JMBFS

Journal of Microbiology, Biotechnology and Food Sciences

International peer-reviewed scientific online journal

Published by
Faculty of
Biotechnology and
Food Sciences

HYDROCOLLOIDS IMPACT on RHEOLOGICAL PROPERTIES of WATERMELON PEEL FLOUR and BALADI BREAD WHEAT FLOUR

Ibrahim Abdrabalrasol ALbahrani [1], *Hossam S. El-Beltagi* [2*], *Manal Hegras* [3], *Abdelrahman R. Ahmed* [1], *Hefnawy Taha* [3], *Haiam O. Elkatary* [1], *Hend Al Akkad* [3], *Hoda A.S. Farag* [1], *Ali Osman*[3], *and Ayman El-Khateeb* [4,*]

Address(es):
[1] Food and Nutrition Department, College of Agriculture and Food Sciences, King Faisal University, Al-Ahsa 31982, Saudi Arabia.
[2] Agricultural Biotechnology Department, College of Agriculture and Food Sciences, King Faisal University, Al-Ahsa 31982, Saudi Arabia.
[3] Biochemistry Department, Faculty of Agriculture, Zagazig University, Zagazig, 44511, Egypt.
[4] Agricultural Chemistry Department, Faculty of Agriculture, Mansoura University, Mansoura, 35516, Egypt.

*Corresponding author: helbeltagi@kfu.edu.sa

https://doi.org/10.55251/jmbfs.12466

ARTICLE INFO

Received 1. 3. 2025
Revised 28. 5. 2025
Accepted 14. 6. 2025
Published 1. 8. 2025

Regular article

OPEN ACCESS

ABSTRACT

The present study estimated the effect of various aqueous colloids (gellan gum, guar gum, gum arabic, and pullulan) on the rheological and quality characteristics of wheat bread. The same analysis was done on a mixture of wheat flour with watermelon peel flour (80:20%). These hydrocolloids were chosen due to their distinct functional properties: gellan gum is known for its strong gelling and water-retention capacity, guar gum for its high viscosity and dough-improving properties, gum arabic for its emulsifying ability and impact on texture, and pullulan for its film-forming and moisture-retention qualities. Flour samples were prepared with and without the addition of aqueous colloids (pullulan, gellan gum, guar gum, and gum arabic) at two different concentrations. Parameters such as farinograph and extensograph measurements, color, loaf size, physical properties, and organoleptic qualities were evaluated. Compared to wheat flour, the wheat flour and watermelon peel flour mixture had lower dough energy, water absorption, dough stability, stretchability, and stretch resistance. However, the addition of aqueous colloids to the dough significantly increased water absorption, dough stability, stretchability and stretch resistance. The incorporation of aqueous colloids resulted in a darker crust color. Additionally, bread with aqueous colloids remained fresher than the control group. Gellan gum (at 0.5%) showed the highest alkaline water retention capacity (AWRC) after 1, 3, and 5 days of storage at 20 ± 5 °C. The results of this study indicate that aqueous colloids can be effectively used to enhance dough quality and the organoleptic acceptability of baladi bread made from wheat flour and watermelon peel flour.

Keywords: Baladi bread, watermelon peel flour, hydrocolloids, rheological properties, wheat flour

INTRODUCTION

Bread industry occupies the thinking of the world, as it is source of eating food for many peoples and humans, especially the poor, as it is considered rich in many elements and compounds that God needs human beings and at the same time also poor in some necessary elements and eating it increasingly from some humans leads to some diseases such as gluten syndrome. Bread is the most significant component of the daily dietary intake. White bread is an effective source of energy for the development of the human organism. Nevertheless, bread may not be able to satisfy all of the macronutrient and micronutrient needs necessary for the body's optimal functioning. Subsequently, individuals who consistently consume wheat bread may be susceptible to malnutrition **(Fitzgerald *et al.*, 2014; El-Beltagi *et al.*, 2017; Atteya *et al.*, 2025)**.

Bread is a fundamental staple food consumed worldwide, playing a crucial role in daily diets due to its affordability, versatility, and energy content. However, traditional wheat-based bread often lacks dietary diversity and may not fully meet modern nutritional requirements. In response to growing consumer demand for healthier food options, there is an increasing interest in improving the nutritional quality of bread by incorporating non-wheat ingredients, such as fruit and vegetable by-products rich in fiber, antioxidants, and other bioactive compounds **(Chakraborty, 2021)**. Numerous studies have been conducted by bakery technologists on bread production involving the partial substitution of wheat with non-wheat ingredients to enhance functional, compositional, and nutritional attributes of baked goods **(Rizzello *et al.*, 2014; El-Beltagi *et al.*, 2022a,b; Elkatry *et al.*, 2023a,b)**. Baladi bread is a basic food for humans, as it contains many compounds that provide humans with the necessities of life such as carbohydrates, protein, fiber, vitamins, and other compounds, and it is also the cheapest source of these compounds. In Egypt, there exists a significant disparity of up to 40% between wheat output and consumption **(Elbeltagi et al. 2020)**. This challenge has numerous solutions, such as sourcing local cereals to blend with wheat flour for bread production, and employing colloids to enhance certain attributes of the mixed bread **(Saeed Omer et al. 2023)**. In response to lifestyle-related disorders, such as diabetes, customers are increasingly opting for foods with reduced carbohydrate content and elevated protein levels **(Abdel-Rahim and El-Beltagi, 2010; Brinkworth and Taylor 2020)**. An efficient method to address global nutrient insufficiency in food is to incorporate natural supplements into important items for enrichment. Watermelon (*Citrullus lanatus* L.), a member of Cucurbitaceae family, comprises a substantial quantity of water (91%) and sugar (6%). This fruit is abundant in vitamin C and the non-essential amino acid citrulline. The pulp and juice of this fruit are typically consumed, while its skin and seeds are regarded as solid waste for feeding **(Hanan *et al.*, 2013).** Nonetheless, various industrial, medicinal, and alimentary applications of watermelon rind (WMR) have recently been identified. Watermelon rind (WMR) has great ability to bind to heavy metals in aqueous solutions due to presence of citrulline and an abundant amount of carboxyls and amino groups. **Sani (2014)** discovered that WMR extracts exhibit potent anti-diabetic activity in alloxan-induced hyperglycaemic mice. This agricultural waste serves as a novel source of pectin during various extraction procedures or in the manufacturing of jams, marmalades, confections, pickles, and preserves **(Sood et al. 2024)**. Partial substitution of WMR with wheat flour in the manufacture of these loaves can markedly enhance their physical, structural, and organoleptic characteristics **(Badr, 2015)**. Waste, whether agricultural or factories, is a source available at the cheapest prices and in abundant quantities and must be viewed from several aspects The abundance and diversity of these wastes On the other hand, how to protect the environment from pollution, especially if left untreated, as this leads to many biological reactions (fermentation), which results in compounds and toxins dangerous to the environment From another angle, these residues can be seen as a pharmacy that is already neglected, and if it is taken care of, it leads to Fruitful results for humans and the environment, as it contains many compounds that perform various functions in various directions, whether in terms of health, food or even industrial **(Schieber *et al.*, 2001; Dhawi *et al.*, 2020).** The food industry will face significant challenges, such as reducing waste arising from processing processes, using by-products, and waste treatment and disposal along with sustainable production. The fruit of watermelon and what distinguishes it from other many fruits of large size and fullness of water associated with the amount of peel that does not eat humans compared to the fruit itself leads to looking at the remains of the fruit and the amount and vital compounds that do not benefit humans, but may harm the environment by leaving them, so the researchers had to take care and direct attention to the remains of this fruit, as it has many compounds, whether compounds of activity against bacteria or against many diseases and abundant fibers in which can Take advantage of it by extracting or adding as a raw material to many products **(Rimando and Perkins-Veazie, 2005 and Wani *et al.*, 2012)**.

