

Chemical, Rheological, and Sensorial Properties of Baladi Bread Supplemented with Buckwheat Flour Produced in Egypt.

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Article

Keywords: Balady bread, rheological and physical properties, sensory evaluation, stalling

Posted Date: October 12th, 2023

DOI: <https://doi.org/10.21203/rs.3.rs-3379932/v1>

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Additional Declarations: No competing interests reported.

Version of Record: A version of this preprint was published at Scientific Reports on February 7th, 2024.
See the published version at <https://doi.org/10.1038/s41598-023-48686-1>.

Abstract

This research aimed to enhance the nutritional and sensory qualities of Balady bread by adding locally Egyptian buckwheat flours, *Fagopyrum esculentum* (FE) and *Fagopyrum tataricum* (FT), to Hard Wheat Flour (HWF) 82% extraction at three levels (10%, 20%, and 30%). The chemical composition, rheological properties, color, sensory evaluation and staling of the balady bread were determined. The chemical composition of raw materials revealed that FE was significantly ($P \leq 0.05$) higher in protein and fat contents compared to HWF and FT. While FT was higher in fiber and ash contents. Meanwhile, HWF was higher in total carbohydrates. Water absorption, arrival time, dough-development time, mixing tolerance index and dough weakening were significantly increased, however dough-stability was decreased parallel with an increment of the WF substitution level using the FE and FT. The addition of FE and FT with HWF with increasing proportions from 10–30% decreased the Extensibility, Resistance to extension and energy of dough, while proportional number increased. Nutritional analysis revealed that the incorporation of either *Fagopyrum* species significantly boosted levels of protein, fat, fiber, and ash, while diminishing carbohydrate content. As for color attributes, the L^* and b^* values decreased as buckwheat supplementation increased. Sensory evaluations exhibited a downward trend for attributes such as taste, aroma, crust hue, crumb structure, bread shape, layer separation, and overall appearance with increasing buckwheat content. In summary, this research offers valuable insights into how locally sourced Egyptian buckwheat flours can be used to both fortify the nutritional profile and influence the rheological and sensory properties of Balady bread.

Introduction

Baladi bread holds great importance in Egypt as a staple food. Efforts have been made to improve its quality and extend its shelf life, with research suggesting that the addition of hydrocolloids, such as pullulan, can enhance the dough properties and delay staling of baladi bread (Al-dalain & Morsy, 2018).

Consuming buckwheat has also been associated with the reduction of hyperlipidemia, blood pressure, and improved weight regulation. It has been found to have a lower postprandial blood glucose and insulin response, making it beneficial for individuals with diabetes. Buckwheat's high levels of rutin and quercetin contribute to its antioxidative activity (Kreft, 2016). On the other hand, buckwheat is a highly nutritious food that offers various health benefits. Its bioactive compounds, such as D-chiro-inositol, buckwheat proteins, and flavonoids, contribute to its positive effects on cholesterol levels, neuroprotection, anticancer and anti-inflammatory properties, hypertension, and diabetes. Rutin, in particular, shows potential therapeutic applications for Alzheimer's disease (Giménez-Bastida & Zieliński, 2015; Kreft, 2016).

Hard Wheat Flour (HWF) is primarily composed of starch (55–75%), proteins (6–12%), lipids (1–4%), soluble carbohydrates (1–2%), total dietary fibers (3–7%), and ash (1–2%) (Al-Snafi, 2017). FE, also known as common buckwheat, contains alkaloids, amino acids, anthraquinones, carbohydrates, flavonoids, phlobatannins, and tannins. It is also rich in high-quality proteins, essential amino and fatty

acids, fiber, vitamins, and minerals such as iron, zinc, and selenium (Al-Snafi, 2017; Ivankov et al., 2021). FT, also known as Tartary buckwheat, is similar to FE in terms of its chemical composition. It is rich in flavonoids, which have antioxidant activity, and has high levels of nutritive compounds (Ji et al., 2016; Aubert et al., 2021). However, Farinograph and extensograph parameters are vital for assessing the quality of bread, especially when wheat flour is supplemented with other ingredients. Basman et al. (2003) used a farinograph to examine the effect of transglutaminase on dough mixed with barley or soy flour. Mashayekhet al. (2008) and Karaoğlu (2006) explored how soy flour and *Cephalariasyriaca* flour, respectively, influenced dough extensibility. Wang et al. (2014) found recombinant lipooxygenase improved both farinograph and extensograph measures, while Xie et al. (2022) found mealworm powder reduced dough elasticity. Darwish et al. (2018) and Onyango et al. (2015) studied the effect of barley and maize flour, finding varied impacts on extensibility. Conversely, the pasting properties of Hard wheat flour Baladi bread can be influenced by various factors, such as the addition of other ingredients and the substitution of wheat flour with alternative flours. Abdel-Kader (2000) investigated the enrichment of Baladi bread with decorticated cracked broad beans flour and found that as the amount of broad beans flour increased, the water absorption, arrival time, and dough development time of the flour increased. Mashayekh et al. (2008) examined the fortification of wheat bread with soy flour to evaluate the sensory and rheological properties of the bread and found that the addition of soy flour affected these properties. Additionally, Choi et al. (2012) studied the substitution of normal and waxy-type whole wheat flour on dough and baking properties and found that the substitution of whole wheat flour decreased pasting viscosity. These studies highlight the potential impact of ingredient substitution on the pasting properties of baladi bread. Nevertheless, the chemical composition of Baladi bread has diversified to explore various ingredient influences. Hadidy & Rizk (2018) focused on the enrichment of fatty acids via coriander seeds. Hussein et al. (2013) evaluated the elemental composition and sensory attributes when supplemented with barley and corn flours. Mohamed et al. (2013) fortified bread with folic acid and whole grains, improving its nutritional content. Yousef et al. (2015) studied red algae enrichment, while Hussein et al. (2011) assessed low-protein variants. Sandak et al. (2009), Mobarak et al. (2010), El-Adly et al. (2012), and Fahmy et al. (2022) experimented with ingredients like seed coats, rice bran, and watermelon rinds, respectively, to assess changes in chemical and sensory properties, as well as potential health benefits. Even so, the Color attributes of Baladi bread can be altered by ingredients and processing techniques. Hussein et al. (2013) found barley and corn flour supplementation changed bread color, while Mezaizeet al. (2009) reported guar gum breads mimicked French bread color. Aider et al. (2012) noted darker crust in breads with whey protein. Hadidy& Rizk (2018), Yousif et al. (2019), and Yousef et al. (2015) highlighted how coriander seeds, nano-powders, and red algae respectively influenced color parameters. Fahmy et al. (2022) and Mobarak et al. (2010) assessed the impact of watermelon rinds and rice bran, while Wahab & Elsalam (2018) compared wheat grain fertilization techniques. Lastly, Gümüş (2022) showed olive oil amounts didn't significantly change ciabatta bread color. However, the impact of various additives on Baladi bread's sensory properties and freshness during storage has been extensively studied. Elkatryet al. (2022), Milovanović et al. (2014), and Bakare et al. (2015) focused on the addition of grape seed, quinoa, and breadfruit flours, respectively, finding improvements in nutritional and sensory aspects. Hussein et al. (2013) and Yousef et al. (2015) studied barley and red algae, observing nutritional gains but some

