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DEVELOPMENT AND QUALITY EVALUATION OF AMARANTH AND SOYBEAN SUPPLEMENTED BREAD

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ABSTRACT

This research sought to improve the nutritional profile of bread by substituting amaranth and soybean flour for wheat flour, as well as to further evaluate its quality and acceptability among consumers. According to proximate analysis, soybean flour had the highest levels of protein (38.07±1.64%) and fat (16.91±0.54%), whereas amaranth flour had the highest levels of fiber (8.76±0.32%). The different flour ratios produced five different treatments. The bread with the greatest amaranth and soybean content (T4) had higher protein levels (17.777±0.181%) and fat levels (5.133±0.425%) but scored less in sensory tests (4.9333±0.851) for color and 4.6667±0.851 for overall acceptability). The control bread (T0), which was produced just with wheat flour, had the highest sensory ratings. Even while bread with more amaranth and soybean content has an improved nutritional profile, finding a balance between nutrition and consumer acceptance is still challenging. These results highlight the potential of amaranth and soybean flour as nutrient-dense substitutes in bread production, but they also highlight the need for formulation optimization to increase consumer acceptability.

Keywords: Malnutrition, Composite Flour, Stunting, Amaranth, Soybean, Bread, South Asia, Nutritional Enhancement, Underutilized Crops, Food Production.

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1. INTRODUCTION

The significance of acquiring wholesome food products has never been more important in a world struggling to feed a constantly expanding population. Malnutrition is still a major problem, especially in Asia's emerging nations, where children's diets pose serious health hazards. The worldwide and Asian backdrop of stunting rates, the function of composite flour in correcting nutritional inadequacies, and the rising desire for healthier baked goods are all covered in this introduction (Prakash et al. 2020). The spread of malnutrition is centered in Asia, especially South Asia. The area has the worst rates of stunting in the world and many children there are at risk for permanent health problems as a result of malnutrition. This is especially concerning since stunting, a typical result of hunger, hinders children's cognitive and physical development. According to estimates by Ssentongo et al. (2021), by 2012, 26% of children worldwide were at risk of stunting and 3% of children were severely underweight. India, in particular, bears a disproportionate amount of this burden, which is made worse by the growing price of food and the lack of access to higher education. More than simple actions are needed to address this; broad nutritional knowledge is also required. Understanding the value of healthy eating may help reverse the negative consequences of malnutrition and promote a healthier, more affluent generation, particularly before the age of five (Neufeld et al. 2020).

Composite flour is a possible remedy for the malnutrition crisis; it is more than simply a combination of various flour, starches, and additives. This mixture may provide a balanced nutritional profile and support local agriculture by using a variety of grains, especially in underdeveloped countries where access to a wide range of food sources may be constrained (Li et al. 2020). The demand for bakery items that are not only tasty but also nourishing is growing as the world's population becomes more health aware (Krasnikova et al. 2020). Alternative ingredients, including composite flour, are used to increase the nutritional content of bakery items and provide customers with more than simply empty calories with each bite. Bread is a common ingredient on every dinner table worldwide. However, despite being traditionally prepared mostly from wheat flour, there is an increasing awareness of its nutritional shortcomings. To ensure that this staple will continue to feed future generations, efforts

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are now being made to improve the nutritional profile of bread by integrating useful nutrients such as amaranth and legume proteins (Natalia et al. 2020). Researchers have examined traditional and contemporary food sources to address the problem of fulfilling nutritional needs while the world's population is rising.

Amaranth has historically been important, notably in pre-colonial American societies. Amaranth is revered as a basic food source and an essential component of religious rituals (Allai et al. 2022). China, India, and Africa are only a few nations where modern agriculture has expanded (Baraniak & Kania-Dobrowolska, 2022). Amaranth stands out among grains in terms of nutrition due to its exceptional protein, fat, and fiber content, which often exceeds other grains (Gandhi et al. 2020). Further highlighting its potential for dietary supplements and treating malnutrition, its unique protein composition offers a rich supply of important amino acids (Olawoye et al. 2021). Due to its higher nutritional and economic significance, soybean, which originated in China, spread across continents over millennia and left its imprint on the world (Ribeiro et al. 2020). With over 90% of the worldwide output, the US, Brazil, Argentina and China now dominate the production of this essential crop (Singhania et al. 2023). Beyond only being important economically, soybeans are a true nutritional powerhouse. It is a complete protein supply packed with proteins, folic acid and iso-flavonoids (Grdeń and Jakubczyk, 2023). Furthermore, the use of soybeans extends beyond simple food production. Its derivatives, such as soybean flour, have been included in a wide range of food items, enhancing them with health advantages (Qin et al. 2022).