Watermelon peel flour (WPF) is produced by drying and milling the green outer rind and white inner portion of the peel. This flour is a rich source of dietary fiber, pectin, phenolic compounds, minerals (such as potassium and magnesium), and antioxidants. Its incorporation into bakery products has shown promise in increasing nutritional value, particularly in terms of fiber enrichment, antioxidant capacity, and functional properties such as water-binding **(Romdhane *et al.*, 2024).** The addition of WPF can improve the dietary fiber content of bread, which is beneficial for digestive health and glycemic control (Xu et al., 2021). Bioactive compounds in watermelon peel, including polyphenols and flavonoids, contribute to the antioxidant capacity of the final product, potentially offering health benefits and extending shelf life **(Meghwar *et al.*, 2024)**. Due to its fiber content, WPF has a high water-holding capacity, which can influence dough hydration and improve the texture and shelf life of bread **(Xu *et al.*, 2021).** Aqueous colloids can enhance moisture retention, regulate water circulation, and modulate rheological qualities **(Das *et al*., 2013).** Impact of aqueous colloids on dough and baking characteristics is influenced by various aspects, including particle size, molecular structure, and the quantity of aqueous colloids. Hydroxy groups in hydrocolloidal structure allow for more aqueous bindings by retaining hydrogen in bread dough **Liu *et al*., (2016)**.

Many of the improvers traded in the markets, especially bakery product improvers, whether bleaching improvers, strength improvers, or other improvers, including natural and also industrial, we find many polysaccharides found in the first place after the discovery of many unique properties of them, as they work as an anti-disease and even more useful in health and for diabetics to reduce glucose absorption and provide the body with a little of it **(Kohajdová and Karovičová, 2009)**, whenever the body needs it, plus it has the ability to retain with water and these increase freshness of products and also increase the volume and improve the sensory properties and these many sugars are also called hydrocolloids **(Mandala *et al*., 2007; Rodge *et al*., 2012)**, **(Guarda *et al*., 2004)**. The inclusion of aqueous colloids altered the gluten mesh or linkages in the wheat flour dough, hence modifying its elastic viscoelastic properties, resulting in larger bread, improved porosity, and an optimal crumb texture **(Pečivová *et al.*, 2011)**.

Guar gum is classified as one of the many sugars heterogeneous vegetable source contains sugar glulose and also manu and galactose and contains alpha bonds 1-4 and so it digests in the human body slowly and a source of energy is also classified within the colloids of water that retain water and therefore is used in many products, whether food or non-food and one of the most uses of it in field of bakery products where it increases water retention and raises the level of dough and improves texture and increases the volume of baked goods Therefore, bakery products such as biscuits, bread of all kinds and cakes of all kinds. Guar gum improves the sensory properties, whether color, taste or taste by retaining water and health safety, which leads to consumer acceptance of products to which Guar gum is added and in dairy products also add Guar gum such as ice cream **(Yadav *et al*., 2007)**. Pullulan is extracellular polysaccharide synthesised by fungus Aureobasidium pullulans, composed of linearly polymerised units of trehalose **(Leather, 2003)**. Pullulan polysaccharides which is classified among the many homogeneous sugars and produced by fungi and also has the ability to retain water and bind and therefore classified within the hydrocolloids hydrocolloids and contains glycoside bonds of type alpha 1-4 and also alpha 1-6 and therefore the body on the ability to digest and benefit from it as a source of energy slow benefits diabetic as it works softness of the paste and softness and improves the sensory qualities, taste and appearance and increases the size of the product by increasing the size **(Ferrero, 2017)**. Gellan gum is a high-molecular-weight anionic polysaccharide synthesised in an aerobic environment by the bacteria *Auromonas (Pseudomonas) elodea*, now reclassified as *Sphingomonas paucimobilis*. Gellan gum is classified as Kilkogel, Gilleret, Vitagel, and Puppy Gel. Kelcogel is primarily utilized in food industry as thickening and crystallization agent, while Gelrite, Phytagel and Gel-Gro are used as hardening agents, as substitutes for agar, and also as media for bacterial growth and plant tissue cultures. Gellan gum is classified among the many heterogeneous sugars and is also a microbial sugars and also an aqueous colloid that has the ability to celebrate With water and dissolves in water and has a high viscosity in aqueous solutions, which adds to the products that are added to them unique properties such as softness to the products in addition to taste and improve the texture and size gellan sugar also contains different sugar units of glucose, mannose and galactose and contains beta-glycane beta 1 bonds – 3 and also beta 1-4, which increases its nutritional value and crosses a type of fiber and improves health, which is also a health safety, so many consumers accept to eat it, which softens the level of glucose in the blood and increased use of gellan sugar in bakery products such as biscuits, cakes and baking because it adds to these products the texture and binding of water molecules. This study sought to elucidate the nutritional quality of watermelon peel powder (WMRP) concerning its dietary fiber, mineral content, and antioxidant components. Furthermore, to utilize WMRP as an economical alternative in production of partially municipal bread instead of wheat flour. Moreover, the impact of incorporating aqueous colloids at varying concentrations (0.5 – 1.0%) on several critical quality attributes, including rheological, physical, and chemical properties, as well as the influence of integrating WMPF on organoleptic qualities of the resulting bread.

MATERIAL AND METHODS

Experimental materials

Flour 82% of West Zagazig Mills Company – Sharqia – Egypt. Hydroclloids (Gellan gum -Arabic gum- Pullulan - Guar gum) from El Gomhoria Company - Zagazig Branch - Sharkia – Egypt. Salt and dry yeast - Supermarket - Zagazig - Sharqia – Egypt.

Preparation of watermelon peel powders

Fresh and ripe watermelon fruits (Citrullus lanatus) were purchased from a local market. Care was taken to select fruits free from physical damage or microbial spoilage. The watermelons were thoroughly washed under running tap water to remove surface dirt and contaminants. This was followed by a final rinse using distilled water to eliminate any residual impurities or chlorine from tap water. Using sterilized Taber scissors, the outer green rind was carefully removed to isolate the white mesocarp layer of the peel. This inner white portion, which has higher fiber content and lower bitterness compared to the green rind, was the targeted component for powder preparation. The separated white peel portions were chopped into small, uniform cubes using Taber scissors to facilitate even and efficient drying. The cut pieces were placed in a vacuum oven and dried at 40 °C for 48 h. The vacuum drying method was used to preserve thermolabile nutrients and minimize oxidative degradation. Drying was continued until complete dehydration was achieved and a constant weight was observed, indicating moisture removal and stability. Once dried, the samples were ground using a laboratory mill. The resulting powder was passed through a sieve with 0.1 mm mesh openings to obtain a fine, homogeneous flour. This ensured consistent particle size, which is important for uniform incorporation into flour mixtures and reproducible rheological behavior. The watermelon peel powder was immediately transferred into clean, airtight polyethylene bags and stored at 4 °C to preserve its quality, minimize moisture uptake, and prevent microbial growth until further use in bread formulation.