sensory changes. Fahmy et al. (2022) found watermelon rind flour could replace up to 15% of wheat flour without affecting sensory attributes. Ghoshal et al. (2013) and El-Sayed (2009) emphasized the role of enzymes and storage temperature on bread freshness, while Wahab & Elsalam (2018) and El-Gammal (2000) linked higher protein content and dairy by-products to extended freshness and shelf-life.

Materials and Methods

MATERIALS:

Buckwheat varieties

In a study from 2018 to 2020, *Fagopyrum tataricum* and *Fagopyrum esculentum* were grown in Bilbies city, Sharkia and Sadat City, Monofiya in Egypt to examine their growth, productivity, and quality under different timings. Grains were harvested, mixed, dried, and purified. The buckwheat seeds, bought from a commercial company based in California USA, were airfreighted to Egypt, inspected internationally and nationally, passed quarantine checks, and underwent germination tests before planting in the study areas.

The Authors obtained the necessary approvals from the Ministry of Agriculture and Land Reclamation (MALR) on importation and cultivation (in both mentioned locations) of Buckwheat seeds for the abovementioned cultivars. However, imported varieties also have got phytosanitary certificate issued by USDA and all the seeds delivered directly from the producer through airfreight, as a comply with relevant institutional, national, and international guidelines and legislation.

Wheat flour and other ingredients

Hard Wheat flour (HWF) with an 82% extraction rate was sourced from the South Cairo Mill Company located in Giza, Egypt. Sugar, salt (sodium chloride), and yeast (*Saccharomyces cerevisiae*) were procured from the local market in Giza, Egypt, for use in the study.

Chemicals and solvents

In this research study, all the chemicals and solvents employed were of analytical reagent grade. Specifically, the solvents used, including trichloroacetic acid (TCA), thio barbituric acid (TBA), and DPPH (2,2-Diphenyl-1-picryl-hydrazyl), were procured from the Gomhoria Company for Chemical and Trading, based in Cairo, Egypt.

METHODS:

Technological treatment

Preparation of flour mixtures: Buckwheat seeds were cleaned and moistened to 15% moisture content. Then, they were ground using a Quadrumat Junior flour mill and sifted through a 40-mesh sieve. The

resulting flour was packed into plastic sachets. We mixed this buckwheat flour with hard wheat flour (HWF) with different proportions: 100% HWF, 90% HWF and 10% BWF, 80% HWF and 20% BWF, and 70% HWF and 30% BWF.

Rheological properties of dough:

We assessed the doughs' rheological characteristics using farinograph, extensograph, and Rapid-viscoanalyzer (RVA) tests following the AACC (2000) guidelines.

Preparation of Baladi bread:

Flour blends (Table 1) were combined with yeast, salt, and water and mixed for 6 minutes. The dough fermented for 1 hour at 30°C and 85% humidity. Afterward, 125g pieces were rested on a bran-sprinkled board for 45 minutes. Each piece was then flattened to 20cm in diameter, proofed for 15 minutes between 30–35°C, and baked at 400–500°C for 1–2 minutes. Baked loaves cooled for 1 hour before evaluation.

Color attributes:

The color characteristics (L, a, and b values) of various types of Baladi bread were measured using a Tristimulus Color Analyzer, specifically the Hunter Lab Scan XE, located in Reston, Virginia. This analysis was performed using a standard white tile as the reference point.

Sensory evaluation:

Trained panelists, a group of 15 individuals, conducted sensory evaluations of the Baladi bread loaves following the methodology outlined by Hussein et al. (2013). Each sample was assessed based on the following criteria:

1. General appearance (worth 20 points)
2. Layers separation (worth 20 points)
3. Roundness (worth 15 points)
4. Crumb distribution (worth 15 points)
5. Crust color (worth 10 points)
6. Taste (worth 10 points)
7. Odor (worth 10 points)

Panelists assigned scores to each of these attributes to evaluate the sensory characteristics of the Baladi bread loaves.

