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Proso Millet and Phalaris as Alternatives for Wheat Flour in Preparing Balady Bread

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ABSTRACT

The influence of partial substitution of wheat flour (87.50% extraction) with proso millet or phalaris flour in balady bread blends, and their effects on bread quality were studied to meet the need for alternative sources for making balady bread suitable for Egyptian consumers. Wheat flour blends were prepared with different substitution levels (10–25%) of proso millet or phalaris flour and used for preparing balady bread. Proximate analysis for raw materials and rheological analysis for the blends were evaluated. Balady bread was examined for sensory evaluation, proximate analysis, color, and staling. The highest contents of protein, ash, fat, fibers, zinc, phenols, carotenoids, antioxidant activity, and water holding capacity were found in phalaris flour, while proso millet flour had a higher iron content and oil holding capacity. Regarding rheological analysis, the water absorption of dough declined as proso millet ratios increased; however, it elevated with increasing phalaris ratios. Substituting wheat flour with proso millet or phalaris flour in the balady bread resulted in an increase in protein, fat, crude fibers, phenols, and carotenoids contents relative to the control bread, as well as antioxidant activity. Likewise, there is an increase in the weight and yellowness of the produced bread with increasing levels of proso millet substitution. The best overall acceptability of the resulting balady bread was achieved by substituting wheat flour with 15% proso millet or 10% phalaris flour, respectively.

1. Introduction

One of the most significant and essential food products consumed worldwide is bread. Wheat balady bread is the primary source of carbohydrates in Egyptian daily diets for both low- and high-income Egyptian consumers (Soliman et al., 2019). The production of wheat doesn't cover the Egyptian requirements because the final yield is insufficient to meet consumers consumption needs (Litwinek et al., 2013 and FAO, 2015). Egypt has the highest wheat, flour, and bread consumption per capita worldwide (it reached 150.40 kg), (Bulletin of Food Balance Sheet, 2021). Consequently, to fill the wheat gap and satisfy consumer demands, it is required to find additional grain or pulse sources that could be used for wheat bread processing (Litwinek et al., 2013). *Panicum miliaceum L.,* frequently recognized as proso millet, is one of the first known cereal grains used by humans, and it is a significant crop in Asia and Africa (Upadhyaya et al., 2011). It had higher protein, minerals (such as iron and zinc), starch, dietary fibers, and vitamin contents compared to wheat, barley, rye, and oat (Kalinová, 2007). Because of its short growing seasons, ranging from 60 to 90 days after planting, and low water and nutrient requirements, it has the potential for agricultural diversification. Besides, it is fully grown under drought and poor soil conditions and gives a yield that exceeds that of all other crops, where other cereal crops would fail. The area, production, and yield statistics for all types of millets are provided under the general title of millet (Kalinová and Moudrý, 2006).

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Millet is an appropriate cereal product for those with celiac disease because it has a low gliadin content (less than 10 mg/100 g) (Petr et al., 2003).

The canary seeds (*Phalaris canariensis L.*) belong to the Poaceae family and have a life cycle comparable to that of other winter cereal crops (Abdel-Aal et al., 2010). It commonly grows on nutrient-rich soils with a pH range of slightly acidic to neutral and also in wet wetlands. It is known as bird seed, and in 2015 it was accepted for human use. Phalaris seeds contain higher amounts of minerals, essential amino acids, and fatty acids. Additionally, its content of phenolic and carotenoid compounds is higher than that of other cereals, which have antioxidant and antibacterial properties (Abdel-Aal et al., 2011 and Chen et al., 2016). Besides, it would lessen the reliance on imported wheat and boost the income of farmers who harvest crops that could be combined with wheat in bread composites (Mitchell, 2008).

Consequently, this study was conducted to utilize proso millet and phalaris flour in balady bread-making and to evaluate the influence of partial substitution of wheat flour (87.50% extraction) with different levels of proso millet and phalaris flour in bread blends. Subsequently, investigating the sensory evaluation, proximate analysis, color, and staling of the produced balady bread.

2. Materials and methods

Materials

Wheat grains (*Triticum aestivum,* Sakha 95 variety) were obtained from the Field Crops Research Institute, ARC, Giza, Egypt. Proso millet grains [*Panicum miliaceum L.*, family: Gramineae (Poaceae)] and phalaris grains [*Phalaris canariensis L.*, family: Gramineae (Poaceae)] were obtained from a local market in Giza, and the seeds were botanically identified and authenticated by the Department of Flora and Phytotaxonomy Research, Horticultural Research Institute, ARC, Egypt. Gallic acid, 2, 2-diphenyl-1-picrylhydrazyl (DPPH), and sodium carbonate were purchased from Sigma-Aldrich Chemical Company (St. Louis, USA). The Folin Ciocalteu reagent was purchased from LOBA Chemie, India. All chemicals were of the analytical grade. Sunflower oil, instant active dry yeast, and salt (sodium chloride) were obtained from local markets in Giza, Egypt.

Methods

Milling

Wheat grains were freed from broken kernels, dockage, and foreign materials. The grains were tempered to 14% moisture content. Then grains were milled using a fraction mill (Brabender Duisburg Roller Mill, Germany). The extraction rate of flour samples was adjusted to obtain 87.50% extraction rate flour. Proso millet and phalaris grains were carefully cleaned and milled using a high-speed grinder (MDY-2000, China), followed by sieving to get fine flour (using a 60-mesh sieve with sizes around 250 microns). Milled samples were packaged in polyethylene bags and kept in the freezer for further analysis.

Dough rheological properties

Using the Brabender Farinograph, the rheological characteristics of wheat dough mixes with levels 10, 15, 20, and 25% proso millet, or phalaris flour, were evaluated (AACC, 2002). The exact method for making bread was used to prepare the dough blends, except salt and yeast were not added. The wet and dry gluten percentages of different blends were determined according to AACC (2002).

Proximate analyses

Moisture, protein, fat, ash, and crude fiber contents of raw materials and bread samples were determined according to AOAC (2019). Moisture content was determined during storage for 72 hours. Carbohydrate content was calculated on a dry weight basis by the difference:

[Carbohydrates = 100 - (protein+fat+ash+crude fibers)].

Iron, zinc, and calcium contents were measured using the Agilent Technologies Microwave Plasma Atomic Emission Spectrometer (Model: 4210-MP, AES, USA) (AOAC, 2019).