Preparation of flour mixtures

The colloids used in the experiment were added as recorded in **Table 1** by replacing 20% of wheat flour with watermelon peel flour, then the flour was divided into 8 parts each two parts, one of them was added hydroclloid at a concentration of 0.5% and the other 1.0% of the same hydroclloids and this was repeated with all hydroclloids (guar gum, gellan gum, pullulan and Arabic gum). All samples were meticulously combined, preserved in airtight containers, and maintained at 5-7°C until utilized.

Table 1 Polysaccharides kinds and concentrations utilized in Baladi bread manufacture

Samples	Polysaccharides Kinds			
	Pullulan	Gellan Gum	Guar gum	Gum arabic
S-1	0.5			
S-2	1.0			
S-3		0.5		
S-4		1.0	0.5	
S-5			1.0	
S-6				0.5
S-7				1.0

[a] Weight of polysaccahrides based on (100 g flour)

Bread-making procedure

Orlandi blender (Orlandi mixer GPA model, Italy) was used to mix dry materials [1000 g of flour (wheat or wheat mix/watermelon peels), 5 g; 0.5% of active dry yeast, and 15 g; 1.5% of salt] at low speed for 1 min **(Hussein *et al.*, 2013)**. Water, determined by Farinograph absorption, was included at 30 °C and blended for 6-8 min until a homogeneous paste was achieved. Following 45 min of bulk fermentation at 30 °C and 85% relative humidity (RH), the dough was portioned into pieces weighing 125±5 g. The components were positioned on wooden board, which was dusted with fine layer of bran, and permitted to rest for 30 min in same brewing cabinet. Dough portions are manually flattened to a diameter of 15-20 cm. All flat dough was evaluated at 30 °C and 85% RH for 10 min, followed by baking at 380-400 °C for 1-2 min. Baked loaves were chilled for 10-15 min prior to being enclosed in plastic bags. All municipal bread processing operations were carried out through the National Agricultural Research Center, Food Industries Division, Giza, Egypt.

Chemical analysis

Proximate composition (moisture, fat, protein, and ash) of each materials and bread were estimated according to **(AACC, 2002)**. Total carbohydrates were calculated by by difference. **Table1** observed type of hydrocolloids and concentrations used in the production of municipal bread.

Water retention capacity and oil retention capability

From each sample, 0.5 g of dried sample was taken in centrifugation tube and mixed with 30 mL distilled water for water holding capacity (WHC) estimation or 10 mL for oil holding capacity (OHC) determination. For WHC, the suspension was stirred for 24 h, while for OHC, suspension was stirred for 30 min followed by centrifugation at 2000 xg for 30 min. Supernatant was removed and precipitate was weighed. The WHC and OHC of sample were reported as g of water per g of dried sample and g of oil per g of dry sample, respectively **(Ahn et al., 2008)**.

Physical properties

After 1 h of baking, the bread's normal weight (g) was weighed, and the average was calculated. Rapeseed displacement method was used to estimate bread volume (cm3) according to **AACC (2002)**. Specific volume (cm3/g) was determined for various bread samples.

Dough characteristics

The Farinograph (Brabender OHG, Duisburg, Germany) was employed to estimate dough softening, tolerance index, development time, and dough stability in accordance with **AACC (2002)**. **AACC (2002)** was employed to evaluate water absorption. Nevertheless, **AACC (2002)** designated the Extensograph (Brabender, Extensograph, Germany 50 HZ) as prescribed method for measuring dough energy, stretchability, and stretch resistance. The Burton instrument (model 1700, Hagberg, Sweden) was employed to ascertain falling number **(AACC, 2002).** Glutomatic (Perten Instrument AB, Stockholm, Sweden) was used to determined gluten index according to **AACC (2002)**.

Bread freshness test

After 1, 2, and 3 days of storage in polyethylene bags at 25 ±2 °C, the freshness rate of municipal bread was measured by the alkaline water retention capacity test (AWRC) according to method described by **Lahtinen *et al.*, (2004).**

Color assessment

Using the Minolta CM-508d spectrophotometer (Minolta Company, Ramsay, NJ, United States), the crust color of the municipal bread samples was ascertained by measuring the values of L* (lightness), a* (redness/greenery), and b* (yellowing/cyanosis) **(Gomez *et al.*, 2003)**.

Statistical analysis

All experiments were performed in triplicate for each sample. The results are expressed as mean values ±SD

RESULTS AND DISCUSSION

Chemical composition of flour

The chemical composition of wheat flour (WF), watermelon peel flour (WPF), and their mixture was analyzed, with results presented in **Table 2.** The key components evaluated included moisture, protein, fat, and ash content—parameters that significantly influence both the nutritional and functional properties of flour used in breadmaking. Wheat flour exhibited a higher moisture content compared to WPF. This difference is primarily attributed to the inherent structural and compositional properties of cereal grains, which generally retain more water than dried fruit by-products. The lower moisture content of WPF is advantageous from a storage perspective, as it enhances shelf life and reduces the risk of microbial contamination. However, in dough preparation, this also affects hydration properties and may require formulation adjustments. The protein content was notably higher in the flour mixture (15.35%) than in wheat flour alone (12.56%), indicating a synergistic effect of blending. Interestingly, although WPF had a lower protein content than WF, the overall increase in the mixture's protein level suggests a possible enhancement in total nitrogen content due to concentration effects or protein-dense non-gluten fractions in WPF. These findings align with those reported by **Egbuonu (2015)**, who also observed an improvement in nutritional profile when incorporating fruit peel powders into conventional flour. WPF showed a higher fat content than WF. While the fat content in both flours remains relatively low, the increased lipid level in WPF could be attributed to residual natural oils present in the peel's cellular structure. These lipids may contribute positively to the sensory attributes of bread, such as mouthfeel and crumb softness, though they may also influence oxidative stability over time. Ash content, an indicator of total mineral presence, was significantly higher in WPF than in WF. This reflects the rich mineral composition of watermelon peels, including elements such as potassium, calcium, and magnesium. The inclusion of WPF in bread formulations may therefore enhance the mineral content of the final product, contributing to dietary mineral intake. Overall, the incorporation of WPF into wheat flour not only enhances the nutritional profile—especially in terms of protein and mineral content—but also offers functional benefits when properly balanced with other ingredients such as hydrocolloids.

Table 2 Chemical composition of wheat flour (WF), watermelon peel flour (WPF), and wheat-watermelon peel flour (WPF; WF 85%: WPF 15%)

Flour kind	Content (%)				
	Moisture	Protein	Fat	Ash	Total carbohydrate
WF	11.14±0.29	12.56±0.37	1.53±0.09	1.12±0.04	73.65±0.95
WPF	10.72±0.32	11.21±0.87	2.38±0.04	12.61±0.09	63.08±0.82
WF: WPF (85:15)	10.36±0.31	15.35±0.42	1.51±0.14	1.62±0.08	71.16±0.77

Values are expressed mean ±SD

Freshness and bread staling rate

The capacity to retain alkaline water (AWRC) is simple and quick test that follows the staling of bread. Higher AWRC values indicate greater bread freshness. **Figure 1** depicts the changes in bread's freshness characteristics at zero time and after 1, 2, and 3 days of room temperature storage. The findings demonstrated that at zero time, freshness values increased from 3.3% with 0.5 gum arabic to 19% with 1.5% gum gellan due to the high range of tested aqueous colloids, including pullulan, guar gum, gum arabic, and gellan gum. When compared to control (to wheat flour only), this increase in AWRC persisted until the end of storage period. There is an agreement with **Cauvain and Young (2007)** and **Maleki and Milani (2014)**. The results obtained corroborated data presented by **Shittu *et al.*, (2009).**

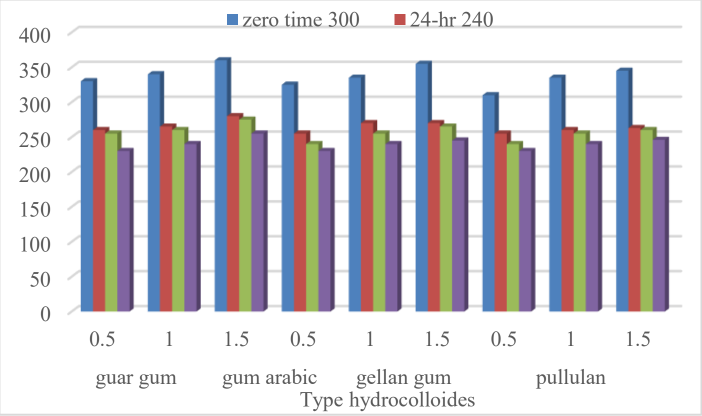

Figure 1 The capacity to retain alkaline water (AWRC) of bread.