Delivering nutrient-rich meals that appeal to more discerning customers is a complex problem the industry must address in the face of a continuously changing food market. Although it is clear that functional ingredients like amaranth and soybean are popular, there is still a struggle to balance retaining palatability and consumer acceptance with improving nutritional profiles (Bauer et al. 2022). One of the most important issues facing the modern food business is finding a way to balance these needs, particularly without using artificial ingredients. Children suffer the worst effects of malnutrition, which is a serious worldwide health problem and is especially common in underdeveloped nations (Budzulak et al. 2022). Creative ideas are required to solve this situation. One of these ideas is the effective use of underutilized food crops, such as amaranth and soybean, to create nutrient-balanced meals. Therefore, the main goal of this study was "to develop a protein-enriched bread using this composite flour, evaluate its quality, and ascertain its general acceptability to consumers."

2. MATERIALS AND METHODS

2.1. Description of Composite Flour

Composite flour produced from a combination of wheat, amaranth, and soybean flour is the subject of the study. While amaranth and soybean are added to increase the nutritional value of the bread, wheat flour remains the primary component since it may provide its structure and volume (Vermelho et al. 2024). Pseudo-cereal amaranth, which contains critical amino acids like lysine and threonine that are lacking in wheat, is high in protein and delivers these nutrients (Chang et al. 2023). It is also devoid of gluten. Wheat lacks lysine, thus soybean flour makes up for it and improves the rheological characteristics of dough (Singh et al. 2020). To investigate the impact on the bread's nutritional and sensory properties, five different treatments were made by varying the flour ratios while maintaining the overall amount at 100%.

2.2. Treatment Plan for Bread Production

The treatments employed various percentages of wheat, amaranth, and soybean flour. The T0 control included just wheat (Table 1). Wheat flour was reduced by 10% each time in succeeding treatments, from T1 (90%) through T4 (60%). The proportions of amaranth and soybean flour increased simultaneously from T1 (5% each) to T4 (20% each).

Table 1: Treatment plan for the production of bread

Treatment	Wheat flour (%)	Amaranth flour (%)	Soybean flour (%)
T_0	100	0	0
T_1	90	5	5
T_2	80	10	10
T_3	70	15	15
T_4	60	20	20

2.3. Bread Production Process

Producing the dough by combining composite flour, salt, yeast, water and other ingredients was the first step in making bread (Fig. 1). The dough was raised by converting carbohydrates to carbon dioxide during yeast fermentation (Hosseini and Jafari, 2020). The dough was pounded to disperse the yeast after the first fermentation; then, it was formed into loaves for a second rise. The usual structure of bread is created during baking at about 220°C, which also starts the Maillard reaction, which gives bread its distinctive flavor and crust (Gigante et al. 2023). Breads from each treatment were baked and their nutritional value and sensory qualities were assessed thereafter.

2.4. Nutritional Analysis

The nutritional components of bread samples were determined using conventional AOAC procedures (AOAC,

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2016). After the oven drying at 105°C, the moisture content was measured. Total carbs were calculated by deducting moisture, protein, and fat percentages from 100, while protein and fat content were evaluated using the Kjeldahl technique and Soxhlet extraction, respectively.

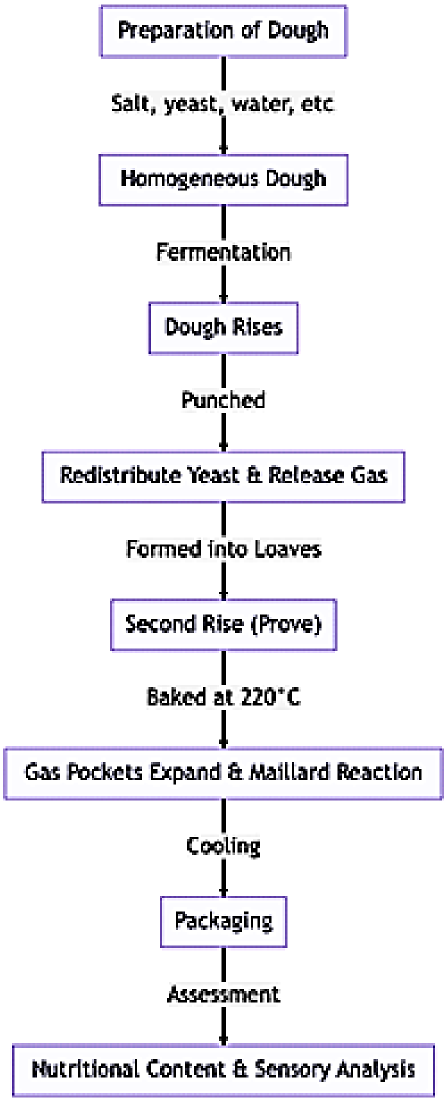

Fig. 1: Bread Production Process.

