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SENSORY EVALUATION AND STALING BEHAVIOR OF LOAF BREAD WITH THE SUBSTITUTION OF WHEAT FLOUR USING FENUGREEK

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ABSTRACT

Bread is a staple food worldwide and plays a crucial role in meeting the nutritional requirements of the population. However, bread's stalling properties deteriorate over time due to several factors, including starch retrogradation, moisture loss, and microbial spoilage. Therefore, researchers are exploring different approaches to improve bread's stalling properties, such as using functional ingredients like fenugreek seed powder (FG). In this study, we investigated the effect of FG on the stalling properties of bread by partially substituting wheat flour with FG at different ratios (5%, 10%, and 15%). The findings showed that the addition of FG improved bread's stalling properties by delaying starch retrogradation, reducing water loss, and increasing water retention. These results suggest that FG has the potential to be a useful functional ingredient in bread production. Furthermore, evaluation of the sensory properties of bread with varying levels of FG substitution was carried out. we found that bread with 10% FG substitution had the lowest stalling rate after 72 hours of storage and was well-accepted by sensory evaluation. In contrast, bread with 15% FG substitution was not sensory acceptable. Therefore, a 10% FG substitution is recommended for improving stalling properties without compromising sensory acceptability. In conclusion, this study highlights the potential of using FG as a functional ingredient to improve bread's stalling properties. These findings could have practical implications for the food industry in developing functional bread products with improved shelf life and sensory quality.

INTRODUCTION

Wheat is a reliable crop that, because of advances in baking technology and shifting consumer preferences, now yields flour used in baking a wide range of items, especially bread, in urban and rural areas **(Noort *et al.*, 2022**). When it comes to production and consumption, wheat is, without a doubt, the most significant cereal crop in the world **(El-Mouhamady *et al.*, 2023**). Even more so, wheat is one of Egypt's most vital crops, with annual outputs in the 8-10 million tonne range between 2010 and 2020 **(Mabrouk *et al.*, 2021**).

Human nutrition relies heavily on bread and other bakery goods. Conversely, bread made with refined flour is substantially less nutritious and fails to provide many essential macro- or micronutrients. White bread prepared with refined flour is said to be poor in micronutrients **(Hooda and Jood, 2005**). Furthermore, important amino acids like lysine, threonine, and valine are unbalanced in wheat flours. Numerous studies are underway to increase bread's

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protein, mineral, vitamin, and/or fibre content to meet the growing needs of contemporary dietary patterns **(Sharma *et al.*, 1999**). Nutritional, protective, and ballast additives to baked goods have risen in favour. Considering their usefulness as transport mechanisms for essential nutrients and phytochemicals, mixed-grain and whole-grain bread and similar products are considered functional foods. Composite loaves could be undertaken by combining wheat flour and other types of flour. These flours help developing nations cut back on wheat imports and increase their usage of domestically produced grains **(Noort *et al.*, 2022**). Incorporating composite blends, including fenugreek (FG), into the production of various food items may improve customers' nutritional and health status due to its many beneficial properties. Incorporating FG into several baked goods has been observed to boost its nutritional, dietary fibre, and antioxidant profiles. This includes biscuits **(Hooda and Jood, 2005; Hegazy and Ibrahium, 2009**) and bread **(Afzal *et al.*, 2016; Chaubey *et al.*, 2018; Man *et al.*, 2019**). However, fenugreek produces satiety simultaneously **(Lee, 2009**). Bakery items, including pizza, bread, muffins, and cakes made with flour supplemented with 8-10% FG fibre, have favourable sensory qualities **(Srinivasan, 2006; Man *et al.*, 2019**). FG can also be added to bread at a 20% level **(Dhull *et al.*, 2020**).

The development of bread fortified with FG proteins by FG seeds flour hybrid has been the addressed of research undertaken by **Chaubey *et al.* (2018**). The authors showed that using FG flour instead of wheat flour and making bread and rusks with flaxseed flour reduced the loaf volume and the baking time **(Dhull *et al.*, 2020**). Furthermore, the impact of Egyptian FG flour addition on the bread's stalling performance and sensory attributes was not adequately described. Furthermore, the good effects linked with this plant from other locations, based on limited published studies, make it important to characterize Egyptian-produced and processed FG. Recent research was conducted in Egypt to determine the sensory and staleness qualities of loaf bread made with partial replacements of FG seeds powder for wheat flour.