Functional and physical properties

The yield (%) of watermelon peel flour (WMPF) and functional properties, and physical characteristics of wheat flour (WF) and WMPF are presented in **Table 3**.

Watermelon peels produced 5.13% flour yield **(Table 3)**. The high water content (85%) of watermelon peels is main cause of decrease in flour yield **(Ram *et al.*, 2005)**. **Table 3** displays water holding capacity (WHC) and oil holding capacity (OHC) for WF and WMPF. CWF and WMPF had WHC of 1.87 and 10.66 g of water per gram of dry matter, respectively. According to **Chen *et al.*, (1988),** the WHC of WMPF was greater than the WHC of the fiber found in yam flour, rice bran, oat bran, and wheat bran. On the other hand, according to **Kim *et al.*, (2003)**, WMPF has a value of WHC that is comparable to apple fibre. This is explained by the fact that the cell wall components in fruit fibres and stems have different structures **(Holloway and Greig, (2019).** Another crucial functional characteristic of dietary components is OHC. The OHC content of WMPF was 5.48 g of oil per gramme of dry matter, which was higher than that of WF (1.35 g of oil per gramme of dry matter), according to the data. This is explained by the fact that WF and WMPF have different physical and chemical characteristics. Insoluble dietary fibre can hold onto oil up to five times its weight, according to **Villarino *et al.*, (2014)**. CWF has a substantially larger bulk density than WMPF, according to the results of bulk density measurements **(Table 3)**. The heat treatment used during flour processing is responsible for WMPF's noticeably low bulk density. The packaging process for flour transportation is heavily influenced by bulk density. It would be easier to package precisely and closely if the bulk density value was high. Better management of big amounts of flour as a result **(Gizachew *et al.*, 2019)**. This is in line with what **Courtin and Delcour (2001)** found. One bioparameter needed for food product quality and safety control is water activity (Therdtha et al., 2002). This investigation revealed that the water activity of CWF was substantially greater than that of WMPF **(Table 3)**. When compared to CWF, WMPF's noticeably lower water activity can be interpreted as a sign of slower enzymatic activity and microorganism growth. As a result, WMPF may live comparatively longer than CWF.

Table 3 The yield (%) of watermelon peel flour (WMPF) and functional properties, and physical characteristics of wheat flour (WF) and WMPF

Parameter	WF	WMPF
Yield		5.13
Functional Properties		
WHC (g of water/g of dry matter)	2.06	10.66
OHC (g of oil/g of dry matter)	2.04	5.48
Physical properties		
Bulk density (g/ml)	1.08	0.43
Water activity (aw)	0.56	0.48

WHC: water holding capacity; OHC: Oil holding capacity; WF: wheat flour; WMPF: watermelon peel flour

Gluten content and gluten quality

As shown in **Figure 2**, the gluten content and gluten quality of WF and WMPF were evaluated. WF showed a high weight of wet gluten compared to WMPF. The index of dry gluten and gluten exhibited similar trends, aligning with previous research by **Aleid *et al.*, (2015)** who reported a gluten index of 99.36% for watermelon peel flour (80% extract). Additionally, the falling number of WMPF was consistently higher than that of wheat flour, suggesting lower enzyme activity and greater stability in watermelon peel flour. These findings are in agreement with **Codina *et al.*, (2012)**, who established a threshold of 350 s for falling numbers to indicate low enzyme activity and stable wheat. Values below 200 s, on the other hand, suggest elevated enzyme activity.

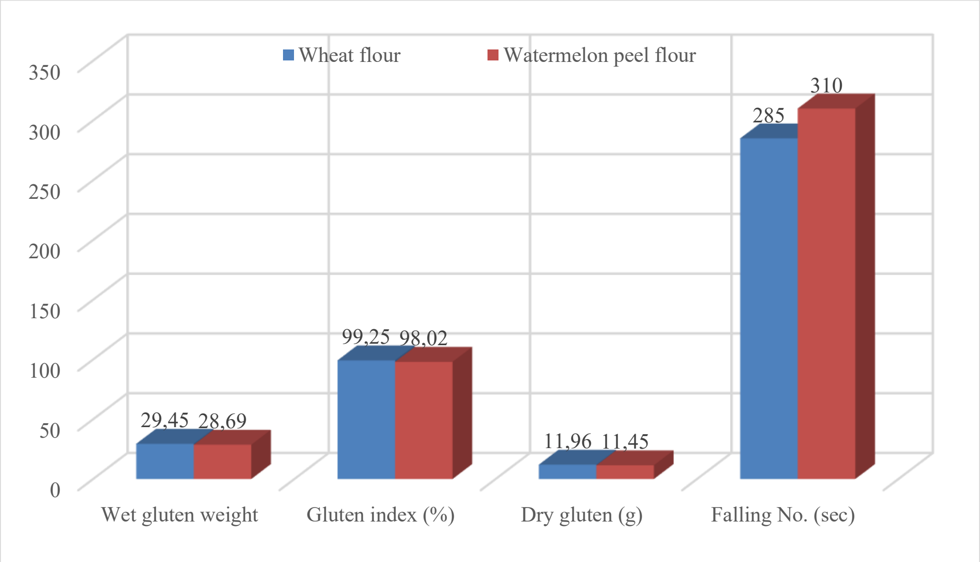

Figure 2 Gluten content and falling number in wheat flour (WF) and wheat-watermelon peel flour (WMPF 20%: WF 80%).