2.5. Color Analysis

The hues of bread were examined using a colorimeter and the CIELAB methodology. Three crucial variables, L* (lightness), a* (redness-greenness), and b* (yellowness-blueness), were assessed on bread samples from each treatment.

2.6. Texture Analysis

The textures of bread were evaluated by using Texture Analyzer TA-XT2. AACC method 74-09 was used to test the following characteristics: hardness, springiness, cohesiveness, and chewiness (Deseta et al. 2021).

2.7. Sensory Evaluation

Using a 9-point hedonic scale, a professional panel evaluated the bread samples regarding appearance, aroma, texture, taste, and overall acceptability. With a palette cleanser in between items, the assessments took place in a quiet setting. This study offered insights regarding customer approval of composite flour bread was offered by this study (Meilgaard et al. 2016).

2.8. Statistical Analysis

Data collected from assessments of nutrition, color, texture, and sensory features were examined using Statistic 8.1 software for statistical analysis (3.2.9). For descriptive statistics, calculations included mean values and standard deviations. One-way Analysis of Variance (ANOVA) was used to identify differences between treatments and the Tukey HSD test was then used to compare the treatment means. It should be noted that a significance cutoff of 0.05 was used (Montgomery, 2017) statistical analysis was used to interpret the data and identify significant variations in the bread samples.

3. RESULTS & DISCUSSION

The empirical portion of the study produced a vast amount of information that clarified the nutritional profiles of the selected flour and the final bread. Here is further information on these results, which are crucial to achieving the study's goals.

3.1. Proximate Analysis

The nutritional value of wheat, amaranth, and soybean flour was determined by a detailed proximate study and presented in Table 2. The proximate analysis mean values for three different kinds of flour, i.e., wheat flour, amaranth flour and soybean flour, are shown in Table 2. Moisture, fat, protein, fiber, ash, and nitrogen-free extract (NFE) percentages are among the factors evaluated. Amaranth flour has the highest moisture content at 11.77±0.54%, closely followed by soybean flour at 11.89±0.55%. Wheat flour, in comparison, has the lowest moisture percentage at 11.05±0.51%.

Soybean flour has the highest rating for fat content (16.91±0.54%), while amaranth flour comes in second (9.81±0.31%). The least amount of fat is found in wheat flour (1.46±0.05%). Soybean flour has the highest protein level, with 38.07±1.64%. Compared to wheat flour, which has a slightly lower protein level of 13.40±0.58%, amaranth flour has a protein value of 14.58±0.63%.

Amaranth flour has the highest rating for fiber content (8.76±0.32%), followed by soybean flour (4.87±0.18%). With 1.40±0.05%, wheat flour contains the least fiber. The highest value for ash content is 4.81±0.15% for soybean flour, followed by 2.74±0.08% for amaranth flour. The least amount of ash is found in wheat flour (0.50±0.02%).

Last but not least, wheat flour has the greatest amount in the nitrogen-free extract (NFE) category, at 72.19±1.21%, followed by amaranth flour, at 52.34±1.88%. The least amount of NFE is detected in soybean flour, at 23.45±3.06%.

Table 2: Proximate Analysis (%) Mean Values of Different Flour

Parameters	Wheat Flour	Amaranth Flour	Soybean Flour
Moisture %	11.05±0.51	11.77±0.54	11.89±0.55
Fat %	1.46±0.05	9.81±0.31	16.91±0.54
Protein %	13.40±0.58	14.58±0.63	38.07±1.64
Fiber %	1.40±0.05	8.76±0.32	4.87±0.18
Ash %	0.50±0.02	2.74±0.08	4.81±0.15
NFE %	72.19±1.21	52.34±1.88	23.45±3.06

Overall, the proximate study highlights the three flour' unique nutritional contents. Wheat flour is characterized by having greater carbohydrate content but a comparatively low fat and protein level. Amaranth flour stands out because of its greater mineral and fiber content. Protein and fat levels in soybean flour are exceptional. These differences in nutritional profiles have a big impact on different gastronomic and dietary applications.