Determination of total phenols

Total phenol contents in raw materials and bread samples were determined by mixing a 2 g sample with 20 ml of methanol (80%) and shaking for two hours. The mixture was then filtrated. 0.50

Folin Ciocalteu phenol reagent, 1.0 ml of Na_2CO_3 (7.50%), and 8.0 ml distilled water (Singleton and Rossi, 1965). The reaction mixture was kept in the dark for thirty minutes. The absorbance of the samples was measured at 725 nm against the blank using a Jenway Spectrophotometer (Model: 6715 UV/Vis, Cole-Parmer Ltd., Staffordshire, UK) and the data were expressed as mg/100g of gallic acid equivalent using the previously designed standard curve.

Free radical scavenging by DPPH

The antioxidant activity of the previous sample extract was determined by adding 3.90 ml of DPPH methanol solution (2.40 mg of DPPH dissolved in 100 ml of methanol) to 0.10 ml of sample extract (Brand-Williams et al., 1995). The reaction mixture was vigorously shaken and allowed to stand in the dark for half an hour. The absorbance of the sample was measured at 515 nm using a Jenway Spectrophotometer, and the radical scavenging percentage as DPPH was calculated using the following equation:

$$Radical\ scavenging\ (\%) = \left[\frac{A0 - A1}{A0}\right] x\ 100$$

where A0 is the absorbance of the control reaction, and A1 is the absorbance of the tested sample after 30 min.

Total carotenoids determination

The content of total carotenoids in raw materials was determined following the technique described by (Santra et al., 2003). 3 g of samples were mixed with 15 ml of water-saturated n-butanol (8:2 ratio of n-butanol with distilled water) and kept for 16–18 hours in the dark. The supernatant absorbance was measured at 440 nm against the blank using a Jenway Spectrophotometer, and β-carotene was used as a standard and expressed as mg/kg.

Water holding capacity (WHC) and oil holding capacity (OHC)

The water holding capacity (WHC) and oil holding capacity (OHC) of the main raw materials were determined by weighing 1 g of sample (W1) in a pre-weighed tube (W2) and mixing it with 10 ml of H_2O or sunflower oil (Hayta et al., 2002). Then samples were allowed to stand for 30 min and centrifuged at 4000 xg for 20 min (Model Z 206 A, HERMLE Labrotechnik GmbH, Wehingen, Germany). Excess water or oil of samples were decanted, allowed to drain, and reweighed (W3). The WHC or OHC percentages were calculated as follows:

$$WHC\ or\ OHC\ \% = W3 - W2\ /\ W1\ x\ 100$$

Color measurement

A tristimulus reflectance colorimeter (CR 400 Chroma Meter; Konica Minolta, Japan) was used to measure the color of the raw materials and bread samples in triplicate. The color parameters were assessed as lightness (L^*)= (100 for lightness and zero for darkness); a^* [chromaticity on a green (-) to red (+)], and b^* [chromaticity on a blue (-) to yellow (+)].

Balady bread manufacturing

Egyptian balady bread was prepared based on preliminary results; wheat flour (100 g of 87.50% extraction) was partially substituted with 10, 15, 20, and 25% proso millet or phalaris flour. 1.00 g of instant active dry yeast and 1.0 g of salt (NaCl), along with an amount of warm water added enough to form optimal bread dough uniformity, were mixed for 10 minutes until a suitable consistency was achieved (Yaseen et al., 2007). Dough samples were allowed to ferment at 85% relative humidity and 30°C±2 for 50 minutes. After the first fermentation stage, the dough was portioned into equal round pieces, positioned on a wooden board spread with a wheat fine bran layer, and placed in a fermentation cabinet at the former relative humidity and temperature for 30 minutes. The dough pieces were flattened (17–20 cm in diameter and 0.50 mm in thickness), left at 85% relative humidity and 30°C±2 for 15 min, and then the flattened dough was baked at 450 to 500°C for around 1-2 min. The balady loaves were cooled and kept until further analysis Figure 1. The weight of the fresh bread samples was determined.

Figure 1. Bread samples pictures at different blends*.

*a= Control bread, b= 10% proso millet flour, c= 15% proso millet flour, d= 20% proso millet flour, e= 25% proso millet flour, f= 10% phalaris flour, g= 15% phalaris flour, h= 20% phalaris flour, and i= 25% phalaris flour.

Sensory evaluation of balanced bread

The sensory acceptability of balady bread samples was estimated by ten panelists from the Food Technology Research Institute on a 9-point hedonic scale (9= like extremely, 8= like very much, 7= like moderately, 6= like slightly, 5= neither like nor dislike, 4= dislike slightly, 3= dislike moderately, 2= dislike very much, 1= dislike extremely), was used to score the variation of the tested attributes according to the Stone and Sidel (1992) method with minor modifications. The panelists were requested to judge the bread samples for appearance, crust color, roundness, separation of layers, crumb color, texture, odor, taste, chewing ability, and overall acceptability.

Water activity (a_w)

The water activity (aw) of the balady bread samples was measured using the Rotronic-Hygrolab3 (CH-8303; Switzerland), as described by Cadden (1988). Sample measurement was performed in triplicate for zero time and during storage for 72 hours at 30°C±2. Sample measurement was performed in triplicate for zero time and during storage for 72 hours at 30°C±2.

Bread staling

Alkaline water retention capacity (AWRC) was used to measure the staling of balady bread samples at 30°C±2 during storage for 0, 24, 48, and 72 hours (Yamazaki, 1953; Kitterman and Rubenthaler, 1971). Bread samples (1 g) previously dried were weighed, 5 ml of 0.10 N $NaHCO_3$ were added, vortexed for 1 min, and then allowed to hydrate at room temperature for 20 min. The samples were centrifuged at 4000 xg for 20 min. The supernatant was discarded, and the precipitate was kept upside-down at a 45° angle for 10 minutes to drain the excess. Dried tubes were weighed, and AWRC was expressed as a percent of weight gain. Reduction percentages, or loss of freshness, were calculated by the following equation:

$$\text{Reduction percentage (RD)} = \frac{AWRC_{zero\,time} - AWRC_{n\,time}}{AWRC_{zero\,time}} \times 100$$

Where n is time of storage

Statistical analysis

The data from this study were statistically analyzed using the Costat statistical software for means and standard deviations (Steel et al., 1997). The data were subjected to one-way analysis of variance (ANOVA) using one way, followed by Duncan's multiple range tests (at $p<0.05$) to assess differences between sample means.