MATERIALS AND METHODS

Materials Description and Preparation

Local Egyptian fenugreek (*Trigonella foenum-graecum* L.; cultivar Giza-30; Arabic name: Hilba) was provided by The Agricultural Research Center (ARC) at Giza, Egypt. Fenugreek seeds were ground in-house using a grain mill (Kenwood Chef XL Stand Mixer, 1200 - UK) to pass a 250 µm sieve. Commercial wheat flour (72% extraction) and other ingredients were purchased from local market in North Sinai, Egypt.

Technological Properties Methods

A dry premix was made by mixing wheat flour (without or with 0, 5, 10, or 15% substitution using fenugreek seeds powder), 2.0% dry yeast, 2.0% salt, and 1.5% flour improver based on ascorbic acid and L-cysteine (50:50; Merck, Germany) (percentage based on flour weight). El-Demery method is used to make bread in industrial mixers **(El-Demery, 2011**). Salt, flour, and the flour improver were mixed in the mixer with a 5-liter bowl (5L Planetary cake mixer, Foodsense, China). A yeast suspension was made with a certain amount of tap water, and it was kept at 35 °C for 20 minutes. The powder and the rest of the water were then added to the premix. The components were combined for 10 minutes using a hooks beater. The dough was then fermented in an industrial fermentation cabinet (Aocno-bakery Co., China) at 28 °C for 90 minutes. Using a rolling method, the dough was cut into small pieces (160 g) and then fermented at 35–37°C for 90 minutes with the relative humidity set to 70–75%. After 30 minutes of baking at 250°C without steaming in an industrial oven (Zanussi FCF/E6-0, Zanussi Co.), the bread was taken out of the pan and cooled at 25°C for 1 hour. The sample was then put in low-density polyethylene Ziploc vacuum bags and kept at room temperature until further investigations.

Bread Loaf Storge Study

At 25°C, the water activity of bread samples was measured using a Decagon Aqualab Series 3 water activity metre (Pullman, WA, USA). After equilibrating the sample within the sealed chamber's headspace, bread samples (about 2 g) were uniformly distributed on the plastic cells. The measurements were taken at intervals under ambient conditions (0, 24, 48, and 72 hr on shelf-life). The centre section of the loaf of bread was sliced into three 12.5 mm-thick slices. The Texture Analyzer (Brookfield CT3 texture analyser operating instruction manual No. M08-372-C0113, Stable Micro Systems, USA) was used to conduct compression tests in order to quantify hardness, cohesion, gumminess, chewiness, adhesiveness, springiness, and resilience. Using the Texture analyzer was under the following conditions: Test-TAP, probe-36 mm cylindrical, Pre-test speed-1 mm/sec., Test speed-1 mm/sec., and Post-test speed-2mm, the sample was compressed twice to 40 percent of its original height. The measurements were made at intervals under ambient conditions (0, 24, 48 and 72 hr on shelf-life). Stalling rate was calculated according to the method described by **Abd-El-Khalek *et al.* (2019)**. $SR\% = [(AWRC_0 - AWRC_n)/AWRC_0] \times 100$, where AWRC is alkaline water retention capacity at 0 storage time and n time.

Sensory Evaluation

Staff and students at Arish University, Faculty of Environmental Agricultural Sciences were asked to rate the loaf bread samples made as toast slices. Panellists were asked to rate each sensory aspect of the bread, including its smell, taste, crust colour, crumb colour, crumb texture, and overall acceptability, on a 9-point hedonic scale. The scale goes from 1 (extremely dislike) to 9 (extremely like) **(Hooda and Jood, 2005**).

RESULTS AND DISCUSSION

Storage Study of Bread

Table 1 shows how the texture of bread changed when FG seeds powder was substitute. The results showed that the hardness, deformation, cohesiveness, resilience, elasticity, gumminess, chewiness, and springiness of bread changed depending on how much FG was substituted and how long it was stored. All of the textural parameters change when FG seeds powder is substituted up to a level of 15%, as shown. In the 15 % FG bread treatment the hardest at 72 hour was 34.5, followed by 48 hour (33.7), 24 hour (29.7), and 0 hours (21.01). The grand average values went up as more FG was added and the storage time went up. Hardness is measured in terms of load per square centimeter and reflects the loss of elasticity and increase in firmness **(Ahmed *et al.*, 2020**). In the current study, mixed flour by substitution exhibited significant increase in hardness values. **Sidhu *et al.* (1997**), reported that, soluble starch and amylose contents decreased as the bread get older during storage course. Stalling is very complex process which cannot be explained by a single effect and involves reorganization of polymers within the amorphous region and amylopectin retrogradation.