3.2. Production and Quality Evaluation

An extensive analysis of each of the bread's constituent parts was done to establish the quality standards for bread manufactured from composite flour. The bread's texture, color, and nutritional makeup were meticulously studied for each treatment.

3.2.1. Nutritional, Texture and Color Values: Based on composite wheat composition, Table 3 explains the mean values and standard deviations of major bread properties across multiple treatments. In addition. Table 4 shows the ANOVA's statistical significance for these observed changes. Table 3 shows that T4 has the greatest average moisture content (24.08% (5.011)), whereas T0 measures 25.32% (2.214). The ANOVA findings in Table 4 show that storage had a very significant impact on moisture and highlight storage's critical role in moisture changes (Jakkamsetty et al. 2024). The substantial interaction between treatment and storage implies that the composition of the flour may have different impacts on moisture over time. According to Table 3, T4 has the highest mean fat content overall, at 5.13% (0.425), well above T0's 1.25% (0.010). According to Twinomuhwezi et al. (2020), the inclusion of amaranth and soybean flour, which are high in fat, increases the bread's fat content. The ANOVA in Table 4 highlights the significant impact of both storage and treatment on fat content. Additionally, their interaction is significant.

Table 3: Various parameters (mean±SD) of on Days 0, 7, and 14 of storage across different treatments

Parameters	Treatments				
	T_0	T_1	T_2	T_3	T_4
Moisture	25.320±2.214	24.970±2.476	24.547±3.081	24.303±3.887	24.08±5.011
Fat	1.25±0.010	2.13±0.026	2.996±0.076	4.55±0.173	5.133±0.425
Protien	12.913±0.032	14.103±0.015	15.48±0.026	16.79±0.035	17.777±0.181
Fiber	1.2367±0.060	1.7967±0.046	2.4433±0.055	3.0067±0.025	3.3267±0.205
Ash	0.43±0.044	0.7767±0.006	1.0967±0.012	1.3767±0.025	1.7633±0.072
Texture	1.9322±0.172	2.1267±0.367	2.46±0.610	3.8989±0.595	5.0589±0.353
l* Value	73.309±0.010	69.753±0.064	64.193±0.190	60.524 ±0.180	58.477±0.387
a* Value	1.4567±0.179	2.33±0.321	3.1333±0.107	4.2±0.191	5.32±0.350
b* Value	20.18±0.113	21.067±0.200	21.627±0.124	23.043±0.064	26.37±1.198

Note: T_0 (control with 100% wheat flour), T_1 with 5% and 5% amaranth and soybean flour, respectively with 90% wheat flour, T_2 with 10% and 10% concentration of both soybean and amaranth flour, respectively, T_3 with 15% and 15% amaranth and soybean, respectively, T_4 with 20% and 20% of both soybean and amaranth flour, respectively.

Table 3 ranks T4's mean value as the highest in terms of protein, with 17.777% (0.181), a rise that may be attributed to the protein rich amaranth and soybean flour (Marcel et al. 2022). The ANOVA in Table 4 shows that there is a very significant treatment effect but that the storage time and its interaction with treatment are not significant (Liu & Chen 2023). Table 3 lists T4 as having the highest fiber content at 3.3267% (0.205), which is much higher than T0's 1.2367% (0.060). The naturally high fiber content of amaranth and soybean flour supports this tendency. Table 4 reveals the substantial impacts of both storage and treatment on fiber content. Table 3 demonstrates T4's supremacy in terms of ash with a value of 1.7633% (0.072), far higher than T0's 0.4300% (0.044). ANOVA in Table 4 highlights the significant influence of flour type on ash concentration. Table 3's analysis of texture demonstrates that T4 has a more noticeable average texture value of 5.0589 (0.353), compared to T0's 1.9322 (0.172). This indicates that amaranth and soybean flour contribute to creating a denser bread texture

