oil holding capacity of the flour, similar findings were reported by [21]. The flatbread made from RMS mixed cereal flour was discovered to have the lowest flavor rating. This might be as a result of the fact that since rice flour is uncommon in the nation, most citizens will find its flavor peculiar. Additionally, rice flour lacks the proteins needed to develop the necessary viscoelastic properties found in traditional flatbread, making it less able to do so. It is therefore of lower quality. Elowefah 2014 reported similar outcomes with RMS flour receiving a lower score.

3.1.4. Aroma

The results of the ANOVA analysis in Table 1 showed that MSR cereal flour performed better than all of the other formulations. Surprisingly, WCTRL performed the least among all flour formulations in terms of aroma. The flour with the highest mean score was the MSR mixed cereal flour at 4.3, followed by SMR, RSM, and WCTRL mixed cereal flours with 4.07, 4.0, and 3.9, respectively. The widespread use of maize in the daily breads could be the cause of MSR's successful performance, whereas the success of the other formulations may have been influenced by their recent milling. This means that it has a fresh aroma due to the freshness and aromas that have recently been released from the newly milled products, which increases its acceptance. Reference [20] [22] reported on additional causes for the poor performance of the wheat flour, who claimed that the amount of flour used in the milling process, the type of dough prepared, the baking method, and the ingredients used in the dough preparation all have a significant impact on the aroma of breads. According to [23], plant breeding for production varieties with higher aroma levels could improve the flavor of wheat flour. This might also imply that it contains fewer aromatic compounds than the other cereal grains. The maize also contains secondary metabolites and phenolic compounds that help the MSR mixed cereal flour achieve the highest score. The main flavoring agents in fresh corn, according to [24], were aromatic compounds with benzene rings. A thorough analysis revealed that the aromatic compounds were better retained in fresh corn kernels that had been dried and cooked.

4. Conclusion and Recommendations

We created a flatbread during the experimental study by adding banana peel to mixed cereal flour to increase its nutritional value. The results of our research have demonstrated that there are notable differences between the various types of breads made from various flour formulations in terms of color, aroma, flavor, and general acceptability. MSR flour, followed by WCTRL flour, was found to have the highest acceptability among the panelists for bread. SMR and RMS breads, the other formulations used to make bread, had significantly less flavor and general acceptability than MSR bread. The fact that flatbread made from only wheat without the addition of maize tends to be more elastic than flatbread made from wheat and maize could be the reason why MSR breads outperformed all other formulations in terms of flavor and color. That might be the cause of MSR outperforming WCTRL in all test parameters except color. The highest mean values for the flour were 4.47 for MSR and 4.03 for WCTRL, while the lowest mean value for the flour was 3.73 for SMR mixed cereal flour. The majority of Somalis are accustomed to eating mufo (local bread), adding maize to flatbread, and are therefore more likely to be attracted to MSR flour's flavor, color, and aroma than they are to other combined. After analyzing the findings of the research, we recommend that: 1. Maize, sorghum, and rice with banana peels are the best ingredients for making quality flour. 2. Building flour mills can play an important role in the production of good mixed flour. 3. The businessmen should reduce the importation of wheat flour. 4. The government should support local farmers in producing enough maize, sorghum, rice, and bananas to make flour. 5. Somali people consume and try to make flour of maize, sorghum, and rice. Finally, the researchers recommend conducting further research in this area to display the importance of making and consuming mixed flour. While banana-peel powder is widely recognized for its high dietary fiber and micronutrient content, this study did not include a proximate composition analysis of the composite flours. As a result, we are unable to present direct evidence of the nutritional contribution made by the banana-peel fortification in this context. Including proximate analysis, such as measurements of moisture, protein, fat, ash, and fiber, would have strengthened the nutritional claims and provided a more complete profile of the formulated products. We recommend that future work incorporate such analyses to validate the functional and nutritional benefits of incorporating agricultural byproducts like banana peel into cereal-based foods.

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Conflicts of Interest

The authors declare no conflicts of interest.

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