Hydrocolloids increase rigidity by decreasing starch granule swelling and amylose leaching, and they weaken starch structure by inhibiting amylose chain associates. The weight of each effect

Table 1. Changes of the texture parameters of bread loaf incorporated with FG stored for 3 days

Texture parameter	Treatment	Storage period			
		0.0 hr	24 hr	48hr	72hr
Hardness N	0%	13.3	14.9	17.6	19.5
	5%	19.7	24.3	27.7	30.6
	10%	17.2	24.1	28.4	29.9
	15%	21.0	29.6	33.7	34.5
Deformation (%)	0%	39.6	40.0	40.0	39.9
	5%	40.0	40.0	40.0	39.9
	10%	39.4	40.0	39.9	39.8
	15%	40.0	39.4	39.9	39.8
Adhesiveness mj	0%	0.300	0.300	0.100	0.100
	5%	0.300	0.100	0.100	0.100
	10%	0.300	0.200	0.200	0.200
	15%	0.100	0.100	0.100	0.100
Resilience	0%	0.400	0.260	0.220	0.190
	5%	0.350	0.240	0.180	0.170
	10%	0.360	0.260	0.280	0.220
	15%	0.370	0.240	0.310	0.200
Cohesiveness	0%	0.910	0.670	0.510	0.540
	5%	0.810	0.630	0.590	0.510
	10%	0.830	0.700	0.680	0.600
	15%	0.820	0.660	0.820	0.750
Springiness mm	0%	4.43	4.41	4.47	4.56
	5%	5.83	5.69	5.60	5.18
	10%	5.46	5.77	5.47	5.75
	15%	6.03	4.95	6.01	6.16
Gumminess N	0%	12.6	10.7	10.0	11.3
	5%	16.5	16.4	16.5	16.9
	10%	14.8	17.7	20.2	19.2
	15%	17.9	21.0	28.8	27.2
Chewiness mj	0%	55.7	47.1	50.0	51.70
	5%	96.3	93.2	90.4	87.5
	10%	80.5	102	111	110
	15%	108	125	173	168

depends on the hydrocolloid used (**Guarda *et al.*, 2004**). **Rosell *et al.* (2001**) found that hydrocolloids' better water retaining capacity increased water activity and moisture retention. Current studies show that extending storage times up to 48 hr, enhanced average water activity (Fig. 1). FG in the dough structure prevents stalling during almost 2-day storage. Hardness decreased water activity throughout storage.

Hardness-water activity link was the key discovery of this segment. Long-life bread has less water. Molds decrease the durability of intermediate and high moisture cookies. FG may prevent bread loaf stalling during storage.

The degree to which a product's crumb recovers its original shape after being compressed and released is a measure of its springiness and resilience. The longer something is stored, the more likely it is to lose its quality (**Young, 2012**). Table 1 shows that the average values for bread springiness increased with increasing amounts of fenugreek seeds powder compared to the control group. The maximum springiness was observed in order 6.16 mm, 6.03mm, 5.77 mm for 15% FG at 72 and 0.0hr and for 10% FG at 48 hr, respectively whereas minimum was observed in control at 24 hr. (4.41mm).

All baked goods benefit from cohesiveness. Moisture level and crumb network strength determine whether items form a ball in the mouth and need some chewing (**Zhang *et al.*, 2023**). The stalling process and moisture loss make biscuits crumbly. Table 1 shows that bread with 15% fenugreek seeds powder had the highest cohesion across storage. The minimal cohesion value in control was 0.0 hr. The dough will be stickier and harder with more cohesion (**Young, 2012**).

Table 1 shows fenugreek powder-supplemented bread gumminess results. Fenugreek powder enhanced bread gumminess from 10 N (control at 48 hr.) to 28.8 N (15% FG at 48 hr.). Gumminess reflects the energy needed to dissolve food for swallowing, which means the storge period requires more energy for human use (**Young, 2012**).