(Omoba et al. 2024). The bread texture clearly responds to both the flour mixture and the amount of storage time, as shown by the ANOVA in Table 4. Table 3 shows that T0 has the highest value for the l value* (which denotes brightness or darkness) at 73.309 (0.010), while T4 trails at 58.477 (0.387). This amplifies the ability of amaranth and soybean flour to darken foods. Table 3 lists T4 with a color value of 5.3200 (0.350) with a value of* (red-green color). The ANOVA in Table 4 supports the strong impacts of both treatment and storage. Table 3 differentiates T4 with a lead value of 26.370 (1.198) in the b value* domain (yellow-blue hue). The ANOVA in Table 4 indicates that treatment had a single, significant impact on the b* value. Overall, a comprehensive understanding of how various composite flour treatments and storage times interact and affect bread's many characteristics may be gained by examining Table 3 and 4. The data emphasizes how important amaranth and soybean flour are in enhancing the bread's nutritional and physicochemical properties. While some parameters, like protein and l* value, remain consistently stable across storage, others, like moisture and fat, show clear changes, the data emphasizes the crucial role that these two flours play in this process.

Table 4: ANOVA for Different Bread Parameters

Parameter	Source	DF	SS	MS	F
Moisture	Days	2	329.32	164.66	153.97**
	Treatment	4	9.062	2.265	2.12NS
	Days* Treatment	8	35.112	4.389	4.10*
Fat	Days	2	0.5992	0.2996	20.41**
	Treatment	4	94.9347	23.7337	1616.74**
	Days* Treatment	8	0.705	0.0881	6.00**
Protein	Days	2	0.086	0.0432	0.12NS
	Treatment	4	139.06	34.765	93.47**
	Days* Treatment	8	0.13	0.0163	0.04NS
Fiber	Days	2	0.158	0.07902	9.87**
	Treatment	4	26.4489	6.61223	825.84**
	Days* Treatment	8	0.1508	0.01884	2.35*
Ash	Days	2	0.01648	0.00824	3.92*
	Treatment	4	9.62432	2.40608	1145.75**
	Days* Treatment	8	0.03112	0.00389	1.85NS
Texture	Days	2	4.9826	2.4913	406.63**
	Treatment	4	64.7644	16.1911	2642.73**
	Days* Treatment	8	1.1072	0.1384	22.59**
l* value	Days	2	0.19	0.097	0.06NS
	Treatment	4	1390.96	347.74	230.23**
	Days* Treatment	8	1.14	0.142	0.09NS
a* value	Days	2	1.4444	0.7222	43.91**
	Treatment	4	83.3061	20.8265	1266.31**
	Days* Treatment	8	0.3884	0.0485	2.95*
b* value	Days	2	3.111	1.5556	2.16NS
	Treatment	4	211.163	52.7908	73.31**
	Days* Treatment	8	5.931	0.7414	1.03NS

*Significant **Highly Significant NSNon-Significant

3.2.2. Sensory Analysis: Consumer acceptance and preference are fundamentally determined by the sensory qualities of food items. Table 5 shows the differences in sensory characteristics across various treatments and storage times. Significant variances were seen in terms of color. The bread produced with the T0 treatment (100 percent wheat flour) had a mean color value of 6.8667, whereas the bread produced with the T4 treatment (60 percent wheat flour, 20 percent amaranth flour, and 20 percent soybean flour) had the lowest mean color value of 4.9333 (Table 5). The natural colors of these flour, which are intrinsically darker than wheat flour, might be the cause of the declining trend in color values with increasing amounts of amaranth and soybean flour. The natural pigmentation of amaranth and soybean flour, which is intrinsically darker than the typically light shade of wheat flour, is responsible for the color's deepening. The inclusion of these darker pigments in the flour mix is the primary cause of this color deepening (Nkesiga et al. 2021). Additionally, the color value was greatly altered by the Maillard reaction, a non-enzymatic browning process that takes place during storage (Table 6). These findings are supported by the ANOVA results, which show significant differences (Table 6).

Another sensory quality that significantly influences customer impression is appearance. The ANOVA findings (Table 6) show that there are significant differences related to treatments, the length of storage, and their interactions. The bread treated with T4 had the lowest mean appearance score (4.8433), whereas loaves made solely of wheat flour and treated with T0 had the greatest mean appearance score (6.4233) (Table 5). This suggests that adding more amaranth and soybean flour can have a negative impact on the bread's aesthetics owing to changes in color, texture and overall appearance (Saati et al. 2020). Consumer approval depends on texture, a crucial sensory feature. The ANOVA revealed that bread texture was significantly impacted by treatment types, storage time, and their synergistic effects (Table 6). Bread made completely of wheat (T0) showed the best texture perception, scoring 6.8011, while the worst was demonstrated by T4 bread, scoring 4.7100 (Table 5). These textural variances may be caused by these flour' diverging gluten concentrations and water absorption capacities compared to wheat flour.