3. Results and Discussion

The proximate analyses of the main raw materials

The proximate analysis of the main raw materials (wheat flour, proso millet, and phalaris flour) is represented in Table 1. The results indicated that phalaris flour had the highest content of protein, fat, ash, crude fibers, and zinc, while proso millet flour had a high iron content (6.67 mg/100g) compared with wheat flour. Wheat flour (87.50% extraction) contains 11.68% protein, 1.61% fat, 1.14% ash, 1.06% crude fibers, 84.51% carbohydrates, 63.55 mg/100 g calcium, 4.79 mg/100g iron, and 1.63 mg/100g zinc. (Kalinová and Moudrý 2006) observed that the protein content in proso millet flour varied from 11.50 to 13.00%, while the ash content ranged from 1.50 to 4.20%, crude fiber ranged from 3.20 to 4.70%, and fat contents were between 3.50 and 6.70%. Besides, calcium ranged from 8–20 mg/100g, iron ranged from 0.80–5.20 mg/100 g, and zinc ranged from 1.40–2.60 mg/100g. (Abdel-Aal et al., 2011) stated that phalaris flour (canary seed flour) contains 20.80–21.50% protein, 6.00–6.30% fats, 0.80–0.90% ash, 40 mg/100 g calcium, 5.90–6.50 mg/100 g iron, and 3.50–3.90 mg/100 g zinc. Table 1. shows the contents of the total phenol and antioxidant activity of raw materials. The data revealed that phalaris flour has the highest phenol contents and antioxidant activities, while wheat flour has the lowest. Phenolic compounds and antioxidant activity are present in proso millet, and ranged from 53.31 to 106.23 mg/100 g on dry weight (Bagdi et al., 2011). **(**Kchaou et al., 2015) found that the kernels of Phalaris canariensis are a potential source of phenolic compounds because of their phenol content and antioxidant activity. The same table showed that the highest content of total carotenoid was found in phalaris flour (6.40 mg/kg), followed by proso millet flour (3.71 mg/kg), and wheat flour (2.41 mg/kg). (Asharani et al., 2010; Hussain et al., 2015, and Abdel-Aal et al., 2022) observed that the total content of carotenoids was 2.49–5.18 mg/kg, 0.78–4.08 mg/kg, and 7.60 mg/kg for proso millet, wheat grains, and canary seed, respectively.

It was obvious that phalaris flour had a greater water holding capacity (WHC) (103.40%), followed by proso millet flour (96.40%) and wheat flour (57.78%). Phalaris flour had the lowest oil holding capacity (OHC) value (67.81%), and proso millet flour had the highest OHC (74.79%). According to (Lima et al., 2021), there is a clear correlation between water WHC and the size of the flour particles. WHC values lower than 55% are not recommended for manufacturing bread. It was obvious that phalaris flour had a greater water holding capacity (WHC) (103.40%), followed by proso millet flour (96.40%) and wheat flour (57.78%). Phalaris flour had the lowest oil holding capacity (OHC) value (67.81%), and proso millet flour had the highest OHC (74.79%). According to (Lima et al., 2021), there is a clear correlation between water WHC and the size of the flour particles. WHC values lower than 55% are not recommended for manufacturing bread. In terms of color values, wheat flour had the highest $L*$ values (95.56), while phalaris flour had the lowest $L*$ values (85.24) compared with the oth-er raw materials; and this may be due to the phenol content. Proso millet flour has the most redness and yellowness of all materials (1.06 and 14.50); similar results were found by (Schoenlechner et al., 2013).

Dough rheological properties

The farinograph parameters of wheat, proso millet, and phalaris flour dough blends are presented in Figure 2. Water is a basic component that helps to get a homogenous mixture between ingredients in the wheat dough, and its distribution during dough mixing provides the dough with the desired viscoelastic structure, which affects the quality of the final product (Popa et al., 2014 and Šćepanović et al., 2018). Flour that is used for flat bread processing has an optimum water absorption that varies between 38 and 85% (Coskuner et al., 1999). Data indicated that water absorption varied from 52.50 to 55.50% of dough at different blends, and this may be due to the differences in protein contents. Besides, water absorption changes as the amount of proso millet or phalaris flour increases compared with the control (wheat flour, 87.50%

Table 1. Proximate analysis of main raw materials*

Constituents	Wheat flour (87.50% extraction)	Proso millet flour	Phalaris flour
Chemical composition (%)			
Moisture content	10.58[a]± 0.01	8.92[b]± 0.02	8.49[c] ± 0.04
Protein	11.68[c] ± 0.04	12.65[b] ±0.13	13.55[a] ± 0.12
Fats	1.61[c] ±0.06	4.29[b] ±0.13	5.96[a] ±0.05
Ash	1.14[c] ±0.01	3.67[b] ±0.21	4.16[a] ±0.09
Crude fiber	1.06[c] ±0.04	2.39[b] ±0.18	4.98[a] ±0.05
Carbohydrates	84.51[a] ±0.15	77.00[b] ±0.66	71.35[c] ±0.31
Minerals (mg/100 on dwb)			
Calcium	63.55[a]± 0.56	48.31[b] ±1.10	45.99[c]± 0.99
Iron	4.79[b] ±0.27	6.67[a] ±0.16	6.30[a]±0.15
Zinc	1.63[c] ±0.09	2.89[b] ±0.13	3.48[a] ±0.15
Total phenol (mg/100 on dwb)	52.47[b] ±1.39	54.45[b] ±2.56	60.87[a]±0.78
Antioxidant activity (% as DPPH)	9.32[c] ±0.22	14.65[b] ±0.52	16.60 [a] ±0.33
Total carotenoids (mg/kg)	2.41[c] ±0.33	3.71[b] ±0.17	6.40[a] ±0.04
WHC (%)	57.78[b]± 0.08	96.40[a]± 4.14	103.40[a]± 5.20
OHC (%)	69.54[a]± 1.79	74.79[a]± 0.05	67.81[b]± 3.22
Color parameters			
*L**	95.56[a]± 0.13	88.63b±0.33	85.24[c]± 1.89
*a**	0.56[b]± 0.03	1.06[a]± 0.07	0.38[c]± 0.08
*b**	9.67[c]± 0.11	14.50[a]± 0.09	9.95[b]± 0.16

*Chemical composition, minerals, phenols, carotenoids and antioxidant activity were calculated based on the dry weight basis (% on dwb). WHC= water holding capacity; and OHC= oil holding capacity. *L**= lightness, *a**= redness and *b**= yellowness. Data are presented as means ± SD (n=3) and different letters in the same row are significantly different at $p<0.05$.