In Table 1 we observe the average values for the chewiness of bread made using fenugreek seeds powder as an additive. The chewiness of food is measured by how long it takes to chew before it can be swallowed (**Young, 2012**). Maximum value was found in 15% at 48 hr. (173 mj) and minimum value was found in control at 24 hr., indicating a non-significant rising tendency with increasing storage duration but a significant increasing trend with increasing percentage of supplementation (47.1 mj).

Adhesiveness is the amount of effort required to peel food away from a certain surface (**Young, 2012**). The adhesive strengths are shown in Table 1. There was no statistically significant variation in the storge duration. There was a steady decline in value over time, nevertheless. Control had the maximum adhesiveness at 0 and 24 hours.

Bread Texture and Stalling Rate During the Shelf-Life Course

Stalling analysis was used to describe textural factors and show how FG extend the shelf life of bread. Wheat flour gluten affects baked goods quality. It affects wheat water absorption, viscosity, cohesion, elasticity, kneadability, extensibility, gas retention, deformation resistance, and dough strengthening qualities (**Lazaridou *et al.*, 2007; Wieser, 2007**). A texture analyzer measured bread texture such as hardness, puncture force, *etc*. The texture analyzer showed that adding dried fenugreek leaves reduced shear force from 829g to 520 and 497g. FG addition enhanced hardness in the current investigation. Lowering shear force improved paratha quality, indicating that desiccated FG made

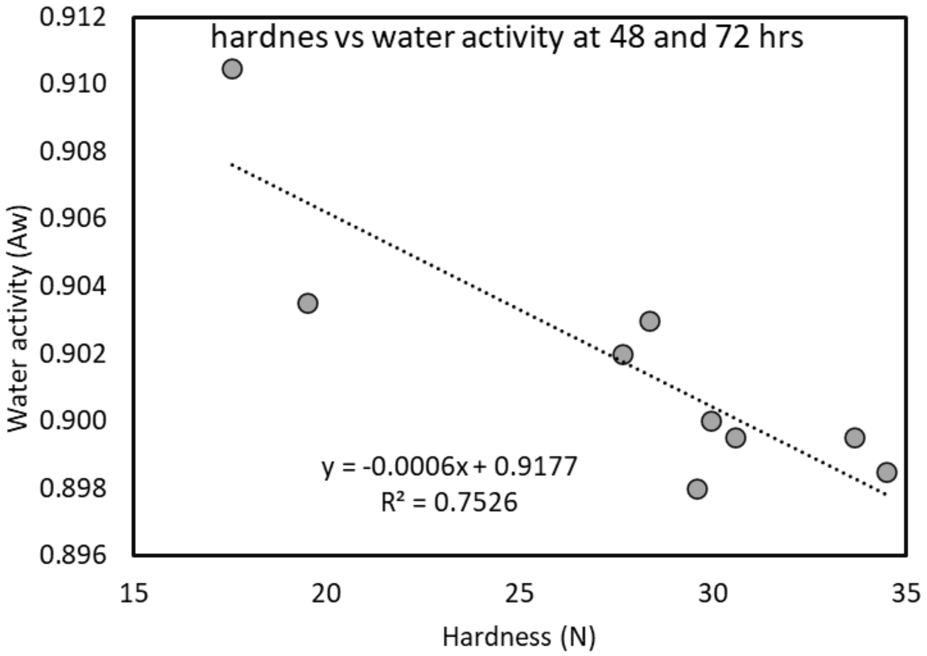

Fig. 1. Relationship between water activity and hardness of bread loaf incorporated with FG stored at 2 and 3 days