Freshness of bread:

The freshness of Baladi bread loaves was assessed after packaging them in polyethylene bags and storing them at room temperature for 1, 3, and 5 days. The assessment was conducted using the Alkaline

Water Retention Capacity test (AWRC), following the procedure initially developed by Yamazaki in 1953 and subsequently modified by Kitterman and Rubenthaler in 1971.

Formula of Baladi bread

The formula for making Baladi Bread with different proportions of Buckwheat flour (*Fagopyrum esculentum* and *Fagopyrum tataricum*) along with the control sample. The ingredients used in the formula are as follows:

- Hard wheat flour (HWF): 100% in the control sample, and varying percentages (90%, 80%, and 70%) in the samples with buckwheat.
- Buckwheat flour (*Fagopyrum esculentum* and *Fagopyrum tataricum*): 0% in the control sample, and 10%, 20%, and 30% in the samples with buckwheat.
- Dry yeast: 1.5 grams in all samples.
- Salt: 1.0 gram in all samples.

In summary, the formula details the proportions of these ingredients used to prepare Baladi Bread with varying levels of buckwheat flour, allowing for different formulations and experimental samples to be created.

Analytical methods:

Chemical composition:

Moisture, protein, fat, ash, and crude fiber contents were assessed using the methods specified in the AOAC (Association of Official Analytical Chemists) 2005 guidelines. To determine the carbohydrate content, the following formula was applied:

Carbohydrates (%) = 100 - (% protein + % fat + % ash + % crude fiber).

This calculation method subtracts the percentages of protein, fat, ash, and crude fiber from 100% to estimate the carbohydrate content in the samples.

Statistical Analysis

The collected results were statistically analyzed using an analysis of variance (ANOVA) method, as described in McClave and Benson's (1991) reporting.

Results and Discussion

Chemical Composition of Raw Materials:

Table 1 shows that the Hard Wheat Flour (HWF) was high in moisture (13.02%) and carbohydrates (83.02%), aligning with (Al-Snafi, 2017). In contrast, *Fagopyrum esculentum* and *Fagopyrum tataricum*

(FE) had lower moisture but higher protein, ash, and fiber contents. Specifically, *Fagopyrum esculentum* (FT) had more protein (14.90%) (Ivankov *et al.*, 2021) while *Fagopyrum tataricum* was rich in fiber (22.08%) and ash (2.85%) (Ji *et al.*, 2016; Aubert *et al.*, 2021). These findings suggest their potential in enriching bread with essential nutrients.

Table 1
Proximate Chemical composition (%) of raw materials

Samples	Chemical composition of flour samples (%)					
	Moisture	Ash	Fiber	Protein	Lipids	CHO
HWF	13.02 ± 0.22	1.47 ± 0.0	1.65 ± 0.01	11.75 ± 0.28	1.81 ± 0.08	83.02 ± 0.78
FE	9.17 ± 0.17	2.58 ± 0.07	12.51 ± 0.32	14.90 ± 0.27	2.18 ± 0.05	59.08 ± 0.56
FT	8.78 ± 0.29	2.85 ± 0.01	22.08 ± 0.37	11.81 ± 0.25	1.57 ± 0.03	52.60 ± 0.85
Where: HWF: Hard wheat flour; <i>Fagopyrum esculentum</i> : <i>Fagopyrum esculentum</i> ; <i>Fagopyrum tataricum</i> : <i>Fagopyrum tataricum</i> ; Cho: total carbohydrate						

Rheological parameters

1. Farinograph parameters

Table 2 and fig. 1 assessed the Farinograph parameters of HWF supplemented with FE. HWF's 100% control displayed specific values for water absorption, arrival time, and dough stability. Notably, 10% FT reduced water absorption and dough stability, increasing the mixing tolerance index significantly. At 30%, a more balanced dough behavior emerged. Conversely, FT supplementation led to decreased dough stability but higher mixing tolerance, particularly at 20%. These results reveal that alternative flour type and level can significantly impact Farinograph parameters, influencing dough handling and product quality (Wang & Sun, 2002). The interplay between dough stability and mixing tolerance underscores the nuanced effects of supplementation on rheological properties, consistent with prior research (Basman *et al.*, 2003). Flour supplementation's profound impact necessitates precise understanding and balance for optimal bread formulations.

Table (2): Farinograph parameters of HWF supplementation with FE and FT

Samples	Water absorption (%)	Arrival time (min)	Dough development time (min)	Dough stability (min)	Mixing tolerance index (BU)	Weakening (BU)
Control (100%HWF)	66.4	1.0	2.5	13.5	20	20
90% HWF + 10% FE	65.00	1.5	6.0	5.5	80	110
80% HWF + 20% FE	64.00	2.0	6.0	4.0	60	110
70% HWF + 30% FE	63.00	2.5	7.0	7.0	20	50
90% HWF + 10% FT	64.00	2.0	4.5	6.5	60	100
80% HWF + 20% FT	63.00	2.5	5.0	3.0	80	130
70% HWF + 30% FT	62.00	2.5	5.0	3.5	90	100
Where: HWF: Hard wheat flour;FE: <i>Fagopyrum esculentum</i> ; FT: <i>Fagopyrum tataricum</i> ; BU: barabender unit						

