Effect of Mixing Date Seed Powder with Wheat Flour on the Rheological Parameters, Nutrients, Bioactive Compounds Content, and Antioxidant Activity of the Egyptian Balady Bread

Neveen S. Ismail[1], Yousif A. Elhassaneen[2] and Heba M. El Kholey[3]

ABSTRACT

The present study aims to determine the chemical composition, nutritional evaluation and bioactive compound content of Khalas date seed powder (DSP). Also, the application of partial replacement of wheat flour with DSP in the manufacture of Egyptian Balady bread will be within the scope of this investigation. The moisture, total protein, crude fat, crude fiber, ash and carbohydrates content of DSP were 8.11, 6.62, 9.03, 17.35, 1.71 and 57.18%, respectively. Also, mineral analysis of DSP revealed that it contains a variety of estimated effective components. K recorded higher content followed by P, Mg, Ca, Na, Fe, Mn, Cu, Zn and Se. For bioactive compounds in DSP, the total phenolic was observed as the most abundant, followed by polysaccharides, flavonoids, saponins, tannins, terpenoids, lutein, triterpenoids, anthocyanins and carotenoids. Mixing DSP (5-20%) into wheat flour increases all the assayed minerals except Zn and Cu, all assayed bioactive compounds except phytates and free radical scavenging activity. In terms of rheological properties, adding DSP to dough increased all farinograph parameters, including water absorption, arrival time, dough development time, dough stability, and farinograph quality number, by 9.38 to 40.94, 13.67 to 102.88, 2.01 to 28.92, 4.99 to 52.91, and 5.43 and 21.81%, respectively. Additionally, all extensograph parameters were enhanced, including extensibility, relative resistance to extension, proportionate number, and energy. The rate of increase in all assayed compounds and parameters as the result of DSP mixing levels was recorded dose-response manner. In conclusion, DSP could play an important role in strategies to contribute a major role to bridging the nutritional gap and improving the quality parameters, as a partial substitute for flour. Therefore, the present study recommended that DSP be included in food processing and therapeutic nutrition applications.

Keywords: Chemical composition, minerals, radicals scavenging activity, farinograph, extensograph, organoleptic evaluation.

INTRODUCTION

Bread has been a staple food around the world for a long time, perhaps due to its good taste, nutritional benefits, and ease of transportation. There are many types of bread, as it is made in different ways and using different ingredients. Currently, wheat is one of the most important basic ingredients for making bread. Bread provides many benefits to human health. It contributes to obtaining the body's daily need for carbohydrates which are the body's preferred source of energy (Malia, 2020). Bread also helps balance blood sugar levels and contains many vitamins, and minerals and some types are rich in fiber (Kourkouta *et al.,* 2017). In Egypt, the bread industry is considered one of the major food industries related to people's daily needs, which concerns all classes of people as it is the basic food. Thus, this industry has developed greatly, which is evident in the many types of bread, the multiple methods of its manufacture, and its monitoring and supervision to ensure its quality. Also, bread in Egypt was and still is one of the most important food elements that go into every meal, and no one can do without it, whether rich or poor. Balady bread is one of the most popular and consumed types of bread in Egypt. It is a round, flat loaf (1 cm in thickness, with a diameter ranging from 10 to 30 cm) composed of two distinct layers. Balady bread is typically produced using high-extraction wheat flour (82%), and it is prepared utilizing a straight dough method (Mousa *et al.,* 1979). The dough for Balady bread is relatively soft (containing 70–75% water), allowed to ferment for 2 hours, and then baked at a significantly elevated temperature (400–500 ºC) for a brief duration of 1-2 minutes. Notwithstanding the significance of these aspects, it has been observed that the overall yield of wheat grains falls short of meeting Egypt's demands.