it somewhat tougher **(Indrani *et al.*, 2011**). Dietary fibre from FG dilutes gluten protein, making the food more extensible and chewy **(Sudha *et al.*, 2015**). The findings are also in harmony with studies of **Abdelghafor (2011**) and **Phattanakulkaewmorie *et al.* (2011**) found that adding sorghum flour to bread hardened it. Moisture migration, redistribution, and gluten-starch interactions determine bread's hardness **(Osella *et al.*, 2005**). When bread cools, starch retrogrades and gels in intergranular gaps, making it hard **(Hebeda, 1996**). Flour with added FG may dilute gluten protein and wheat starch: 1) After baking, gelatinized starch retrograded in room temperature, but adding FG diluted and modified the pure starch ratio, decreasing the retrogradation rate; 2) Due to its hydrophilic nature, FG molecules retained moisture and maintained textural profiles; 3) the interaction between FG and starch slowed starch retrogradation *via* moisture retention and affected amylose contacts and amylopectin associations, respectively **(BeMiller, 2011**). Thus, FG may delay crumb stalling, which needs further investigation. In conclusion, the water holding capacity of the FG and a projected interaction between FG and starch delayed starch retrogradation, delaying the rise in hardness, gumminess, chewiness, cohesiveness, springiness, and resilience during storage (Table 1). Alkaline water retention capacity during multiple storge periods was used to calculate stalling rate (Fig. 2).

The results showed that SR of bread was increased to become 19.3% at 72 hr. of storage for control. However, 10% FG showed the lowest SR% after 72 hr., (4.49%). Both treatments of 5 and 10% FG showed closeness results in term of SR (Fig. 2); they represented the highest R^2 values to the liner model (R^2 > 0.90). This finding confirms the superior of 10% FG addition to wheat flour for baked bread. This results were in agreement with **Abd-El-Khalek *et al.* (2019**). The authors found that SR was increased as a function of storage period for Balady bread.

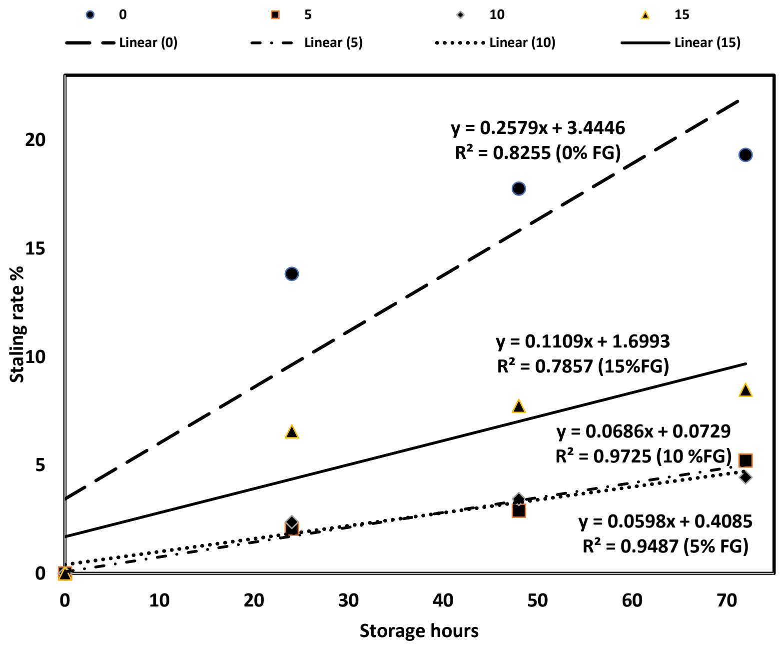

Fig. 2. Changes in stalling rate (SR%) during bread storage period for 0, 24, 48 and 72 hours

Sensory Evaluation of Bread

Bread is a fermented confectionery food made by combining, kneading, proving, shaping, and baking wheat flour, sugar, water, salt, and yeast **(Sawettanun and Ogawa, 2022**). Bread is a good source of vitamins and minerals, notably Fe and Zn, but it is nutritionally poor because wheat protein, its primary constituent, lacks several necessary amino acids **(Kiran *et al.*, 2022**). Composite flour improves bread's nutritional value and meets vegetarians' protein needs. Consumers accept a product based on its sensory qualities. Table 2 compares bread loaves with different fenugreek flour substitutions. Crust color, scent, taste, appearance, texture, and acceptance were measured.

The crust colour of bread with fenugreek flour added got the most points (7.99) when there was 5% FG, then 7.99 for 10% FG, and 6.04 for 15% FG. The control sample got 8.30 points. When fenugreek flour was added at 5 and 10 %, it made a significant difference in the colour of the bread crust (Table 2). Colour of the crust got less intense as the amount of fenugreek flour used went up as reported by **Sharma and Chauhan (2000**).