Table 5: Various Sensory Parameters (Mean±SD) on Days 0, 7, and 14 of Storage across Different Treatments

	Treatments				
Parameters	T_0	T_1	T_2	T_3	T_4
Color	6.8667±1.179	5.9778 ±1.055	6.0656 ±1.093	5.3767±0.705	4.9333±0.851
Appearance	6.4233±1.110	5.8222±1.110	6.0000±1.048	5.1344±0.480	4.8433±0.618
Texture	6.8011±1.046	5.9100±0.541	6.3111±1.202	5.2000±0.503	4.7100±0.869
Aroma	6.776±0.910	6.332±0.721	6.312±1.267	4.93±0.355	4.691±0.731
Flavor	6.888±0.619	5.821±0.640	6.443±0.804	4.821±0.378	4.865±0.634
Taste	6.6444±0.953	5.9778±0.778	6.3333±0.867	5.0667±0.406	4.6444±0.735
Overall Acceptability	7.2911±1.120	6.6900±0.803	6.8889±1.167	5.2667±0.659	4.6667±0.851

Table 6: ANOVA for Different Bread Sensory Parameters

Parameter	Source	DF	SS	MS	F
Color	Days	2	27.6916	13.8458	256.74**
	Treatment	4	19.4449	4.8612	90.14**
	Days* Treatment	8	1.8232	0.2279	4.23**
Appearance	Days	2	21.2703	10.6351	213.58**
	Treatment	4	14.9991	3.7498	75.30**
	Days* Treatment	8	3.7743	0.4718	9.47**
Texture	Days	2	20.6486	10.3243	194.71**
	Treatment	4	25.4047	6.3512	119.78**
	Days* Treatment	8	2.3867	0.2983	5.63**
Aroma	Days	2	18.8506	9.42531	174.76**
	Treatment	4	31.3361	7.83402	145.25**
	Days* Treatment	8	2.8259	0.35324	6.55**
Flavor	Days	2	11.1758	5.58792	104.39**
	Treatment	4	30.8366	7.70916	144.02**
	Days* Treatment	8	0.7296	0.0912	1.70NS
Taste	Days	2	16.5147	8.25734	157.80**
	Treatment	4	25.92	6.48	123.83**
	Days* Treatment	8	1.3081	0.16351	3.12*
Overall acceptability	Days	2	25.0976	12.5488	206.43**
	Treatment	4	46.0771	11.5193	189.49**
	Days* Treatment	8	1.4118	0.1765	2.90*

*Significant **Highly Significant ^{NS}Non-Significant

The foundation of sensory analysis, taste, largely determines customer approval. The ANOVA showed that storage time, treatment type, and their interaction; all significantly impacted on flavor (Table 6). While T4 samples consistently fell behind, bread samples from the T0 and T2 treatments initially had impressive taste ratings (Table 5). According to Mospah et al. (2023), these flour' distinctive flavor profiles and possible staling-induced flavor alterations during storage may be to blame. The viability of a product's market depends largely on its general appeal. The ANOVA findings from Table 6 show that both treatment kinds, storage time, and their interaction have significant impacts. The T0 treatment's bread samples originally showed the greatest acceptance, but T4 items persistently performed poorly (Table 5). This implies that although adding amaranth and soybean flour enhances nutritional value, it calls for careful calibration to guarantee the best level of customer acceptability. Overall, these sensory qualities provide a holistic picture, permitting product refinement and strategic positioning in the complex

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market environment, supported by the statistical insights from Table 5 and 6.

4. CONCLUSION

This study endeavor has shown the significant potential for integrating amaranth and soybean flour in bread-making to improve its nutritional profile. Notably, adding this flour has been shown to increase the bread's protein, fiber, and fat content, potentially addressing malnutrition issues worldwide. Amaranth and soybean are underutilized commodities, but their combined potency makes a strong argument for their inclusion in bread recipes, emphasizing their crucial contribution to developing a nutrient-dense global population. Further research into optimizing the ratio of amaranth and soybean in bread for the optimum sensory and nutritional results is advised, building on the insights gained. The food sector might also investigate mass manufacturing and promoting such nutritionally enriched bread varieties. Future studies may also look at the possibilities of other underutilized crops, broadening the range of alternative flour and their potential to improve the nutritional value of typical dishes.

Author's Contributions

It has been a collaborative effort between all authors who have all contributed equally to the manuscript and have critically revised and finalized it.

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