In addition, by increasing the level of replacement of wheat flour with proso millet flour, the absorption of water decreased compared with the control. (Lorenz and Dilsaver 1980) found that increasing the amount of proso millet flour between zero and 20% in the wheat-millet flour mixture reduced the farinograph water absorption from 67.00 to 61.50%. On the other hand, the replacement of wheat flour with phalaris flour increased water absorption as the amount of phalaris flour increased compared with other blends. This could be explained by the fact that polyphenols are more capable of forming hydrogen bonds and have greater swelling potential than starches. As well, fiber enhances water absorption due to its high content of hydroxyl groups, which assists its ability to retain water molecules due to hydrogen bonding (Sudha et al., 2007). The results are in line with (Morita et al., 2002), who observed that some types of composite flour dough absorb more water than those made from only wheat flour.

Regarding dough development time, it could be noticed that it decreased from 4.50 to 2.00 min for proso millet blends and from 6.50 to 2.00 min for phalaris blends as a result of increasing addition. Dough stability decreased with increasing levels of addition from 9.50 to 8 min for proso millet blends compared with control. Besides, dough stability for phalaris blends was higher than control and decreased from 14 to 9 minutes as the amount of phalaris flour increased. Concerning the dough degree of softening, it could be noticed that it varied from 50 to 90 B.U. for proso millet blends and from 45 to 30 B.U. for phalaris blends. The addition of 10% proso millet flour had a higher degree of softening compared with the control and other mixtures. (Zhang et al., 2018) mentioned that flour with a high amount of dietary fiber may increase the percentage of water absorption. For the better progress of bakery products, proso millet and phalaris grains need to be combined with other flour types.

Regarding the farinograph of wheat flour (87.50% extraction), it had 55.50%, 6.50 min, 12 min, and 50 B.U. for water absorption, development time, stability, and degree of softening, respectively.

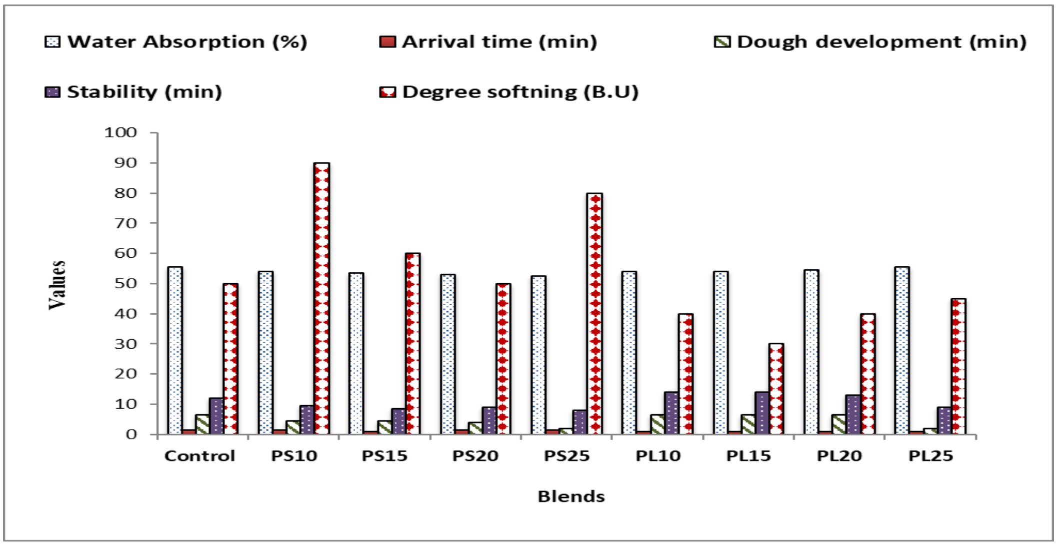

Figure 2. Farinograph parameters of dough blends*

*Control= 100% wheat flour (87.50% extraction), PS10= 10% proso millet flour, PS15= 15% proso millet flour, PS20= 20% proso millet flour, PS25= 25% proso millet flour, PL= 10% phalaris flour, PL15= 15% phalaris flour, PL20= 20% phalaris flour, and PL25= 25% phalaris flour. B.U= Brabender unit.

Table 2. shows the wet and dry gluten of the control and different blends. The data revealed that wet and dry gluten varied between 20.38 and 23.54%, 8.83 and 9.70%, 21.44 and 23.68%, and between 9.78 and 10.04% for proso millet and phalaris/wheat blends. receptivity, and it decreased as the amount of substitution increased. The highest wet and dry gluten were observed in control wheat (87.50% extraction) (24.76% and 10.24%, respectively) compared with other blends.

Table 2. Wet and dry gluten of dough blends*

Blends	Wet Gluten (%)	Dry Gluten (%)
Control	24.76[a]±1.09	10.24[a]±0.27
PS10	23.54[bc]±0.38	9.70[bc] ±0.09
PS15	22.76[cd]±0.39	9.56[c]±0.11
PS20	21.78[ef]±0.21	9.11[d]±0.46
PS25	20.38[g]±0.14	8.83[d]±0.35
PL10	23.68[b]±0.16	10.04[ab]±0.13
PL15	23.07[bcd]±0.05	9.93[abc]±0.03
PL20	22.32[de]±0.60	9.88[abc]±0.12
PL25	21.44[f]±0.37	9.78[bc]±0.03

*Control= 100% wheat flour (87.50% extraction), PS10= 10% proso millet flour, PS15= 15% proso millet flour, PS20= 20% proso millet flour, PS25= 25% proso millet flour, PL= 10% phalaris flour, PL15= 15% phalaris flour, PL20= 20% phalaris flour, and PL25= 25% phalaris flour. Data are presented as means ± SD (n=3) and different letters in the same column are significantly different at $p<0.05$.