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[1]Nutrition and Food Science Department, Faculty of Home Economics, Helwan University, Cairo, Egypt, [2]Nutrition and Food Science Department, Faculty of Home Economics, Menoufia University, Shebin El-Kom, Egypt, and [3]Home Economics Department, Faculty of Specific Education, Damietta University, Damietta, Egypt.
*Corresponding authors: yousif12@hotmail.com,
https://orcid.org/0000-0003-1391-3653

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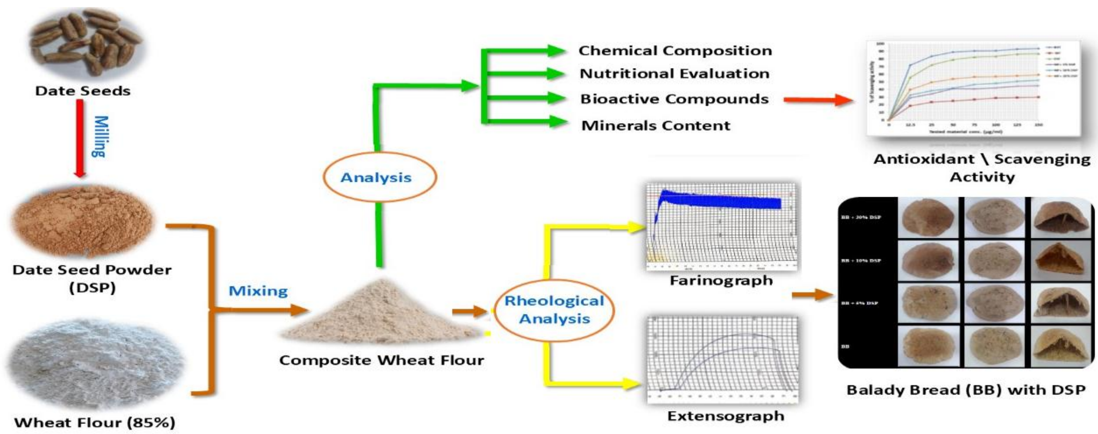

Graphical Abstract

The total wheat grain production fulfills only approximately 55% of the nation's overall requirements. Thus, it was necessary to search for many ways to overcome this problem. One of these ways was to search for sources of local grains that could be used in making bread from wheat flour, but this method was not successful enough to fill the previous gap (Yaseen *et al.,* 2007). For this reason, researchers turned their attention to other alternative methods, including the use of waste or by-products resulting from food and agricultural industries in mixing with wheat flour (Elhassaneen *et al.*, 2016 a, b; Mashal, 2016; Sayed Ahmed, 2016 and Hallabo *et al.,* 2018). Given the good results recorded by these studies, which were encouraging for further expansion in this field, the current study was designed to benefit from one of the most important wastes produced by the date industry, which is a date seed.

Dates have traditionally been a profitable crop throughout the world's arid and semiarid regions, playing an essential role in the economic and social lives of the people who live in these zones (Besbes *et al.,* 2004). According to the Statistics Division of the Food and Agriculture Organization of the United Nations (FAOSTAT, 2020), the global production of date palm fruit is around 9.5 million tons a year. Also, there are nearly 2000 varieties of dates distributed around the world. Many of these varieties are available during an eight-month growing period each year. The date (*Phoenix dactylifera* L.) fruit is composed of a fleshy pericarp and seed, which constitute between 10% and 15% of the date fruit weight (Hussein *et al.,* 1998). Date seeds are regarded as a waste byproduct; date processing factories manufacture pitted dates, date powders, date syrup, date juice, chocolate-coated dates, and date confectionary (Hamada *et al.,* 2002). Date seeds are thrown or utilized mostly as animal feed for cattle, sheep, camels, and poultry (Rahman *et al.*, 2007; Al-Farsi & Lee, 2008 and Oladzad *et al.,* 2021). In 2017, global date production reached 8.1 million tons, resulting in the generation of approximately 1.01 million tons of date seeds (Briones *et al.,* 2011). Consequently, the effective utilization of this byproduct is crucial for date cultivation and enhancing profitability within this sector.