Rheological properties of the dough

The rheological behavior of dough is a critical determinant of bread quality, influencing mixing performance, gas retention, dough handling, and final product texture. The results of the Farinograph and Extensograph assessments (Table 4) provide insight into how the inclusion of watermelon peel flour (WPF) and various aqueous colloids—gellan gum, guar gum, gum arabic, and pullulan—affects key dough properties such as water absorption, development time, stability, and extensibility. The presence of WPF and hydrocolloids increased water absorption across all samples, with the highest value recorded in the formulation containing pullulan at 10 g/kg of flour (S7). This enhancement can be attributed to the hydrophilic nature of pullulan, which contains multiple hydroxyl groups capable of forming hydrogen bonds with water molecules, thereby increasing the dough's water retention capacity. In contrast, the control wheat flour (without additives) exhibited the lowest water absorption. Dough development time increased with the inclusion of WPF and hydrocolloids, indicating a delay in achieving optimal dough consistency. This delay is likely due to the colloids' interaction with gluten and starch, which modifies hydration kinetics and slows protein network formation. The colloids may encapsulate water or compete with gluten for hydration, thus extending the time required for proper dough development. Stability also improved with the incorporation of colloids, particularly in WPF-containing samples. This suggests that the hydrocolloids contribute to strengthening the dough structure, potentially by forming a secondary matrix that supports the weakened gluten network in the presence of WPF. Gellan gum and guar gum are especially known for their network-forming and viscosity-enhancing properties, which can reinforce dough elasticity and resistance to breakdown during mixing. While dough stability improved, dough weakness also increased in samples with WPF and colloids. This indicates that despite stronger structural integrity, the dough becomes more susceptible to overmixing or mechanical stress. The high fiber content and non-gluten proteins in WPF, along with the viscoelastic effects of the hydrocolloids, likely contribute to this behavior. These findings are consistent with those reported by **Elhassaneen *et al.* (2018),** who found that hydrocolloids enhance hydration and dough performance through their water-binding and network-forming capabilities. Both stretchability and dough energy were reduced upon the addition of WPF and colloids. The reduction in these parameters can be attributed to the dilution of gluten proteins by WPF, which weakens the gluten network responsible for dough elasticity and extensibility. Moreover, the fiber-rich WPF may disrupt the continuous gluten matrix, reducing the dough's ability to stretch and store energy during deformation. Interestingly, resistance to stretching (maximum resistance) increased with the addition of WPF and colloids. This suggests that the dough becomes firmer and more resistant to deformation. While this might seem advantageous, it can negatively impact bread volume and crumb softness if not balanced properly. The increase in resistance is likely due to the fiber content of WPF and the gel-forming behavior of certain hydrocolloids, which create a denser, more rigid dough structure. These observations align with findings by **Ribotta *et al.* (2005),** who reported that non-gluten ingredients like fruit peels tend to reduce stretchability and energy while enhancing resistance, due to interference with the gluten-starch matrix.

Table 4 Effect of hydrocolloids on rheological properties of dough (Farinograph-stenograph parameters.

Dough formula									
Parameters	WF	WMPF	S-1	S-2	S-3	S-4	S-5	S-6	S-7
Farinograph									
Water absorption (%)	64.1	66.3	67.2	67.1	67.4	68.2	67.4	68.3	69.2
Arrival time (min)	1.8	1.9	1.8	1.9	1.8	1.9	1.8	1.9	1.9
Dough development time (min)	1.9	2.4	2.3	1.9	1.9	2.5	1.9	2.4	2.6
Dough stability (min)	4.7	3.8	5.1	4.9	5.9	7.6	6.8	8	9.5
Mixing tolerance index (BU)	39	59	69	79	59	49	39	49	49
Dough weakening (BU)	88	109	116	127	108	99	101	88	79
Extensograph									
Extensibility (min)	115	118	99	`101	99	98	114	123	120
Resistance to extension (BU)	238	277	211	224	257	276	258	279	311
Dough energy (cm3)	90	80	79	70	75	85	80	90	90

Values are expressed mean ±SD
WF; Wheat flour and WMPF; wheat watermelon Flour (WF 80%; WPF 20%).

Municipal bread chemical composition and energy value

Table 5 presents the composition and energy value of the aqueous colloids derived from watermelon peels and wheat bread. The findings revealed that watermelon peel wheat bread possesses elevated levels of moisture, protein, fat, and ash, while exhibiting a reduced total carbohydrate load compared to traditional wheat bread. Wheat bread exhibited the greatest energy value among all samples. A notable disparity was seen in moisture and protein levels among the aqueous colloids including wheat bread, watermelon peels, and wheat bread. Elevated humidity in bread attributed to aqueous colloids that preserve moisture levels. Nonetheless, the augmentation of flour was incorporated. Addition of watermelon peel flour to wheat flour played an important role in increasing nutritional value **(Das *et al.*, 2013).**

Table 5 Chemical composition and energy value of Baladi bread without/with hydrocolloids

Components	WF	WPF	S-1	S-2	S-3	S-4	S-5	S-6	S-7
Humidity (%)	34.26 ±0.53	35.08 ±0.19	35.62 ±0.79	36.04 ±0.49	36.1 ±0.22	36.52 ±0.22	35.78 ±0.36	36.34 ±0.45	37.02 ±0.59
Protein (%)	11.36 ±0.54	13.21 ±0.27	13.36 ±0.27	13.17 ±0.55	13.21 ±0.88	13.34 ±1.13	13.15 ±1.3	13.19 ±0.64	13.26 ±1.41
Fat (%)	1.34 ±0.1	1.59 ±0.09	1.48 ±0.18	1.55 ±0.34	1.54 ±0.28	1.53 ±0.06	1.57 ±0.06	1.59 ±0.11	1.69 ±0.15
Ash (%)	1.19 ±0.09	1.70 ±0.26	1.73 ±0.23	1.75 ±0.09	1.78 ±0.05	1.89 ±0.02	1.68 ±0.12	1.77 ±0.06	1.81 ±0.19
Total carbohydrate (%)	52.10 ±0.33	48.42 ±0.25	47.81 ±0.22	47.49 ±0.51	47.37 ±0.68	46.72 ±0.73	47.82 ±1.11	47.1 ±0.54	46.22 ±0.98
Energy value (Kcal $100g^{-1}$)	274.87 ±6.45	266.51 ±4.89	265.94 ±5.47	264.44 ±3.67	264.03 ±4.23	261.83 ±5.34	265.88 ±3.66	263.34 ±4.82	260.91 ±5.35

Values are expressed mean ±SD
WF: Wheat Flour and WMPF; Wheat-Watermelon peel Flour (WF 80%; MPF 20%).

Physical properties of municipal bread prepared with watermelon peels and/or aqueous colloids

The physical characteristics of bread, particularly loaf weight, loaf size (dimensions), and specific volume, are critical indicators of product quality and consumer acceptability. These parameters are directly influenced by the flour composition, the presence of functional ingredients, and the overall dough structure. In this study, the impact of incorporating watermelon peel flour (WMPF) and various aqueous colloids (gellan gum, guar gum, gum arabic, and pullulan) on these physical properties were examined, with results summarized in **Table 6.** Bread made with a 15% substitution of WMPF exhibited a significant increase in loaf weight compared to the control (pure wheat flour). This increase can be attributed to the higher water-holding capacity of WMPF, which absorbs and retains more water during dough mixing and baking. The fiber and polysaccharide components in watermelon peel act as hydrophilic agents, contributing to a denser and heavier final product. While increased loaf weight can be perceived positively in terms of yield, it may also indicate a denser crumb structure, which is typically less desirable in leavened bread. In contrast to loaf weight, the incorporation of WMPF led to a reduction in loaf size and volume. This is a common observation when substituting high-gluten wheat flour with non-gluten, fiber-rich ingredients. The reduction in volume is primarily due to the dilution of the gluten network, which is essential for trapping gas and enabling bread expansion during proofing and baking. Without sufficient gluten strength, gas cells collapse more readily, resulting in a smaller loaf. Specific volume—defined as the volume-to-weight ratio (cm^3/g)—is a key indicator of bread quality, with higher values generally associated with softer texture, better aeration, and higher consumer preference. The bread samples containing WMPF alone showed a decrease in specific volume, which is consistent with the aforementioned reduction in loaf expansion. However, the addition of aqueous colloids significantly improved specific volume across all formulations. Among the hydrocolloids tested, pullulan (Pu), gellan gum (G), guar gum (Gu), and gum arabic (GA) all contributed to better loaf expansion and volume retention. These ingredients likely enhanced gas cell stability by increasing dough viscosity and strengthening the gluten-starch matrix. Pullulan, in particular, is known for its film-forming and water-retention properties, which support gas cell integrity during baking. Similarly, guar gum and gellan gum increase dough elasticity and viscosity, reducing gas diffusion and promoting volume expansion.