Sensory evaluation of balady bread

Organoleptic acceptability is the key limiting factor for consumer acceptance of balady bread. Appearance, crust color, roundness, separation of layers, crumb color, texture, odor, taste, chewing ability, and overall acceptability of the balady bread are represented in Table 3. The results observed that there were significant differences (p<0.05) between the bread samples made from wheat flour (87.50%) incorporated with proso millet and phalaris flour at levels from 10–25% for all measured characteristics except for roundness and separation of layer values, which were non-significantly different (p>0.05). Concerning crumb and crust color, it could be observed that the replacement of wheat flour with proso millet or phalaris significantly decreased color scores, especially for phalaris, and this may be due to the gray color of phalaris. Bread crumb color became darker with higher amounts of proso millet flour (Lorenz and Dilsaver 1980). Besides, adding proso millet or phalaris flour to the balanced bread formula decreased taste values compared with the wheat control. The higher levels of proso millet or phalaris flour caused significant (p<0.05) changes in all parameters compared with control bread, except for roundness and separation of layer values. In contrast, balady bread samples incorporating proso millet and phalaris flour at 25% were less acceptable compared with other levels and the control. The results showed that substituting of wheat flour for up to 15% proso millet flour and 10% phalaris flour would lead to higher overall acceptability for consumers. (Angioloni and Collar 2013 and Schoenlechner et al., 2013) found that millet flour is a suitable substitute cereal for bread making. While the incorporation of millet flour in bread processing is suitable and acceptable, it may affect the texture and color of the bread. Leavened bread cannot be made from millet flour alone because millet does not have gluten proteins. Up to 15% replacement levels, it is fairly acceptable compared with wheat bread, and it has a nutty taste and satisfying flavor (Lorenz and Dilsaver 1980). (Jašovskij 1987) mentioned that bread can be baked from wheat and millet flour mixtures at levels ranging from 20–30% millet flour with a completely satisfactory taste, color, and porosity. (Schoenlechner et al., 2013) found that using proso-millet flour in bread formulas lowers the porosity and texture of bread crumbs.

Table 3. Sensory evaluation of balady bread *

Bread samples	Appearance	Crust color	Roundness	Separation of layers	Crumb color	Texture	Odor	Taste	Chewing ability	Overall acceptability
Control	$8.75^{a}\pm0.42$	$8.80^{a}\pm0.42$	$9.00^{a}\pm0.00$	$8.80^{a}\pm0.63$	$8.85^{a}\pm0.34$	$8.75^{a}\pm0.49$	$9.00^{a}\pm0.00$	$9.00^{a}\pm0.00$	$8.90^{a}\pm0.32$	$8.80^{a}\pm0.35$
PS10	$8.80^{a}\pm0.42$	$8.80^{a}\pm0.43$	$8.90^{a}\pm0.32$	$9.00^{a}\pm0.00$	$8.65^{a}\pm0.67$	$8.65^{ab}\pm0.41$	$8.80^{ab}\pm0.42$	$8.75^{ab}\pm0.43$	$8.80^{a}\pm0.43$	$8.85^{a}\pm0.34$
PS15	$8.75^{a}\pm0.43$	$8.75^{a}\pm0.48$	$8.90^{a}\pm0.32$	$8.95^{a}\pm0.16$	$8.65^{a}\pm0.41$	$8.60^{ab}\pm0.46$	$8.75^{ab}\pm0.63$	$8.75^{ab}\pm0.60$	$8.80^{a}\pm0.42$	$8.80^{a}\pm0.35$
PS20	$8.50^{a}\pm0.67$	$8.50^{ab}\pm0.41$	$8.80^{a}\pm0.42$	$8.95^{a}\pm0.16$	$8.45^{ab}\pm0.37$	$8.35^{abc}\pm0.41$	$8.70^{ab}\pm0.48$	$8.30^{bc}\pm0.58$	$8.50^{ab}\pm0.47$	$8.35^{b}\pm0.24$
PS25	$7.95^{bc}\pm0.64$	$8.15^{bc}\pm0.53$	$8.70^{a}\pm0.42$	$8.85^{a}\pm0.34$	$7.85^{b}\pm0.71$	$8.20^{abc}\pm0.59$	$8.45^{abc}\pm0.69$	$7.80^{cd}\pm0.89$	$8.40^{ab}\pm0.66$	$8.00^{c}\pm0.24$
PL10	$8.35^{ab}\pm0.47$	$7.90^{c}\pm0.61$	$8.80^{a}\pm0.48$	$8.90^{a}\pm0.32$	$7.95^{b}\pm0.60$	$8.25^{abc}\pm0.72$	$8.65^{abc}\pm0.47$	$8.60^{ab}\pm0.39$	$8.35^{ab}\pm0.58$	$8.65^{a}\pm0.37$
PL15	$7.60^{cd}\pm0.57$	$7.40^{d}\pm0.32$	$8.80^{a}\pm0.48$	$8.90^{a}\pm0.32$	$7.15^{c}\pm0.53$	$8.10^{bcd}\pm0.74$	$8.45^{abc}\pm0.94$	$7.95^{cd}\pm0.50$	$8.10^{bc}\pm0.57$	$7.80^{c}\pm0.26$
PL20	$7.30^{de}\pm0.42$	$7.00^{d}\pm0.47$	$8.80^{a}\pm0.63$	$8.90^{a}\pm0.32$	$6.90^{c}\pm0.57$	$7.90^{cd}\pm0.61$	$8.20^{bc}\pm0.92$	$7.55^{d}\pm0.60$	$7.75^{c}\pm0.63$	$7.40^{d}\pm0.39$
PL25	$6.90^{e}\pm0.32$	$6.10^{e}\pm0.74$	$8.75^{a}\pm0.49$	$8.85^{a}\pm0.34$	$6.30^{d}\pm1.23$	$7.55^{d}\pm0.96$	$8.05^{c}\pm1.07$	$6.90^{e}\pm0.88$	$7.20^{d}\pm1.01$	$6.95^{e}\pm0.16$

*Control= 100% wheat flour (87.50% extraction), PS10= 10% proso millet flour, PS15= 15% proso millet flour, PS20= 20% proso millet flour, PS25= 25% proso millet flour, PL= 10% phalaris flour, PL15= 15% phalaris flour, PL20= 20% phalaris flour, and PL25= 25% phalaris flour. Data are presented as means ± SD (n=10) and different letters in the same column are significantly different at p<0.05.