Research on date seeds has been minimal, primarily concentrating on their chemical makeup for nutritional analysis. Therefore, investigations into the development of products derived from date seeds remain scarce (Devshony *et al.,* 1992). Some uses, such as oil extraction from the seeds and usage of the seeds as a nutritional fiber source in baking recipes, have been documented (Rahman *et al.,* 2007). Others believe that date seeds and their contents might be used in cosmetics, medicines, and, to a lesser extent, food items (Al-Farsi *et al.,* 2007). In exploring alternative applications for this plentiful byproduct, one can consider its conversion into roasted date seeds, resulting in a caffeine-free beverage that serves as a coffee alternative. This coffee substitute, derived from roasted date kernels, offers a more appealing aroma and flavor compared to conventional coffee. Milder and gentler, it has been traditionally utilized by the ancient Bedouins of the desert. Coffee made from date stones is recognized for its numerous benefits, including being rich in minerals as well as both soluble and insoluble fibers (Lowry *et al.*, 1951). Conversely, date seeds are acknowledged as an exceptional source of bioactive compounds, including phenolics, dietary fibers, and oils, which exhibit a range of biological functions (Besbes *et al.*, 2004; Al-Farsi *et al.,* 2007; Al-Farsi & Lee, 2008 and Ammar & Habiba, 2010). The chemical composition of date seeds reveals a significant proportion of fiber (75–80%), fat (10–13%), proteins (5–6%), and ash (1.3-

2.7) (Hamada *et al.*, 2002; Besbes *et al.*, 2004; Al-Farsi *et al.*, 2007 and Al-Farsi & Lee, 2008). Nonetheless, these seeds are currently underutilized. This byproduct from date processing industries is viewed as an excellent source of food ingredients with notable technological properties, suitable for incorporation into food as a significant source of dietary fiber and protein (Besbes *et al.*, 2004; Besbes *et al.*, 2009 and Bouaziz *et al.*, 2010). Furthermore, date fruit seeds are recognized as a source of flavonoids and polyphenols, varying by variety. The polyphenolic and flavonoid content in date fruit seeds surpasses that found in other polyphenol-rich foods such as flaxseeds, grapes, and green tea (Hilary *et al.*, 2020). Importantly, the polyphenolic compounds present in date fruit seeds have demonstrated anti-inflammatory and antioxidant properties, which may be beneficial in preventing and treating obesity, cancer, cardiovascular diseases, and neurodegenerative disorders (Alkhoori *et al.*, 2022; Kamal *et al.*, 2023 and Elhassaneen & Mahran, 2024). In light of the aforementioned considerations, the current investigation seeks to evaluate the Khalas date seed powder (DSP) from various perspectives, encompassing its chemical composition, nutritional profile, mineral content, and bioactive compounds. Additionally, this study will examine the impact of incorporating date seed powder into wheat flour on the rheological properties, nutrient and bioactive compound content, as well as the antioxidant activity of the Egyptian Balady bread.

MATERIALS AND METHODS

Wheat flour:

The Giza 155 variety of wheat (*Triticum vulgare*) was sourced from the markets of Shebin El-Kom, located in the Menoufia Governorate, Egypt, during the 2023 harvesting season. The gathered samples were promptly transported to the laboratory and refrigerated at 0°C for preservation until they were utilized for flour preparation. The grain samples underwent verification by the faculty members at the Faculty of Agriculture, Minoufiya University, Shebin El-Kom, Egypt.

Date seeds:

Khalas date seed (*Phoenix dactylifera* L.) was kindly obtained by special arrangement with some date factories in Siwa Oasis, Matrouh Governorate, Egypt. Date seed samples underwent verification by the date's experts in the Faculty of Agriculture, Minoufiya University, Shebin El-Kom, Egypt.

Chemicals:

Standard bioactive compounds (GA) gallic acid, (CA) catechin, linalool, and ursolic acid), butalyted hydroxyl toluene (BHT), DPPH (2,2-diphenyl-1-picrylhydrazyl), and dimethyl sulfoxide (DMSO) were obtained from Sigma Chemical Co., St. Louis, MO. All other chemicals, reagents, and solvents were of analytical grade and purchased from El-Ghomhorya Company for Trading Drugs, Chemicals, and Medical Instruments, El-Amiria, Cairo, Egypt, unless otherwise specified.

Instruments:

In study Absorbance measurements for various assays were obtained using a UV-160A spectrophotometer (Shimadzu Corporation, Kyoto, Japan). Additionally, an atomic absorption spectrophotometer (PerkinElmer, Model 2380) was employed in Waltham, MA, USA was used for mineral determination. Micro-Kjeldahl semiautomatic apparatus, Velp company, Italy was used for total nitrogen determination. Soxhlet semiautomatic apparatus Velp Company, Italy, was used for crude fat determination.