2. Extensograph parameters

Table 3 and fig. 2 show that the extensograph profiles of dough made from Hard Wheat Flour (HWF) supplemented with *Fagopyrum esculentum* and *Fagopyrum tataricum*. At 10% *Fagopyrum esculentum*, extensibility and resistance improved, but at 30% levels, both metrics decreased dramatically. Meanwhile, 30% *Fagopyrum tataricum* resulted in a softer dough with reduced extensibility and resistance. These findings are consistent with previous studies that show the variable effects of different supplementations on extensograph parameters (Mashayekh et al., 2008; Karaoğlu, 2006; Wang et al., 2014; Xie et al., 2022; Darwish et al., 2018; Onyango et al., 2015). Our results indicate that the type and level of supplementation have a significant impact on dough's mechanical properties and ultimately on bread quality. Understanding these extensograph parameters in the context of alternative flour types is crucial for optimized bread formulations.

Table (3) Extensograph parameters of HWF supplementation with FE and FT

Samples	Extensibility (E) (cm)	Resistance to extension (R) (BU)	maximum Resistance to extension (BU)	Proportional number (R/E)	Dough energy (cm ²)
Control (100%HWF)	155	490	410	2.64	97
90% HWF + 10% FE	165	580	430	2.60	112
80% HWF + 20% FE	132	430	380	2.78	72
70% HWF + 30% FE	92	270	270	2.93	32
90% HWF + 10% FT	165	360	270	2.24	71
80% HWF + 20% FT	100	250	240	1.54	47
70% HWF + 30% FT	125	180	180	1.44	30
Where: HWF: Hard wheat flour; FE: <i>Fagopyrum esculentum</i> ; FT: <i>Fagopyrum tataricum</i> ; BU: barabender unit					

3. Pasting profile (RVA)

Our study examined how *Fagopyrum esculentum* and *Fagopyrum tataricum* supplementation affect the pasting properties of Hard Wheat Flour (HWF)-based baladi bread as table 4 and Fig. 3. The control sample showed a peak viscosity of 1192 CP, which declined with *Fagopyrum esculentum* and rose significantly with *Fagopyrum tataricum*, peaking at 4949 CP at 30% supplementation. These findings echo earlier research on the influence of various ingredients like soy flour and decorticated cracked broadbeans on pasting properties (Abdel-Kader, 2000; Mashayekh et al., 2008). Moreover, Choi et al. (2012) reported similar effects with whole wheat flour substitution. Pasting and peak temperatures also varied but stayed within narrow ranges. These alterations in pasting properties are crucial, as they provide insights into potential textural and sensory changes in the final bread product, affirming the significant role of ingredient supplementation in bread formulation.

Table (4)

Pasting properties of HWF supplementation with FE and FT at different levels

Samples	Peak Vis. (CP)	Trough1 (CP)	Break down (CP)	Final Vis. (CP)	Setback (CP)	Peak Time (Min)	Pasting Temp. (°C)	Peak Temp. (°C)
Control (100%HWF)	1192	887	956.7	630.7	561	8.23	56.7	91.8
90% HWF + 10% FE	927.1	297.05	630	671.5	255.6	9.37	57.3	94.4
80% HWF + 20%FE	1291	503.93	885.3	836.4	455	9.07	60.4	94.4
70% HWF + 30% FE	1028	518.31	509.3	999.2	489.8	9.53	68.1	94.5
90% HWF + 10% FT	1731	837.6	1196	1045	686.4	8.87	61.3	93.1
80% HWF + 20% FT	1928	755.4	1172	1406	521.3	8.9	58.5	93.6
70% HWF + 30% FT	4949	1939.8	3019	4242	706.8	8.5	63.5	92.5
Where: Where: HWF: Hard wheat flour; FE: <i>Fagopyrum esculentum</i> ; FT: <i>Fagopyrum tataricum</i> ; BU: barabender unit; Vis: viscosity; CP: centipoise								

Chemical composition of Baladi bread

Table 5 shows that the chemical composition of Baladi bread supplemented with FE and FT showed significant enhancements in key nutritional metrics. Specifically, the breads with 30% FE or FT supplementation had notably higher levels of protein, moisture, ash, and fiber compared to the control made from 100% HWF. This aligns well with previous studies that have explored the nutritional enhancement of Baladi bread through various supplements. For example, research by Hadidy& Rizk (2018) and Mohamed *et al.* (2013) also observed improvements in fatty acids and micronutrients like folic acid when using different additives. Hussein et al. (2013) extended this by examining mineral content, corroborating the increase in ash content seen in our study with FE and FT supplements. Studies by Yousef *et al.* (2015) and Sandak *et al.* (2009) showed that unconventional additives like red algae and seed coats can also alter the bread's chemical composition. In summary, the current study's results contribute to a growing body of literature that suggests supplementation can substantially improve the nutritional profile of Baladi bread.

Table 5
Chemical composition of Baladi bread supplemented with different levels of FE and FT (on dry weight basis).