Proximate analysis of balady bread

Table 4. represents the poximate analysis of balady bread. The partial substitution of wheat flour with proso millet or phalaris flour significantly increased ($p<0.05$) the contents of protein, fat, ash, and crude fibers in bread, whereas moisture and carbohydrate content decreased ($p<0.05$) with increasing millet flour. The protein content of balady bread ranged from 11.55 to 11.68% and from 11.79 to 12.32% for substituted bread with proso millet and phalaris flour, respectively, compared with the control. Besides, fat content ranged from 1.77 to 2.47% and from 1.87 to 2.66% for substituted bread with proso millet and phalaris flour, respectively, compared with the control. In terms of fiber content, it ranged from 1.36 to 1.58% and from 1.60 to 2.12% for substituted bread with proso millet and phalaris flour, respectively, compared with the control. Control wheat bread had higher carbohydrates and moisture content. The results are in accordance with (Abdel-Aal et al., 2011), who mentioned that using phalaris flour (canary seed flour) in bread formula increased the content of protein, crude fibers, and fat in baked bread. The same table shows the content of total phenols and antioxidant activity in bread samples. The results showed that phenol content and antioxidant activities significantly ($p<0.05$) increased with increasing levels of substitution, while wheat bread was the lowest.

Table 4. Proximate analysis of balady bread samples*

Constituents / Bread	Moisture Content (%)	Protein (%)	Fats (%)	Ash (%)	Crude fiber (%)	Carbohydrates (%)	Total phenol (mg/100 g)	Antioxidant activity (%) as DPPH)
Control	$37.97^{a}\pm0.48$	$11.43^{g}\pm0.02$	$1.65^{e}\pm0.02$	$1.68^{f}\pm0.03$	$1.27^{e}\pm0.06$	$83.97^{a}\pm0.11$	$50.57^{f}\pm0.13$	$10.35^{f}\pm0.19$
PS10	$37.73^{a}\pm0.41$	$11.55^{f}\pm0.02$	$1.77^{de}\pm0.14$	$1.93^{e}\pm0.04$	$1.36^{de}\pm0.07$	$83.39^{b}\pm0.14$	$58.70^{e}\pm0.80$	$10.61^{f}\pm0.34$
PS15	$36.56^{b}\pm0.64$	$11.58^{f}\pm0.01$	$1.96^{cd}\pm0.12$	$2.24^{c}\pm0.06$	$1.42^{cd}\pm0.04$	$82.80^{c}\pm0.23$	$60.00^{d}\pm0.06$	$11.21^{e}\pm0.17$
PS20	$35.26^{c}\pm0.56$	$11.61^{ef}\pm0.01$	$2.17^{bc}\pm0.44$	$2.42^{b}\pm0.05$	$1.48^{bc}\pm0.04$	$82.32^{cd}\pm0.54$	$61.71^{c}\pm0.11$	$11.75^{d}\pm0.21$
PS25	$34.81^{cd}\pm0.92$	$11.68^{e}\pm0.04$	$2.47^{ab}\pm0.07$	$2.52^{ab}\pm0.19$	$1.58^{ab}\pm0.10$	$81.75^{ef}\pm0.41$	$63.74^{b}\pm0.04$	$12.36^{bc}\pm0.03$
PL10	$37.49^{ab}0.39\pm$	$11.79^{d}\pm0.03$	$1.87^{cde}\pm0.05$	$2.05^{de}\pm0.04$	$1.60^{cde}\pm0.03$	$82.69^{c}\pm0.14$	$59.22^{de}\pm0.14$	$11.46^{de}\pm0.40$
PL15	$37.11^{ab}\pm0.76$	$11.94^{c}\pm0.04$	$2.06^{cd}\pm0.05$	$2.22^{cd}\pm0.03$	$1.77^{cd}\pm0.01$	$82.01^{de}\pm0.13$	$61.83^{c}\pm0.27$	$12.14^{c}\pm0.06$
PL20	$34.60^{cd}\pm0.23$	$12.10^{b}\pm0.04$	$2.37^{ab}\pm0.08$	$2.38^{bc}\pm0.02$	$1.91^{ab}\pm0.03$	$81.24^{f}\pm0.17$	$63.26^{b}\pm0.49$	$12.68^{b}\pm0.15$
PL25	$33.92^{d}\pm0.24$	$12.32^{a}\pm0.11$	$2.66^{a}\pm0.05$	$2.62^{a}\pm0.20$	$2.12^{a}\pm0.06$	$80.28^{g}\pm0.41$	$66.11^{a}\pm0.40$	$13.33^{a}\pm0.08$

*Control= 100% wheat flour (87.50% extraction), PS10= 10% proso millet flour, PS15= 15% proso millet flour, PS20= 20% proso millet flour, PS25= 25% proso millet flour, PL= 10% phalaris flour, PL15= 15% phalaris flour, PL20= 20% phalaris flour, and PL25= 25% phalaris flour. Chemical composition was calculated as dry weight basis. Data are presented as means ± SD (n=3) and different letters in the same column are significantly different at $p<0.05$.

Color parameters and weight of Balady bread

Table 5. presents the color parameters and weight of balady bread. With increasing levels of substitution, the lightness (L^*) of balady bread values for the crust and crumb reduced significantly ($p<0.05$), from 68.51 to 66.29 and from 72.89 to 71.57 for proso millet bread samples and, correspondingly, from 67.38 to 62.72 and from 72.47 to 66.33 for phalaris bread samples. On the other hand, redness (a^*) values were significantly ($p<0.05$) increased by increasing proso millet or phalaris flour levels compared with the control. In terms of yellowness (b^*) values, data revealed that it increased with increasing proso millet while decreasing with increasing phalaris flour levels, since both flour samples have different colors. The amount of proso millet flour in the bread formula had a significant impact on the bread crust and crumb color characteristics (Mannuramath et al., 2015). (Schoenlechner et al., 2013) pointed out that the color of bread samples was significantly influenced

by the addition of proso millet flour to wheat flour; it became slightly darker, and the redness values increased to a small extent. Meanwhile, the consumer most often evaluates color (together with appearance) because it is essential since an appealing color of the final product promotes the consumer's acceptability. The partial substitution of wheat flour with proso millet or phalaris flour significantly increased ($p<0.05$) the weight of bread with increasing proso millet flour, while it decreased with increasing phalaris flour compared with the control (wheat flour, 87.50% extraction). The weight of balady bread varied between 141.39 and 142.98 g and between 139.62 and 141.62 g for proso millet and phalaris bread, respectively.