These findings are in agreement with previous research by **Aleid *et al. (*2015),** who reported that hydrocolloids can act as structural stabilizers in gluten-diluted dough systems, compensating for the weakened protein matrix and supporting improved bread volume and texture. Higher loaf weight with WMPF may suggest improved water retention but could also indicate denser crumb structure and lower palatability if not balanced with volume-enhancing agents. Reduced loaf size and specific volume due to WMPF highlight the challenges of using high-fiber, non-gluten ingredients in conventional bread formulations. Hydrocolloids effectively mitigate these negative effects, helping to restore desirable loaf volume and texture by stabilizing the dough matrix, improving gas retention, and enhancing moisture distribution. Thus, while the incorporation of WMPF improves nutritional value, it is essential to optimize its concentration and combine it with suitable hydrocolloids to preserve or improve physical bread quality.

Table 6 Physical properties of baladi bread without/with hydrocolloids

Samples	Weight (g)	Size (cm^2)	Specific volume (cm^3/g)
MWF	121.36±0.77	291.33±1.86	2.5±0.03
WMPF	117.69±0.39	282±1.53	2.4±0.01
S-1	118.91±0.39	283±2.08	2.38±0.03
S-2	119.96±0.49	284±2.33	2.37±0.02
S-3	120.48±0.42	285±1.15	2.37±0.02
S-4	121.29±0.38	286.6±2.03	2.36±0.02
S-5	119.88±0.89	284.6±2.33	2.37±0.02
S-6	120±0.51	286.33±1.2	2.39±0.01
S-7	119.41±0.24	289.6±1.76	2.43±0.02

Values are expressed mean ±SD

The color of crust of municipal bread supplemented with watermelon peel flour and/or aqueous colloids

The hue of the crust is a significant characteristic of baking that influences consumer preference. The crust colouration of city bread samples was assessed as depicted in **Table 7**. Addition of watermelon peel flour altered the bread crust colour from creamy white to pale brown, as lightness (L*) and redness (b*) diminished, while the Browning Index (BI) and colour difference (ΔE) escalated.

A notable variation in the crust's colouration was noticed due to the addition of watery colloids. The bread sample integrated into the aqueous colloids (guar gum and gum Arabic) exhibited a deeper hue than the samples with gellan gum and pullulan; nonetheless, the sample with pullulan was the lightest in colour. The colour disparity may have resulted from AG and C being dark, whilst P, XG, and Pu were light. These results align with those documented by **Eissa *et al.*, (2007)**.

Table 7 Crust color of baladi bread supplemented with watermelon peel flour and/or polysaccharides (Hunter color parameters)

Samples	L^*	a^*	b^*	chroma	Browning index (BI)	ΔE
MWF	59.32	6.01	23.86	24.27	96.43	40.01
WPF	56.72	5.97	22.56	23.08	99.58	39.37
S-1	54.73	5.84	22.32	23.83	99.39	39.98
S-2	55.44	5.75	22.66	23.76	99.76	39.54
S-3	57.21	6.02	23.02	24.47	101.36	38.76
S-4	57.11	6.11	23.73	24.09	100.21	37.33
S-5	57.32	5.96	23.09	24.97	100.24	37.42
S-6	58.71	5.31	23.47	24.45	101.37	37.35
S-7	59.03	4.98	23.24	24.21	100.42	40..09

L^*,a^*,and b^*; color parameters

CONCLUSION

This study investigated the effects of various aqueous colloids—gellan gum, guar gum, gum arabic, and pullulan—on the rheological and quality characteristics of wheat bread and a composite flour blend containing 80% wheat flour and 20% watermelon peel flour (WPF). The hydrocolloids were selected for their distinct functional roles in dough systems, including water retention, viscosity enhancement, emulsification, and film formation. The inclusion of WPF reduced dough performance parameters such as water absorption, stability, stretchability, and dough energy due to gluten dilution. However, the addition of aqueous colloids significantly improved these properties. The colloids enhanced water absorption, dough stability, and stretchability, compensating for the weakened gluten network. Bread made with WPF showed increased loaf weight but reduced volume and specific volume, likely due to the high fiber content affecting gas retention. The use of aqueous colloids improved loaf expansion, volume, and overall texture, with pullulan- and gellan-containing breads showing particularly favorable results. The incorporation of hydrocolloids led to a darker crust color, likely due to increased Maillard reactions. Bread samples containing colloids also retained moisture better and remained fresher for longer periods. Gellan gum at 0.5% demonstrated the highest alkaline water retention capacity (AWRC) after 1, 3, and 5 days of storage, indicating superior freshness preservation. Sensory evaluation confirmed that bread prepared with aqueous colloids had improved acceptability, particularly in terms of texture, softness, and freshness, compared to control and WPF-only samples. The results underscore the functional effectiveness of aqueous colloids in enhancing the quality of fiber-enriched breads, particularly those formulated with non-gluten ingredients like watermelon peel flour. These hydrocolloids serve as vital structuring agents that compensate for gluten dilution, improving dough handling, bread volume, shelf life, and sensory attributes. Their inclusion offers a viable strategy for developing nutritionally enhanced, sustainable bakery products without compromising consumer acceptance. Future studies should focus on identifying the optimal type and concentration of each hydrocolloid to achieve the best balance between dough performance, bread volume, and sensory acceptability. Fine-tuning these concentrations using experimental designs such as response surface methodology (RSM) could help in developing standardized formulations for commercial applications. Extending this research to other baked goods such as flatbreads, muffins, or gluten-free products could broaden the application of watermelon peel flour and aqueous colloids across the bakery sector. By addressing these future directions, researchers can contribute to the development of more sustainable, nutritious, and consumer-acceptable bread products, further enhancing the value of agricultural by-products and functional food ingredients.

Acknowledgments: We thank to Deanship of Scientific Research, Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Saudi Arabia (KFU250845), for support this research work.

Funding: Supported by Deanship of Scientific Research, Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Saudi Arabia (KFU250845).

Competing interests: Authors declare that they have no conflicts of interest.

REFERENCES

AACC (2002) Approved Methods of the American Association of Cereal Chemists. American Association of Cereal Chemists, St. Paul.

Abdel-Rahim, E. A., El-Beltagi, H. S. (2010). Constituents of apple, parsley and lentil edible plants and their therapy treatments for blood picture as well as liver and kidney functions against lipidemic disease. *Electronic Journal of Environmental, Agricultural and Food Chemistry* 9, 1117-1127.

Ahn, H.K., Richard, T.L., & Glanville, T.D. (2008). Laboratory determination of compost physical parameters for modeling of airflow characteristics. *Waste Manag,* 28 (3), 660–670. https://doi.org/10.1016/j.wasman.2007.04.008

Aleid, S. M., Al-Hulaibi, A. A., Ghoush, M. A., & Al-Shathri, A. A. (2015). Enhancing arabic bread quality and shelf life stability using bread improvers. *Journal of food science and technology*, *52*, 4761-4772. https://doi.org/10.1007/s13197-014-1618-x

Atteya, M.R., Romeilah R.M., Ramadan, K.M.A., El-Beltagi H.S., Gaber, A.M., Al Hashedi, S.A., AboZaid, N. A., Mahmoud, M.A.A., Youssef, R., Mohamed, R.A., & Bendary, E.S.A. (2025). Clove and thyme essential oils: from molecular docking to food application - a study of their preservative properties in buttermilk. ACS Omega 2025, 10, 5, 5119–5137. https://doi.org/10.1021/acsomega.4c11538

Badr, S. A. (2015). Quality and antioxidant properties of pan bread enriched with watermelon rind powder. *Current Science International*, *4*(1), 117-126.