Baladi bread	Moisture	Protein	Ash	Fat	Fiber	Carbohydrate
Control (100%HWF)	34.52e ± 1.65	11.60e ± 0.25	1.50d ± 0.06	1.62d ± 0.08	1.65g ± 0.01	83.63 ^a ± 2.35
90% HWF + 10% FE	35.65 ^d ± 1.25	12.05 ^c ± 0.15	1.75 ^d ± 0.03	1.60 ^d ± 0.01	2.70 ^f ± 0.10	81.90 ^b ± 1.39
80% HWF + 20%FE	36.80 ^c ± 1.50	12.65 ^b ± 0.10	2.00 ^d ± 0.09	1.55 ^e ± 0.03	3.50 ^e ± 0.07	80.30 ^d ± 1.65
70% HWF + 30% FE	37.90 ^b ± 1.45	13.10 ^a ± 0.07	2.35 ^{ab} ± 0.11	1.52 ^e ± 0.05	4.06 ^c ± 0.13	78.97 ^e ± 1.35
90% HWF + 10% FT	36.00 ^d ± 1.60	11.65 ^e ± 0.11	1.80 ^{cd} ± 0.02	1.70 ^c ± 0.07	3.95 ^d ± 0.12	80.90 ^c ± 1.15
80% HWF + 20% FT	37.50 ^b ± 1.70	11.70 ^d ± 0.09	2.10 ^{bc} ± 0.05	1.80 ^b ± 0.05	5.80 ^b ± 0.15	78.60 ^f ± 0.95
70% HWF + 30% FT	38.70 ^a ± 1.75	11.80 ^d ± 0.16	2.50 ^a ± 0.07	1.89 ^a ± 0.02	7.50 ^a ± 0.17	76.31 ^g ± 0.89
LSD at 0.05	0.665	0.067	0.379	0.0579	0.0597	0.0585
Where: HWF: Hard wheat flour; FE: <i>Fagopyrum esculentum</i> ; FT: <i>Fagopyrum tataricum</i>						

Results are presented as means for triplicate analyses ± standard deviation (SD). Means within column with different letters are significantly different ($P \leq 0.05$).

Color attributes of Baladi bread

In a comprehensive analysis of color parameters in bread samples, several noteworthy trends were observed in table (6). Firstly, the L^* value for brightness demonstrated a noticeable decline with increased FE (Fiber Enrichment) and FT (Flavor Treatment) supplementation. Specifically, the control sample, composed of 100% HWF, exhibited the highest brightness with an L^* value of 64.97. As the FE content was increased to 30%, the L^* value significantly plummeted to 33.18, while a similar trend was observed for 30% FT, where the L^* value decreased to 38.82. Secondly, the a^* values, representing red-green chromaticity, showed a distinctive increase with FE and FT supplementation. The control sample recorded the lowest redness with a value of $a^* = 4.86$. Upon the inclusion of 30% FE, the a^* value peaked at 11.20, indicating an augmented redness; although FT also increased redness, the effect was comparatively less pronounced. Thirdly, for the b^* values, which signify yellow-blue chromaticity, the control sample displayed a moderate yellowness at $b^* = 17.50$. An interesting observation was that 10% FE resulted in increased yellowness ($b^* = 18.57$), but further FE supplementation (20%) led to a decrease in b^* to 15.70. FT supplementation maintained a relatively consistent yellowish hue across varying

concentrations. Fourthly, saturation measurements indicated that the sample with 30% FE had the highest saturation value (20.97), whereas the one with 10% FT recorded the lowest (16.80). Fifthly, in terms of color difference (ΔE), the control sample had the highest ΔE value of 67.46, indicating that increased FE or FT supplementation led to a reduced ΔE , signifying a departure from the control's color. Lastly, the red to yellow ratio (a/b) was lowest in the control sample at 0.28, suggesting a yellowish tint. However, this ratio was observed to increase with FE and FT supplementation, indicating a shift towards the red spectrum.

The study quantified the color parameters of Baladi bread supplemented with varying concentrations of FE and FT using the $L^*a^*b^*$ color model. Even so, our findings revealed a consistent reduction in brightness (L^*) as FE and FT percentages increased, echoing Aider et al.'s (2012) observation that the inclusion of alternative proteins resulted in bread with lower L values. Importantly, we noted a marked rise in redness (a^* value) as the FE content increased, a feature that parallels the results of Yousef et al. (2015), who found that red algae supplementation changed the color attributes of Baladi bread. Then, our study also confirmed that both FE and FT fortification led to an increase in saturation, suggesting more vivid color characteristics. This was in line with Mezaizeet al. (2009), who found that guar gum supplementation yielded color attributes similar to traditional French bread. This phenomenon could be particularly useful for product differentiation in a crowded marketplace. Moreover, we found significant changes in a/b ratio as the percentage of FE or FT increased, indicating a shift towards the red spectrum. This finding could be considered complementary to those of Hadidy& Rizk (2018) and Fahmy et al. (2022), where the crust color was among the criteria for evaluating bread quality. Our results indicate that the addition of FE and FT could be a viable avenue for modifying both the aesthetic and potentially the nutritive quality of Baladi bread, reminiscent of Mobarak et al. (2010), who found that rice bran supplementation not only affected sensory properties but also had potential health benefits. However, our study expands on Hussein et al.'s (2013) work by employing a similar methodology to quantify how different flours alter color parameters. In their study, barley and corn flour had a significant impact on bread color; our study takes this a step further by investigating less commonly used, yet nutritionally rich, flours like FE and FT.