Table 5. Color parameters and weight of balady bread *

Bread samples	Crust color			Crumb color			Weight (g)
	*L**	*a**	*b**	*L**	*a**	*b**	
Control	69.47[a]±0.23	1.59[d]±0.02	18.61[d]±0.16	73.04[a]±0.18	1.35[f]±0.09	16.15[bc]±0.66	140.27[de]±0.91
PS10	68.51[b]±0.29	1.73[ab]±0.15	19.30[c]±0.16	72.89[a]±0.13	1.56[e]±0.17	16.46[ab]±0.31	141.39[c]±0.67
PS15	68.06[c]±0.09	1.94[c]±0.11	19.66[b]±0.14	72.65[ab]±0.10	1.94[cd]±0.06	16.76[a]±0.04	141.95[bc]±0.08
PS20	67.40[d]±0.21	2.50[ab]±0.13	19.90[b]±0.23	72.11[c]±0.08	2.17[b]±0.10	16.93[a]±0.17	142.85[ab]±0.10
PS25	66.29[e]±0.11	2.66[a]±0.16	20.55[a]±0.09	71.57[d]±0.05	2.65[a]±0.15	17.00[a]±0.18	142.98[a]±0.64
PL10	67.38[d]±0.20	1.71[cd]±0.05	18.31[d]±0.19	72.47[bc]±0.16	1.41[ef]±0.04	15.74[c]±0.04	141.62[c]±0.45
PL15	66.28[e]±0.12	1.81[cd]±0.18	16.97[e]±0.21	71.26[d]±0.14	1.55[e]±0.12	14.82[d]±0.06	141.17[cd]±0.11
PL20	65.27[f]±0.47	2.24[b]±0.06	16.47[f]±0.25	67.73[e]±0.19	1.83[d]±0.09	13.94[e]±0.17	139.85[e]±0.26
PL25	62.72[g]±0.29	2.47[ab]±0.31	15.33[g]±0.21	66.33[f]±0.58	2.04[bc]±0.05	12.77[f]±0.16	139.62[e]±0.74

*Control= 100% wheat flour (87.50% extraction), PS10= 10% proso millet flour, PS15= 15% proso millet flour, PS20= 20% proso millet flour, PS25= 25% proso millet flour, PL= 10% phalaris flour, PL15= 15% phalaris flour, PL20= 20% phalaris flour, and PL25= 25% phalaris flour. *L**= lightness, *a**= redness and *b**= yellowness. Data are presented as means ± SD (n=3) and different letters in the same column are significantly different at $p<0.05$.

Water activity (a_w) and moisture content of balady bread

Water is an essential element in food, especially free water. The a_w provides important data about the product quality and the surface microbiological growth possibility, and it gives clear information about the stability and strength of the food product. It can predict which microorganisms will be possible causes for infection and spoilage (the difference between bacterial and fungal physiology; a_w of 0.91 versus that of 0.70). It plays a crucial role in food products by preserving their chemical stability (Barbosa-Cánovas et al., 2020 and Rahman, 2010). The a_w and moisture content of balady bread with proso millet and phalaris flour during storage at 30ºC±2 are presented in Figures 3a and b. Regarding the results of a_w, it could be concluded that there was a significant decrease ($p<0.05$) in a_w of balady bread samples with an increasing level of substitution of wheat flour with proso millet and phalaris flour compared with the control sample. The a_w of bread samples ranged between 0.942 and 0.972 (Ayub et al., 2003). (Lazaridou et al., 2007) observed a reduction in a_w during storage, and the changes in a_w were parallel to changes in moisture content.

Regarding the balady bread moisture content, the data showed that the moisture content significantly decreased ($p<0.05$) with increasing levels of substitution and during storage, except for bread samples with 10% proso millet and phalaris flour, which were not significantly decreased ($p>0.05$). The moisture content of bread samples on the first day of baking varied between 36.05 and 45.49% (Ayub et al., 2003 and El-Sayed, 2009) revealed that after 24 hours of storage at room temperature, the moisture content of the bread began to decline, reaching its maximum loss after 72 hours. Therefore, the water loss coincided with increased loaf firmness and decreased freshness values. (Schiraldi and Fessas 2012) found that water forms hydrogen bonds among the starch polymers or between the starch and the proteins, with the decrease in moisture content yielding greater firmness.