METHODS

Preparation of wheat flour:

Wheat flour was prepared following the method of Ahmed *et al.* (1982). Wheat grains were manually cleaned and sorted before being dried to approximately 10% moisture content in a hot air oven (Horizontal Forced Air Drier, Proctor and Schwartz Inc., Philadelphia, PA) at 60 °C. The dried grains were milled into flour in a miller (Moulinex Egypt, ElAraby Co., Benha, Egypt). The flour samples were sieved in standard sieves to prepare flour samples with an 85% extraction rate.

Preparation of Khalas date seeds powder:

Khalas date seed (*Phoenix dactylifera* L.) samples were cleaned, sorted manually, and washed with water to remove all the attached parts. Subsequently, the samples were dried in a hot air oven (Horizontal Forced Air Drier, Proctor and Schwartz Inc., Philadelphia, PA) at 70°C for duration of three hours. The dehydrated date seed specimens were then ground into a fine powder using a high-speed mixer (Moulinex Egypt, ElAraby Co., Benha, Egypt). The resultant material that passed through a 40-mesh sieve was collected, stored in polyethylene bags, and refrigerated at 4 °C for subsequent experimental applications.

Preparation of control and composite wheat flour extracts:

Control (wheat flour, WF) and composite wheat flour samples (WF+5% DSP, WF+10% DSP and WF+20%DSP) were used for their aqueous extracts according to the method mentioned in Gharib *et al.* (2022a). In brief, 20 g sample was homogenized in 180 mL of water and stirred for one hour at room temperature (23±3 °C) using an orbital shaker

(Unimax 1010, Heidolph Instruments GmbH & Co. KG, Germany). The resulting mixture was filtered to separate the extract, which was then concentrated under reduced pressure at 55 °C using a rotary evaporator (Laborata 4000; Heidolph Instruments GmbH & Co. KG, Germany). This process was repeated twice with the residue, and the combined extracts were collected. All aqueous extracts could be ready for analytical studies.

Chemical analysis of control and composite wheat flour samples:

Control and composite samples of wheat flour were subjected to analysis for their proximate chemical composition, which encompassed moisture, protein (Total Nitrogen (T.N.) × 6.25), fat (using petroleum ether as a solvent), ash, crude fiber, and dietary fiber contents, utilizing the methodologies outlined by AOAC (2000). The carbohydrate content was computed by difference, following the equation: Carbohydrates (%) = 100 - (% moisture + % protein + % fat + % ash + % fiber).

Determination of the nutritional value of control and composite wheat flour samples:

Total energy value:

The total energy content (kcal/100 g) of control and composite wheat flour samples was determined using the equation from Insel *et al.* (2002): Total energy (kcal/100 g = 4 (protein% + carbohydrates%) + 9 (fat%).

Satisfaction of the daily protein needs for an adult male (ages 25-50):

The grams consumed (G.D.R., g) of food (on a wet weight basis) necessary to meet the daily protein requirements of an adult male (63 g) were determined utilizing the National Research Council (1989) standards. Additionally, the percentage satisfaction of the daily protein requirement for an adult male (P.S./80 g) was computed based on the potentially typical portions consumed in Egypt, specifically one loaf (weighing 80 g).

Satisfaction of the daily energy requirements for an adult male (ages 25–50):

The grams of food consumed (on a wet weight basis) necessary to meet the daily energy requirements for a man (G.D.R., g) were determined using the Recommended Dietary Allowances (RDA), which prescribe a daily intake of 2900 Kcal for men, as stated by the National Research Council (1989). Additionally, the percentage of fulfillment (P.S.) of the daily energy needs for an adult male (ages 25–50, weighing 79 kg and standing at 176 cm) was assessed based on the typical portion consumed at households in Egypt, specifically one loaf weighing 80g.