Table (6)

Color attributes for Baladi bread supplemented with different levels of FE and FT

Baladi bread	Color parameters					
	L*	a*	b*	a/b	Saturation	ΔE^{**}
Control (100%HWF)	64.97a $\pm$ 1.01	4.86g $\pm$ 0.06	17.50c $\pm$ 0.32	0.28f $\pm$ 0.001	18.16 ^e $\pm$ 0.19	67.46 ^a $\pm$ 0.62
90% HWF + 10% FE	52.11c $\pm$ 1.05	8.65d $\pm$ 0.16	18.57a $\pm$ 0.14	0.47d $\pm$ 0.02	20.49 ^b $\pm$ 0.13	55.99 ^b $\pm$ 0.45
80% HWF + 20%EF	39.92e $\pm$ 0.56	10.97b $\pm$ 0.22	15.70f $\pm$ 0.07	0.70a $\pm$ 0.02	19.15d $\pm$ 0.15	44.28 ^e $\pm$ 0.33
70% HWF + 30% FE	33.18g $\pm$ 0.85	11.20a $\pm$ 0.42	17.73b $\pm$ 0.18	0.63b $\pm$ 0.01	20.97 ^a $\pm$ 0.07	39.25 ^g $\pm$ 0.42
90% HWF + 10% FT	53.25b $\pm$ 1.45	5.99f $\pm$ 0.13	15.70f $\pm$ 0.22	0.38e $\pm$ 0.003	16.80g $\pm$ 0.16	55.84 ^c $\pm$ 0.38
80% HWF + 20% FT	42.82d $\pm$ 1.20	7.44e $\pm$ 0.15	16.37e $\pm$ 0.26	0.45d $\pm$ 0.002	17.98f $\pm$ 1.15	46.44 ^d $\pm$ 0.37
70% HWF + 30% FT	38.82f $\pm$ 0.65	9.60c $\pm$ 0.09	17.20d $\pm$ 0.12	0.56c $\pm$ 0.002	19.70c $\pm$ 0.08	43.53 ^f $\pm$ 0.42
LSD at 0.05	0.041	0.0430	0.145	0.0322	0.0694	0.0774
Where: HWF: Hard wheat flour;FE: <i>Fagopyrum esculentum</i> ; FT: <i>Fagopyrum tataricum</i>						

Results are presented as means for triplicate analyses $\pm$ standard deviation (SD). Means within column with different letters are significantly different ($P \leq 0.05$).

Sensory properties of Baladi bread

The impact of supplementing HWF with FE and FT on the sensory attributes of Baladi bread was investigated as per table 7. Sensory parameters including general appearance, layer separation, roundness, crumb distribution, crust color, taste, and odor were assessed. The findings revealed that low levels (10%-20%) of FE or FT incorporation did not significantly alter these sensory attributes, while a 30% FE supplementation led to a slight but significant decline in certain attributes like general appearance and crumb distribution. Comparatively, Elketryet al. (2022) and Milovanović et al. (2014) found that the water absorption rate and overall sensory quality improved with grape seed and quinoa-buckwheat-pumpkin seed blends, respectively. Bakare et al. (2015) and Hussein et al. (2013) demonstrated that breadfruit flour and barley/corn flour also had positive effects on rheological properties and nutritional content, albeit with minor sensory changes. Yousef et al. (2015) and Fahmy et al. (2022) improved nutritional quality by incorporating red algae and watermelon rinds flour, respectively, without affecting the sensory acceptability significantly.

Table (7) Effect of FE and FT supplementation with HWF on sensory properties of Baladi breads.

Baladi breads	General Appearance (20)	Separation of layers (20)	Roundness (15)	Distribution of crumb (15)	Crust colour (10)	Taste (10)	Odour (10)
Control (100%HWF)	18.5 ^a ± 0.88	19.5 ^a ± 0.87	14.5 ^a ± 0.48	14.5 ^a ± 0.70	9.3 ^a ± 0.88	9.18 ^a ± 0.67	8.88 ^a ± 0.79
90% HWF + 10% FE	18.3 ^a ± 0.82	19.4 ^a ± 0.76	14.3 ^a ± 0.53	13.8 ^{ab} ± 0.67	8.3 ^{bc} ± 0.87	8.48 ^{bc} ± 0.45	8.78 ^{ab} ± 0.33
80% HWF + 20%FE	17.5 ^b ± 0.74	19.3 ^a ± 0.82	14.1 ^a ± 0.53	13.1 ^{bc} ± 0.82	7.5 ^{cd} ± 0.82	8.38 ^c ± 0.65	8.6 ^{bc} ± 0.48
70% HWF + 30% FE	17.0 ^{bc} ± 0.95	19.6 ^a ± 0.65	14.2 ^a ± 0.52	12.8 ^c ± 1.17	7.5 ^{cd} ± 0.95	7.58 ^f ± 0.49	8.4 ^c ± 0.66
90% HWF + 10% FT	18.7 ^a ± 0.92	19.2 ^a ± 0.57	14.3 ^a ± 0.42	13.4 ^{bc} ± 0.95	9.3 ^a ± 0.74	8.9 ^{ab} ± 0.52	8.18 ^c ± 0.41
80% HWF + 20% FT	18.5 ^a ± 0.64	19.1 ^a ± 0.66	14.5 ^a ± 0.48	13.5 ^{bc} ± 1.34	9.2 ^a ± 0.97	8.5 ^{cd} ± 0.62	8.29 ^c ± 0.47
70% HWF + 30% FT	18.0 ^{ab} ± 1.08	19.3 ^a ± 0.77	14.4 ^a ± 0.88	13.3 ^{bc} ± 1.03	8.3 ^{bc} ± 0.74	8.08 ^{cd} ± 0.74	8.0 ^b ± 1.15
LSD at 0.05	1.29	NS	NS	0.91	0.81	0.44	0.47
Where: HWF: Hard wheat flour; FE: <i>Fagopyrum esculentum</i> ; FT: <i>Fagopyrum tataricum</i>							

Results are presented as means for triplicate analyses ± standard deviation (SD). Means within a column with different letters are significantly different ($P \leq 0.05$).