People put a lot of value on aroma, which is something you can feel with your nose. Scores for the smell of fenugreek flour ranged from 8.76 for the control bread to 7.87 for the bread with 5% fenugreek flour. The 10% FG (5.53), 15% FG blend (3.10), and 15% FG blend (8.76) versions all had much lower scores. **Hooda and Jood (2004**) also found that bread made with germinated fenugreek flour had a stronger flavour, which is what we found as well. The results for the bread with 5% and 10% fenugreek flour added were very close to those for the "control" bread. Sensory panels couldn't tell the difference in taste between the control bread and bread samples with 5, 10, or 15% fenugreek flour. However, they could tell the difference at 15%. Bread samples made with both the 5% and 10% FG mixtures were good in terms of how they looked, felt, and were accepted. Bread samples that were used as

Table 2. Sensory evaluation of bread loaf supplemented with the different substitutional percentages of fenugreek flour

Sensory variable	Substitute percentage of FG with WF			
	0.00%	**5.0%**	**10.0%**	**15.0%**
Crust Color	8.30	7.99	7.87	6.04
Aroma (odor)	8.76	7.87	5.53	3.10
Taste	7.31	7.23	7.03	3.46
Appearance	7.73	7.37	7.13	5.30
Texture	8.71	8.13	7.63	6.83
Overall acceptability	7.98	7.91	7.63	3.90

checks were not hurt. Based on these results, FG treatments with 15 percent are not safe for people to eat. So, the 10 percent FG replacement was good enough to use in this study.

Conclusion

This study demonstrated that incorporating fenugreek seed powder as a partial replacement for wheat flour enhanced bread stalling properties by delaying the retrogradation of starch, improving moisture retention, and enhancing the texture and sensory attributes of bread. The optimal ratio of fenugreek seed powder for bread production was determined to be 10%. These findings could potentially benefit the food industry in the development of functional bread products with improved sensory quality and longer shelf life. Further research is required to investigate the suitability of fenugreek seed powder in other bakery products and to understand the mechanism of action that underpins its effect on bread stalling properties.

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الملخص العربي

التقييم الحسى وسلوك البيات لخبز القالب باستبدال دقيق القمح بالحلبة

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الخبز هو الغذاء الرئيسي في جميع أنحاء العالم ويلعب دورا حاسما في تلبية الاحتياجات الغذائية للسكان. ومع ذلك، فإن خصائص الخبز تتدهور بمرور الوقت بسبب عدة عوامل، بما في ذلك تراجع النشا وفقدان الرطوبة والتلف الميكروبي. لذلك، يستكشف الباحثون طرقا مختلفة لتحسين خصائص تلف الخبز، مثل استخدام المكونات الوظيفية مثل مسحوق بذور الحلبة (FG). في هذه الدراسة، قمنا بالتحقيق في تأثير FG على خصائص تلف وبيات الخبز عن طريق استبدال دقيق القمح جزئيا ب FG بنسب مختلفة (٥%، ١٠% و١٥%). أظهرت النتائج أن إضافة FG حسنت خصائص البيات عن طريق تأخير تراجع النشا، وتقليل فقد الماء، وزيادة احتباسه. تشير هذه النتائج إلى أن FG لديها القدرة على أن يكون مكونا وظيفيا مفيدا في إنتاج الخبز. علاوة على ذلك، تم إجراء تقييم للخصائص الحسية للخبز بمستويات متفاوتة من استبدال FG. وجدنا أن الخبز الذي يحتوي على استبدال FG بنسبة ١٠% كان لديه أدنى معدل بيات بعد ٧٢ ساعة من التخزين وكان مقبولا جدا من خلال التقييم الحسي. في المقابل، لم يكن الخبز الذي يحتوي على استبدال ١٥% FG مقبولا من الناحية الحسية. لذلك، يوصى باستبدال FG بنسبة ١٠% لتحسين خصائص البيات دون المساس بالخصائص الحسية. تسلط هذه الدراسة الضوء على إمكانية استخدام FG كمكون وظيفي لتحسين خصائص بيات الخبز. يمكن أن يكون لهذه النتائج آثار عملية على صناعة الأغذية في تطوير منتجات الخبز الوظيفية مع تحسين مدة الصلاحية والجودة الحسية.

الكلمات الإسترشادية: مسحوق بذور الحلبة، دقيق القمح، بيات الخبز، الخصائص الحسية.

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