Assessment of Mineral Content:

The mineral content across various samples was assessed following the methodology established by Sundarrao *et al.* (1991). In summary, 0.5 g of defatted sample was placed into a digestion glass tube within a Kjeldahl digestion apparatus, and 6 ml of a tri-acid mixture (composed of nitric acid, perchloric acid, and sulfuric acid in a volumetric ratio of 20:4:1, respectively) was introduced into each tube. The contents of the tubes underwent a gradual digestion process comprising 30 minutes at 70 °C, followed by 30 minutes at 180 °C, and concluding with 30 minutes at 220 °C. Upon completion of the digestion, the mixture was allowed to cool, dissolved in distilled water, and the total volume was adjusted to 50 ml in a volumetric flask. Following filtration through ashless filter paper, aliquots were analyzed for various minerals (Ca, K, Mg, P, Fe, Zn, Na, Mn, Cu, and Se) using an atomic absorption spectrophotometer.

Bioactive compounds determination:

The quantification of total phenolics in various sample extracts was conducted utilizing the Folin-Ciocalteu reagent, following the methodologies established by Singleton & Rossi (1965) and Wolfe *et al.* (2003**).** The findings are reported as gallic acid equivalents (GAE). The assessment of total carotenoids in the 80% acetone extract was performed using the procedure outlined by Litchenthaler (1987), with results conveyed as µg of carotenoid per gram of dry extract. Total flavonoid content was estimated via the colorimetric assay detailed by Zhishen *et al.* (1999), expressed as catechin equivalents (CAE) with the standard curve equation: $y = 0.0003x - 0.0117$, $r^2 = 0.9827$, in mg of CA per gram of dry extract. The extraction and quantification of total polysaccharides were carried out in accordance with the technique described by Vazirian *et al.* (2014), using starch as a standard, with results presented as mg of starch equivalents per gram of dry weight (DW). Total terpenoids were extracted and quantified following the methodology of Ghorai *et al.* (2012), with linalool serving as the standard, and results expressed in mg of linalool equivalents per gram of DW. The extraction and measurement of total triterpenoids were conducted as per the approach of Schneider *et al.* (2009), utilizing ursolic acid as a standard, with results reported in mg of ursolic acid per 100 grams. The saponins content was assessed following the protocol established by Fenwick and Oakenfull (1983), using gallic acid to formulate the standard curve, enabling the determination of saponins levels in the sample. Lutein was extracted from molokhia leaves in accordance with the methods described by Wu *et al.* (2022), and expressed as µg.100 g^{-1}. Oxalate was determined as described by Oke (1965). Tannins were quantified utilizing the technique established by Van-Burden and Robinson (1981). Gallic acid (GA) served as a reference standard for constructing the calibration curve, which facilitated the estimation of tannin content. Phytate levels were assessed in accordance with the colorimetric procedure outlined by Latta and Eskin (1980).

DPPH radical scavenging assay:

The free radical scavenging capacity of both control and composite wheat flour extracts was evaluated using the DPPH radical scavenging assay as outlined by Desmarchelier *et al.* (1997). In summary, 2.4 mL of a 0.1 mM solution of 2,2-diphenyl-1-picrylhydrazyl (DPPH) in methanol was combined with 1.6 mL of the control and composite wheat flour extracts at various concentrations (12.5–150 µg/mL). The mixture was thoroughly vortexed and allowed to sit in the dark at room temperature for 30 minutes. The absorbance (Abs) of the resultant mixture was measured spectrophotometrically at 517 nm, with BHT serving as a reference compound. The percentage of DPPH radical scavenging activity was calculated using the following formula: DPPH radical scavenging activity (%) = $[(A0-A1)/A0] \times 100$, where A0 represents the Abs of the control, and A1 denotes the Abs of the wheat flour/composite wheat flour/BHT. Subsequently, the inhibition percentage was graphed against concentration, from which the IC50 value was derived.

Preparation of Balady bread:

The Balady bread samples were created following the modified protocol established by Yaseen *et al.* (2007). The formulation of the bread consists of the following ingredients: wheat flour, 1000 g; salt, 20 g; dried yeast, 2 g; and water, 500 g. The yeast was combined with water at 30 °C to form a suspension, to which the other components were subsequently added and kneaded to achieve uniform dough. The substitution of wheat flour with DSP was performed at levels of 5%, 10%, and 20% of the total weight of the wheat flour. The dough was then allowed to proof for 2 hours in a proofer (Bakbar E81, New Zealand), after which it was divided into 80 g loaves before being baked at 170 °C for a duration of 10 minutes.