Freshness of Baladi bread

Table (8) and Fig. (4) indicate that Baladi bread supplemented with FE, particularly at 30%, shows a slower rate of staling compared to control and FT supplemented bread over 72 hours. This aligns with studies on bread freshness and staling e.g., Ghoshal et al. (2013) found that enzyme supplementation, like xylanase, improves bread freshness and shelf life. El-Sayed (2009) highlighted that storage temperature influences bread freshness more than moisture content, pointing to the potential benefits of storing FT-supplemented bread at optimal temperatures. Wahab & Elsalam (2018) suggested higher protein content, as found in FT-supplemented bread, can improve bread freshness. Collectively, these findings indicate that supplementing Baladi bread with FT, especially at 30%, not only slows down staling but could further benefit from controlled storage conditions and enzyme or protein fortifications to maximize freshness and extend shelf life.

Table (8)

Staling of Baladi bread supplemented with different levels of FE and FT

Baladi bread from	Zero Time	After 24 hours	After 48 hours	After 72 hours
Control (100%HWF)	365 ^e ± 3.60	350 ^d ± 3.70	290 ^{bc} ± 3.50	245 ^d ± 4.20
90% HWF + 10% FE	370 ^d ± 4.15	345 ^e ± 4.20	280 ^e ± 4.70	240 ^c ± 3.50
80% HWF + 20%FE	380 ^c ± 2.16	340 ^f ± 5.00	285 ^{de} ± 5.20	250 ^e ± 4.30
70% HWF + 30% FE	390 ^b ± 2.70	350 ^d ± 1.50	290 ^{cd} ± 3.20	260 ^b ± 2.90
90% HWF + 10% FT	370 ^d ± 3.65	355 ^c ± 2.70	290 ^{cd} ± 5.50	245 ^{de} ± 4.50
80% HWF + 20% FT	380 ^c ± 2.80	365 ^b ± 4.50	300 ^b ± 5.20	265 ^b ± 3.50
70% HWF + 30% FT	400 ^b ± 3.50	370 ^a ± 1.50	320 ^a ± 4.60	280 ^a ± 4.20
LSD at 0.05	1.751	1.563	5.629	3.645
Where: HWF: Hard wheat flour; FE: <i>Fagopyrum esculentum</i> ; FT: <i>Fagopyrum tataricum</i>				

Results are presented as means for triplicate analyses ± standard deviation (SD). Means within column with different letters are significantly different ($P \leq 0.05$).

Conclusion

This study confirms that supplementing Baladi bread with FE or FT leads to significant changes in nutritional profile, dough mechanics, color attributes, sensory qualities, and shelf life. Specifically, both *Fagopyrum* species offer nutritional benefits, such as increased protein and fiber, while imparting varied effects on dough handling and bread quality. FT, especially at 30% concentration, shows promise in slowing down the staling process, thereby potentially extending shelf life. These findings collectively highlight the utility of these alternative flours in enhancing both the nutritional and functional aspects of Baladi bread.

Declarations

Data Availability statement:

All data generated or analysed during this study are included in this published article.

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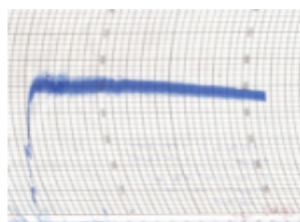
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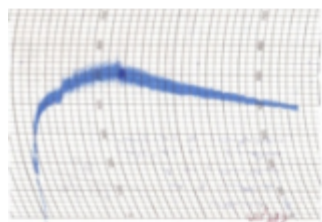
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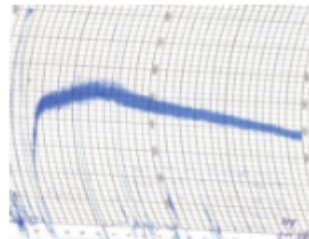
Figures



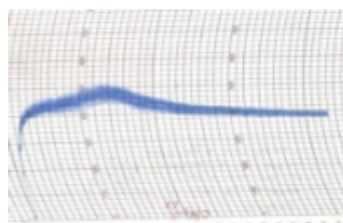
Control (100%HWF)



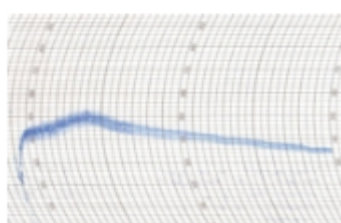
90% HWF+10% FE



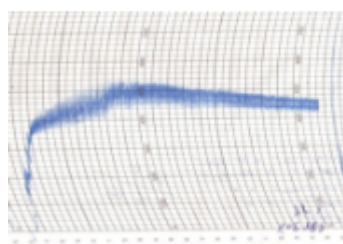
90% HWF+10% FT



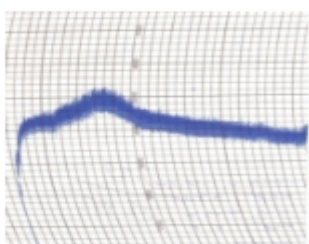
80% HWF+20% FE



80% HWF+20% FT



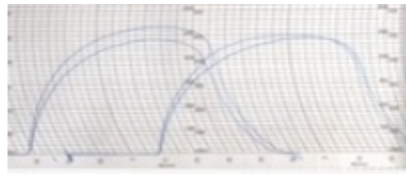
70% HWF+30% FE



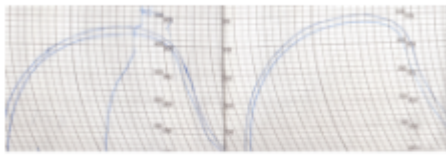
70% HWF+30 FT

Figure 1

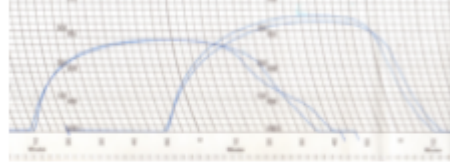
Farinograph parameters of dough sample supplemented with 10, 20, 30% *Fagopyrum esculentum* (FE) and *Fagopyrum tataricum* (FT) with Hard wheat flour(HWF).