Brinkworth, G., & Taylor, P. (2020). *The CSIRO Low-carb Diabetes Diet & Lifestyle Solution* (Vol. 1). Macmillan Publishers Aus.

Cauvain, S.P. & Young, L.S. (2007). *Technology of Breadmaking* (2nd ed.). Springer Science and Business Media, LLC. New York, pp. 285–286.

Chakraborty, R. (2021). Dynamic role of natural antioxidant sources on different parameters of bread quality: a review. *International Journal on Nutraceuticals, Functional Foods and Novel Foods,* 15, 163-178.

Codina, G. G., Mironeasa, S., & Mironeasa, C. (2012). Variability and relationship among Mixolab and Falling Number evaluation based on influence of fungal α-amylase addition. *Journal of the Science of Food and Agriculture*, *92*(10), 2162-2170. https://doi.org/10.1002/jsfa.5603

Courtin, C. M., & Delcour, J. A. (2001). Relative activity of endoxylanases towards water-extractable and water-unextractable arabinoxylan. *Journal of Cereal Science*, *33*(3), 301-312. https://doi.org/10.1006/jcrs.2000.0354

Chen, H., Rubenthaler, G. L., Leung, H. K., & Baranowski, J. D. (1988). Chemical, physical, and baking properties of apple fiber compared with wheat and oat bran. *Cereal chem*, *65*(3), 244-247.

Das, L., Raychaudhuri, U., & Chakraborty, R. (2013). Role of hydrocolloids in improving the physical and textural characteristics of fennel bread. *International Food Research Journal*, *20*(5), 2253-2259.

Dhawi, F., El-Beltagi, H. S., Aly, E., Hamed, A. M. (2020). Antioxidant, Antibacterial Activities and Mineral Content of Buffalo Yoghurt Fortified with Fenugreek and Moringa Oleifera Seed Flours. Foods, 9 (9), 1157. https://doi.org/10.3390/foods9091157

Eissa, H. A., Hussein, A. S., & Mostafa, B. E. (2007). Rheological properties and quality evaluation on Egyptian balady bread and biscuits supplemented with flours of ungerminated and germinated legume seeds or mushroom. *Polish journal of food and nutrition sciences*, *57*(4), 487-496.

Elbeltagi, A., Aslam, M. R., Malik, A., Mehdinejadiani, B., Srivastava, A., Bhatia, A. S., & Deng, J. (2020). The impact of climate changes on the water footprint of wheat and maize production in the Nile Delta, Egypt. *Science of the Total Environment*, *743*, 140770. https://doi.org/10.1016/j.scitotenv.2020.140770

El-Beltagi, H.S., El-Senousi, N.A., Ali, Z.A., & Omran, A. (2017). The impact of using chickpea flour and dried carp fish powder on pizza quality. PloS one 12: e0183657. https://doi.org/10.1371/journal.pone.0183657

El-Beltagi, H.S., Eshak, N.S., Mohamed, H.I., Bendary, E.S.A., & Danial, A.W. (2022a). Physical characteristics, minerals content, anti-oxidants and antibacterial activities of *Punica granatum* or *Citrus sinensis* peel extracts and their applications to improve cake quality. Plants 11: 1740. https://doi.org/10.3390/plants11131740

El-Beltagi, H.S., El-Mogy, M.M., Parmar, A., Mansour, A.T., Shalaby, T.A., Ali, M.R. (2022b). Phytochemical characterization and utilization of dried red beetroot (Beta vulgaris) peel extract in maintaining the quality of *Nile Tilapia* fish fillet. *Antioxidants 11*, 906. https://doi.org/10.3390/antiox11050906

Elhassaneen, Y., Ghamry, H., & Elbassyouny, G. (2018). Improvement of rheological properties, bioactive compounds content and antioxidant activity in soft dough biscuits with the incorporation of prickly pear peels powder. In *Proceeding of the 1st Scientific International Conference of the Faculty of Specific Education, Minia University,"Specific Education, innovation and labor market* (pp. 16-17).

Elkatry, H.O., El-Beltagi, H.S., Ahmed, A.R., Mohamed, H.I., Al-Otaibi, H.H., Ramadan, K.M., & Mahmoud, M.A. (2023a). The potential use of Indian rice flour or husk in fortification of pan bread: assessing bread's quality using sensory, physicochemical, and chemometric methods. Front Nutr 10: 1240527. https://doi.org/10.3389/fnut.2023.1240527

Elkatry, H. O., El-Beltagi, H. S., Ahmed, A. R., Mohamed, H. I., Al-Otaibi, H. H., Ramadan, K. M. A., Mahmoud, M. A. A. (2023b). The Potential Use of Indian Rice Flour or Husk in Fortification of Pan Bread: Assessing Bread's Quality Using Sensory, Physicochemical, and Chemometric Methods. Front Nutr, 10:1240527. https://doi.org/10.3389/fnut.2023.1240527

Egbuonu, A. C. C. (2015). Comparative investigation of the proximate and functional properties of watermelon (Citrullus lanatus) rind and seed. *Research Journal of Environmental Toxicology*, *9*(3), 160. https://doi.org/10.3923/rjet.2015.160.167

Ferrero, C. (2017). Hydrocolloids in wheat breadmaking: A concise review. *Food Hydrocolloids*, *68*, 15-22. https://doi.org/10.1016/j.foodhyd.2016.11.044

Fitzgerald, C., Gallagher, E., Doran, L., Auty, M., Prieto, J. & Hayes, M. (2014). Increasing the health benefits of bread: assessment of the physical and sensory qualities of bread formulated using a renin inhibitory *Palmaria palmate* protein hydrolysate. *Food Science and Technology,* 56, 398– 405. https://doi.org/10.1016/j.lwt.2013.11.031

Gizachew, D., Chang, C. H., Szonyi, B., De La Torre, S., & Ting, W. T. E. (2019). Aflatoxin B1 (AFB1) production by Aspergillus flavus and Aspergillus parasiticus on ground Nyjer seeds: The effect of water activity and temperature. *International journal of food microbiology*, *296*, 8-13. https://doi.org/10.1016/j.ijfoodmicro.2019.02.017

Gomez, M., Ronda, F. B., Caballero P. & Apesteguia, A. (2003). Effect of dietary fiber on dough rheology and bread quality. *European Food Research and Technology*, 216, 51-56. https://doi.org/10.1007/s00217-002-0632-9

Guarda, A., Rosell, C. M., Benedito, C., & Galotto, M. J. (2004). Different hydrocolloids as bread improvers and antistaling agents. *Food hydrocolloids*, *18*(2), 241-247. https://doi.org/10.1016/S0268-005X(03)00080-8

Hanan, M.A., Abdelrahman, R. (2013). Utilization of watermelon rinds and sharlyn melon peels as a natural source of dietary fiber and antioxidants in cake. *Annals of Agricultural Science*, 58 (1), 83–95. https://doi.org/10.1016/j.aoas.2013.01.012

Holloway, W. D., & Greig, R. I. (1984). Water holding capacity of hemicelluloses from fruits, vegetables and wheat bran. *Journal of Food Science*, *49*(6), 1632-1633. https://doi.org/10.1111/j.1365-2621.1984.tb12867.x

Hussein, A. M., Kamil, M. M., Hegazy, N. A., & Abo El-Nor, S. A. H. (2013). Effect of wheat flour supplemented with barely and/or corn flour on balady bread quality. *Polish Journal of Food and Nutrition Sciences*, *63*(1), 11-18. https://doi.org/10.2478/v10222-012-0064-6

Kim, D. O., Chun, O. K., Kim, Y. J., Moon, H. Y., & Lee, C. Y. (2003). Quantification of polyphenolics and their antioxidant capacity in fresh plums. *Journal of agricultural and food chemistry*, *51*(22), 6509-6515. https://doi.org/10.1021/jf0343074

Kohajdová, Z., Karovičová, J., & Schmidt, Š. (2009). Significance of emulsifiers and hydrocolloids in bakery industry. *Acta Chimica Slovaca*, *2*(1), 46-61.