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

WHC and OHC were determined according to the method of Larrauri *et al.* (1996). 25 ml of either distilled water or commercial corn oil was incorporated into 0.5 g of the samples, which underwent vigorous agitation for a duration of 1 min., prior to being centrifuged for 15 minutes at a force of 10,000 g. The remaining residue was subsequently weighed, and the (WHC) and (OHC) were computed as g of water or oil per gram of dry material, respectively.

Determination of rheological properties of dough:

AACC (1969), procedures were used to determine both control and composite samples, utilizing farinograph and extensograph testing. The individual measurements were performed in DSP by 5, 10 and 20% of additions. The amounts of the 5, 10 and 20% of DSP were selected according to their chemical structure and effect on the dough's rheological properties.

Farinograph measurement:

Prior to conducting the farinograph analysis, it is essential to ascertain the moisture content. This measurement was executed in accordance with ISO standard 5530-1 (1997). The moisture level of the flour was evaluated following ISO standard 712 (2009). The assessment of water absorption, dough development time, dough stability, and farinograph quality number was performed utilizing a Brabender R Farinograph (BrabenderR GmbH & Co., Duisburg, Germany). A visual comparison of the resulting curves was conducted using the Farinograph Data Correlation software (Brabender R GmbH & Co., Duisburg, Germany).

Extensograph test:

Extensograph testing was performed on a Brabender R Extensograph (Brabender R GmbH & Co, Duisburg, Germany) to measure the maximum resistance to extension, extensibility, and strength of the dough (energy) of the wheat flour control sample and samples containing DSP.

Sensory evaluation:

Ten panelists, all postgraduate students from Menoufia University in Shebin El-Kom, Egypt, participated in a sensory evaluation. Each panelist was presented with five bread samples arranged randomly on a rectangular plastic tray. The loaves were individually packaged in pouches and assigned a three-digit code prior to the evaluation. The five samples included four varieties of composite flour loaves alongside a control sample made entirely of wheat flour. Water was made available for palate cleansing between the samples. Panelists were instructed to assess the color, flavor, and overall acceptability of the bread using a 9-point hedonic scale, where 1 represents extreme dislike, 2 indicates very much dislike, 3 signifies moderate dislike, 4 denotes slight dislike, 5 reflects neutrality, 6 indicates slight liking, 7 represents moderate liking, 8 signifies very much liking, and 9 indicates extreme liking.

Statistical Analysis:

All tests/measurements were performed in triplicate and shown as mean ± Standard Deviation (SD). The Student t-test was used in conjunction with the MINITAB 12 computer software (Minitab Inc., State College, PA).

RESULTS AND DISCUSSION

Chemical composition, nutritional evaluation, mineral content and bioactive compounds of Khalas date seed powder (DSP):

The results for the chemical composition, nutritional evaluation, mineral content and bioactive compounds of Khalas date seed powder (DSP) are presented in Table (1). Such data indicated that carbohydrates (57.18 $g.100g^{-1}$) were the most abundant compounds, followed by crude fiber (17.35 $g.100g^{-1}$), crude fat (9.03 $g.100g^{-1}$), total protein (6.62 $g.100g^{-1}$) and ash (1.71 $g.100g^{-1}$). In a similar study, Al-Farsi *et al*. (2007) found that the proximate composition of Omani date kernels was 2.3–6.4% protein, 5.0–13.2 fat, 0.9–1.8% ash and 22.5–80.2% dietary fiber. Also, the data of the present study are partially according to that reported in several studies (Ali *et al.*, 2015 and Oladipupo Kareem *et al.*, 2021). Ultimately, date seeds exhibit a notable fiber concentration.