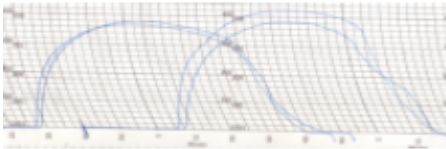
Control sample (100%HWF)



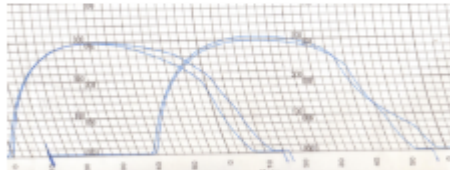
90% HWF+10% FE



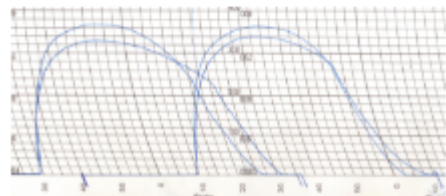
90% HWF+10% FT



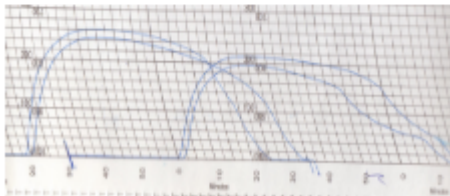
80% HWF+20% FE



80% HWF+20% FT



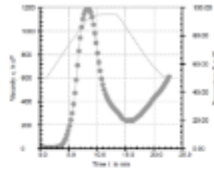
70% HWF+30% FE



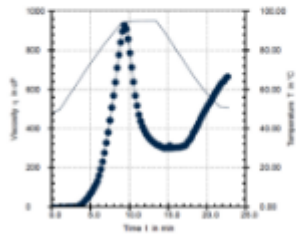
70% HWF+30% FT

Figure 2

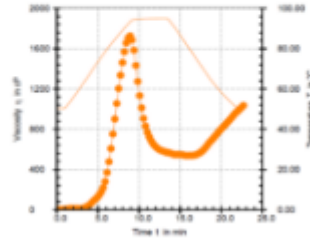
Extensograph parameters of dough sample supplemented with 10, 20, 30% *Fagopyrum esculentum* (FE) and *Fagopyrum tataricum* (FT) with Hard wheat flour (HWF).



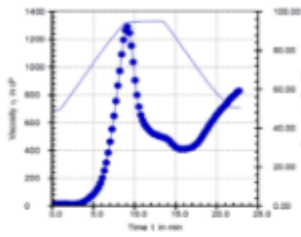
Control (100% HWF)



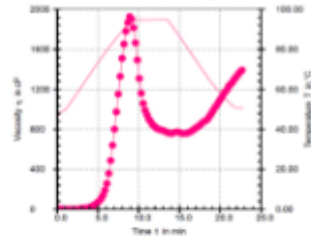
90% HWF+10% FE



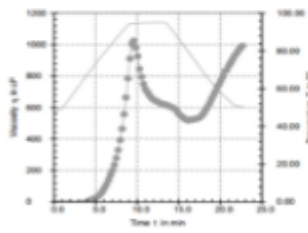
90% HWF+10% FT



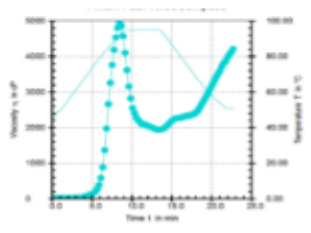
80% HWF+20% FE



80% HWF+20% FT



70% HWF+30% FE



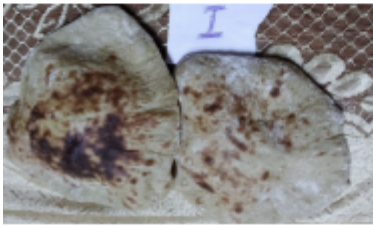
70% HWF+30% FT

Figure 3

Pasting profile (RVA) of dough supplemented with 10, 20, 30% *Fagopyrum esculentum* (FE) and *Fagopyrum tataricum* (FT) with Hard wheat flour (HWF).



Control (100%HWF)



90% HWF+ 10% FE



80% HWF+ 20% FE



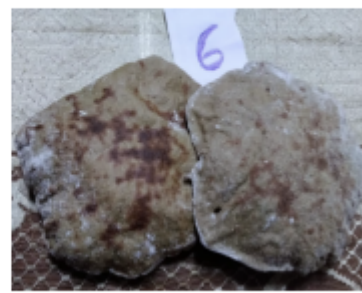
70% HWF+ 30% FE



90% HWF+ 10% FT



80% HWF+ 20% FT



70% HWF+ 30% FT

Figure 4

Photo of bread from hard wheat flour (HWF) supplementation with *Fagopyrum esculentum* (FE) and *Fagopyrum tataricum* (FT) at different levels