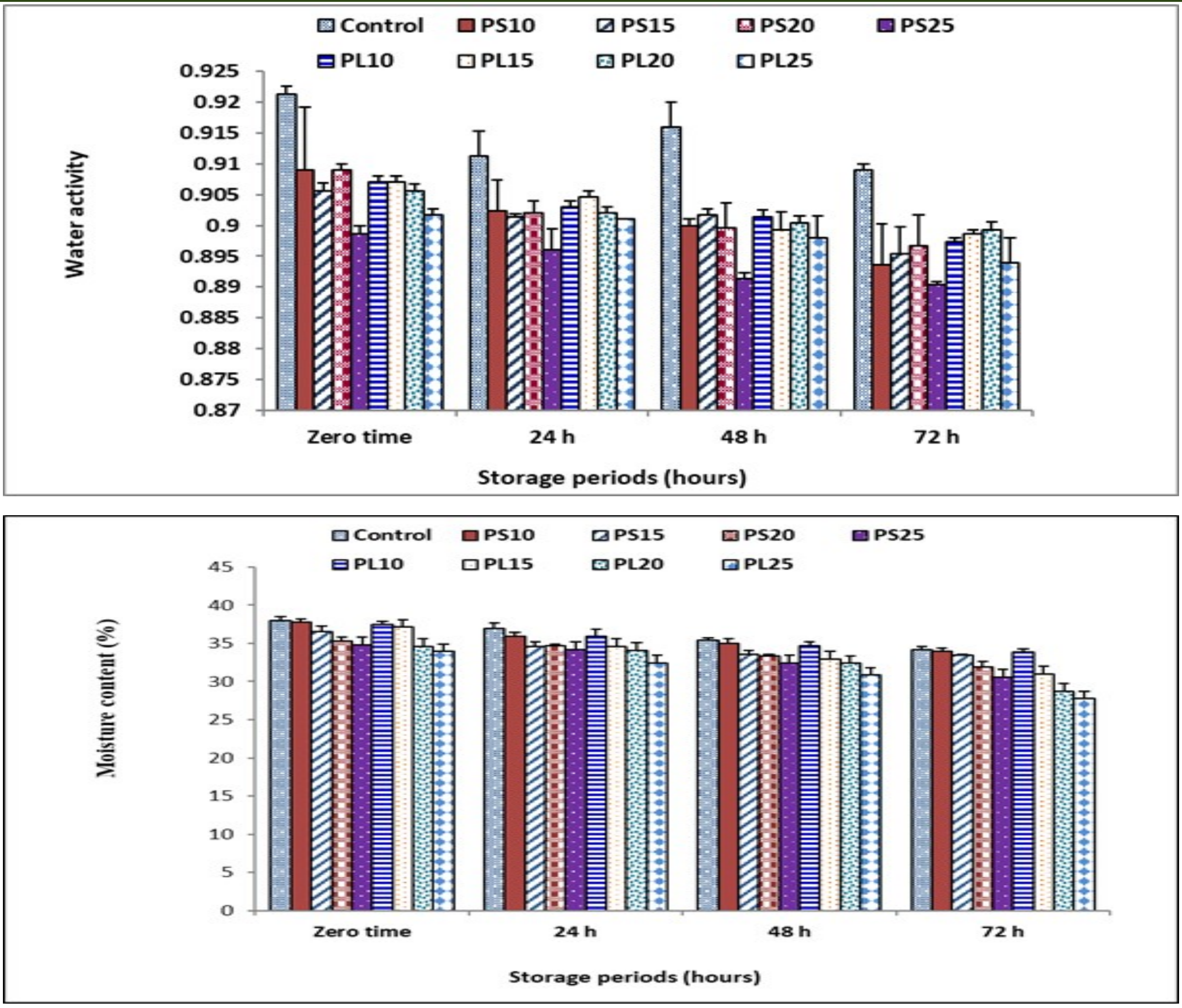

Figure 3. Water activity (a_w) (a) and moisture content (b) of balady bread during storage

*Control= 100% wheat flour (87.50% extraction), PS10= 10% proso millet flour, PS15= 15% proso millet flour, PS20= 20% proso millet flour, PS25= 25% proso millet flour, PL= 10% phalaris flour, PL15= 15% phalaris flour, PL20= 20% phalaris flour, and PL25= 25% phalaris flour. Values are mean of three replicates ±SD

Balady bread staling

Alkaline water retention capacity (AWRC) is used to measure bread staling, and it is an indirect indication of bread freshness and the crystallization degree of starch. Higher AWRC percentages are linked with starch gelatinization, which increases the water-binding capacity and bread freshness. Lower AWRC percentages indicate a higher fraction of starch, which has lost its ability to bind water (*i.e.,* retrograded starch) and caused a loss of freshness (Licciardello et al., 2014). Table 6. displays the AWRC of balady bread with various levels of proso millet or phalaris flour at zero time and different storage periods (24, 48, and 72 h) at 30°C±2. Data revealed that the AWRC values significantly decreased ($p<0.05$) when the amount of proso millet or phalaris flour was increased and during storage periods. Besides, substitution of wheat flour with phalaris flour had higher AWRC percentages compared with bread samples substituted with proso millet flour. Similarly, there is a significant ($p<0.05$) decrease in AWRC values with increasing storage period in all bread samples along with control. The storage temperature has a more important effect on the freshness of balady bread samples than its moisture content. Concerning reduction percentage (RD), it could be observed that it decreased for proso millet blends and for phalaris blends as a result of increasing addition and during storage. The AWRC values of fresh baked bread decreased significantly during the first 24 hours of storage (El-Sayed, 2009).

Table 6. Alkaline water retention capacity (AWRC) of balady bread*

Bread samples	Storage period (h)						
	Zero time	24 h	RD (%)	48 h	RD (%)	72 h	RD (%)
Control	450.68^{a}_{a}±1.82	415.15^{a}_{b} ±3.72	7.88	392.00^{a}_{c}±4.24	13.02	312.00^{a}_{d}±4.50	30.77
PS10	430.13^{c}_{a}±1.55	404.00^{b}_{b}±6.92	6.07	375.00^{b}_{c}±2.35	12.82	307.10^{ab}_{d}±7.20	28.60
PS15	382.73^{ef}_{a}±0.87	361.00^{d}_{b}±5.00	5.68	352.00^{d}_{c}±2.30	8.03	288.67^{cd}_{d} ±6.11	24.58
PS20	373.67^{fg}_{a}±5.69	353.00^{de}_{b}±3.00	5.53	343.79^{e}_{c}±3.50	7.99	286.00^{cd}_{d}±4.68	23.46
PS25	364.00^{g}_{a}±4.00	344.00^{e}_{b}±3.10	5.49	336.00^{f}_{c} ±3.00	7.69	282.00^{d}_{d} ±4.86	22.53
PL10	446.67^{ab}_{a}±2.31	399.17^{b}_{b}±6.82	10.63	366.00^{c}_{c} ±6.00	18.06	305.00^{ab}_{d} ±6.00	31.72
PL15	438.00^{bc}_{a}±3.50	396.00^{b}_{b}±4.00	9.59	361.40^{c}_{c} ±2.50	17.49	300.00^{b}_{d} ±1.16	31.51
PL20	410.00^{d}_{a}±5.00	372.40^{c}_{b}±4.40	9.17	344.00^{e}_{c} ±2.93	16.10	292.67^{c}_{d}±4.16	28.62
PL25	386.00^{e}_{a}±4.00	351.00^{de}_{b}±3.60	9.07	340.00^{ef}_{c}±4.92	11.92	286.00^{cd}_{d} ±2.50	25.91

*RD= Reduction percentage, control= 100% wheat flour (87.50% extraction), PS10= 10% proso millet flour, PS15= 15% proso millet flour, PS20= 20% proso millet flour, PS25= 25% proso millet flour, PL= 10% phalaris flour, PL15= 15% phalaris flour, PL20= 20% phalaris flour, and PL25= 25% phalaris flour. Data are presented as means ± SD (n=3) and number in the same column (superscript letter) or row (subscript letter) followed by the same letter are not significantly different at 0.05 level.

4. Conclusion

To conclude, the objective of this study was to create different alternative ingredients for balady bread processing using proso millet and phalaris flour that can be regarded as having a good nutritional value with higher acceptability and are likely to be merged into Egyptian balady bread. To this extent, different substitution levels were used. Bread prepared from different blends of proso millet and phalaris flour had higher elemental concentrations, adequate bioactive molecules, and antioxidant activity compared with control wheat bread. Besides, the most abundant macronutrients in bread were protein, fat, and fibers, as well as phenols, carotenoids, and antioxidant activity. Similarly, the addition of proso millet and phalaris flour increased the weight of the bread, which led to a decrease in the amount of wheat flour used to produce balady bread. Also, increasing the amount of proso millet flour improves the yellowness of the bread produced. Thus, we recommend using proso millet up to 15% and phalaris flour up to 10% of the substitution level to be applied in bakery product manufacturing to face the wheat flour shortage.

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