Lahtinen, S. J., Haskard, C. A., Ouwehand, A. C., Salminen, S. J., & Ahokas, J. T. (2004). Binding of aflatoxin B1 to cell wall components of Lactobacillus rhamnosus strain GG. *Food additives and contaminants*, *21*(2), 158-164. https://doi.org/10.1080/02652030310001639521

Liu, X. L., Mu, T. H., Sun, H. N., Zhang, M., & Chen, J. W. (2016). Influence of potato flour on dough rheological properties and quality of steamed bread. *Journal of Integrative Agriculture*, *15*(11), 2666-2676. https://doi.org/10.1016/S2095-3119(16)61388-6

Maleki, G., & Milani, J. M. (2014). Effect of different hydrocolloids on barbari bread texture and microstructure. *Acta Alimentaria*, *43*(4), 584-591. https://doi.org/10.1556/AAlim.2013.0008

Mandala, I., Karabela, D., & Kostaropoulos, A. (2007). Physical properties of breads containing hydrocolloids stored at low temperature. I. Effect of chilling. *Food hydrocolloids*, *21*(8), 1397-1406. https://doi.org/10.1016/j.foodhyd.2006.11.007

Meghwar, P., Saeed, S. M. G., Ullah, A., Nikolakakis, E., Panagopoulou, E., Tsoupras, A., ... Khaneghah, A. M. (2024). Nutritional Benefits of Bioactive Compounds from Watermelon: A Comprehensive Review. *Food Bioscience*, 104609. https://doi.org/10.1016/j.fbio.2024.104609

Pečivová, P., Juříková, K., Burešová, I., Černá, M. & Hrabě, J. (2011). The effect of pectin from apple and arabic gum from acacia tree on quality of wheat flour dough. Acta Universitatis Agriculturae Et Silviculturae Mendelianae Brunensis 59(6), 255-270. https://doi.org/10.11118/actaun201159060255

Ram, S., Dawar, V., Singh, R. P., & Shoran, J. (2005). Application of solvent retention capacity tests for the prediction of mixing properties of wheat flour. *Journal of Cereal Science*, *42*(2), 261-266. https://doi.org/10.1016/j.jcs.2005.04.005

Rizzello, C.G., Calasso, M., Campanella, D., De Angelis, M., Gobbetti, M. (2014). Use of sourdough fermentation and mixture of wheat, chickpea, lentil and bean flours for enhancing the nutritional, texture and sensory characteristics of white bread. *International Journal of Food Microbiology,* 180, 78–87. https://doi.org/10.1016/j.ijfoodmicro.2014.04.005

Ribotta, P. D., Arnulphi, S. A., Leon, A. E., & Añón, M. C. (2005). Effect of soybean addition on the rheological properties and breadmaking quality of wheat flour. *Journal of the Science of Food and Agriculture*, *85*(11), 1889-1896. https://doi.org/10.1002/jsfa.2191

Rimando, A. M., & Perkins-Veazie, P. M. (2005). Determination of citrulline in watermelon rind. *Journal of Chromatography A*, *1078*(1-2), 196-200. https://doi.org/10.1016/j.chroma.2005.05.009

Rodge, A. B., Sonkamble, S. M., Salve, R. V., & Hashmi, S. I. (2012). Effect of hydrocolloid (guar gum) incorporation on the quality characteristics of bread. Journal of Food Processing and Technology, 3(2), 136.

Romdhane, M. B., Bouallegue, A., Bourhia, M., Bougatef, A., Salamatullah, A. M., Ellouz-Chaabouni, S., Haddar, A. (2024). Watermelon Rind Dietary Fibers as Natural Source to Enhance Texture of Wheat Bread. Foods, 13(18), 2909. https://doi.org/10.3390/foods13182909

Saeed Omer, S. H., Hong, J., Zheng, X., & Khashaba, R. (2023). Sorghum Flour and Sorghum Flour Enriched Bread: Characterizations, Challenges, and Potential Improvements. *Foods*, *12*(23), 4221. https://doi.org/10.3390/foods12234221

Shittu, T. A., Aminu, R. A., & Abulude, E. O. (2009). Functional effects of xanthan gum on composite cassava-wheat dough and bread. *Food hydrocolloids*, *23*(8), 2254-2260. https://doi.org/10.1016/j.foodhyd.2009.05.016

Sood, S., Li, K., Sand, C., Pal, L., & Hubbe, M. A. (2024). Fruit wastes: a source of value-added products. In *Adding Value to Fruit Wastes* (pp. 3-48). Academic Press. https://doi.org/10.1016/B978-0-443-13842-3.00001-0

Sani, U. (2014). Phytochemical screening and antidiabetic activity of extracts of Citrullus lanatus rind in alloxan-induced diabetic albino mice. *International Journal of Chemistry and Pharmaceutical Sciences*, 2, 1211–1215.

Shallan, M. A., El-Beltagi, H. S., Mona, A. M., Amera, T. M., Sohir, N. A. (2010). Effect of amylose content and pre-germinated brown rice on serum blood glucose and lipids in experimental animal. *Australian Journal of Basic and Applied Sciences 4*, 114-121.

Schieber, A., Stintzing, F. C., & Carle, R. (2001). By-products of plant food processing as a source of functional compounds—recent developments. *Trends in food science & technology*, *12*(11), 401-413. https://doi.org/10.1016/S0924-2244(02)00012-2

Villarino, C. B., Jayasena, V., Coorey, R., Chakrabarti-Bell, S., & Johnson, S. (2014). The effects of bread-making process factors on Australian sweet lupin-wheat bread quality characteristics. *International Journal of Food Science and Technology*, *49*(11), 2373-2381. https://doi.org/10.1111/ijfs.12595

Wani, A. A., Sogi, D. S., Singh, P., Sharma, P., & Pangal, A. (2012). Dough-handling and cookie-making properties of wheat flour–watermelon protein isolate blends. *Food and Bioprocess Technology*, *5*, 1612-1621. https://doi.org/10.1007/s11947-010-0466-6

Xu, J., Li, Y., Zhao, Y., Wang, D., Wang, W. (2021). Influence of antioxidant dietary fiber on dough properties and bread qualities: A review. *Journal of Functional Foods*, 80, 104434. https://doi.org/10.1016/j.jff.2021.104434

Yadav, M. P., Johnston, D. B., Hotchkiss Jr, A. T., & Hicks, K. B. (2007). Corn fiber gum: A potential gum arabic replacer for beverage flavor emulsification. *Food Hydrocolloids*, *21*(7), 1022-1030. https://doi.org/10.1016/j.foodhyd.2006.07.009