Table 1. Chemical composition, nutritional evaluation, mineral content and bioactive compounds of date seed powder (DSP)

Parameter	Range	Mean±SD
Chemical composition ($g.100g^{-1}$)		
Water	7.89 - 8.85	8.11 ± 0.67
Total Protein	6.01 −7.14	6.62 ± 0.45
Crude fat	8.45 - 9.78	9.03 ± 0.53
Crude fiber	16.09 - 18.23	17.35 ± 1.54
Ash	1.43 - 2.05	1.71 ± 0.23
Carbohydrates	55.02 - 59.05	57.18 ± 3.05
Nutritional evaluation		
Energy (Kcal/100g)	331- 342	336 ± 6.0
G.D.R. (g) for protein (63 g)	942.10 - 965.12	951.66 ± 11.54
G.D.R. (g) for energy (2900 Kcal)	853.34 - 873.98	861.89 ± 9.46
P.S./ 80 g (One loaf, %) For protein (63g)	8.40 - 9.52	8.41 ± 1.05
P.S./80 g (One loaf, %) For energy (63g)	8.66 - 9.90	9.28 ± 0.78
Mineral ($mg.100g^{-1}$)		
Ca	30.78 - 37.06	33.02± 3.17
K	362.13 -374.02	370.12 ± 5.83
Mg	95.54 - 9.98	98.95 ± 2.90
P	283.56 - 291.76	287.94 ± 4.05
Fe	3.39 - 4.21	4.03 ± 0.54
Zn	0.56 - 0.74	0.69 ± 0.09
Na	12.03 - 14.53	13.02 ± 1.23
Mn	1.02 - 1.29	1.13 ± 0.12
Cu	0.39 - 0.46	0.42 ± 0.04
Se		0.01± 0.00
Bioactive compounds		
Total phenolics (mg gallic acid.100 g^{-1})	876.34 - 896.63	889.93 ± 16.78
Total carotenoids (mg catechin.100 g^{-1})	3.99 - 4.89	4.51 ± 0.43
Total flavonoids (mg RE.100 g^{-1})	332.15 - 352.10	344.32 ± 8.11
Lutein (µg.100 g-1)	73.16 - 82.56	76.43 ± 4.98
Polysaccharides (mg starch.100 g^{-1})	760.56 - 790.23	781.33 ± 15.56
Terpenoids (mg linalol.100 g^{-1})	104.01- 112.84	110.04 ± 4.90
Triterpenoids (mg ursolic acid.100 g^{-1})	60.56 - 69.32	63.90 ± 5.12
Tannins (mg catechine equivalent.100 g^{-1})	148.01 - 160.45	156.52 ± 6.09
Saponin (mg .100 g^{-1})	191.67 - 212.98	198.61 ± 9.23
Phytates (mg .100 g^{-1})	1.99 - 2.46	2.29 ± 0.23

*Each value represents the mean of three replicates ±SD.

This fiber serves a crucial nutritional function as it contributes to stool bulk and facilitates transit within the digestive system (Elhassaneen *et al.*, 2023). The nutritional assessment of the Khalas DSP revealed that the total energy content was measured at 336 ± 6.0 kcal/100 g. The G.D.R. (g) for protein was 951.66 g, while the G.D.R. (g) for energy (2900 Kcal) amounted to 861.89 g. For protein (63 g), P.S./80 g (one loaf) was calculated at 8.41%, and for energy (2900 kcal), P.S./80 g (one loaf) was determined to be 9.28%. These findings align partially with those presented by Al-Farsi *et al.* (2007), who concluded that the DSP serves as a moderately adequate protein source and offers moderate-calorie options. This is attributable to their fat composition, which contributes to a generally moderate caloric content (9.03 $g.100g^{-1}$). Such evidence supports the potential for effectively incorporating DSP into dietary interventions for individuals dealing with excess weight. The mineral analysis of Khalas DSP indicated richness in various essential elements, with potassium demonstrating the highest concentration, followed by phosphorus, magnesium, calcium, sodium, iron, manganese, copper, zinc, and selenium. This data corroborates findings from Nehdi *et al.* (2018) and Alharbi *et al.* (2021), who indicated that date seeds comprise an array of minerals, predominantly potassium alongside calcium, copper, cobalt, iron, magnesium, phosphorus, fluorine, selenium, sodium, and zinc (Hinkaew *et al.*, 2021). Also, such data seem to confirm those mentioned by Al-Farsi *et al*. (2007) and Habib & Ibrahim (2009) except for Mg content. Bioactive and antinutrient compounds including total phenolics, carotenoids, flavonoids, lutein, anthocyanins, polysaccharides, terpenoids, triterpenoids, tennis, saponins and phytates determined in DSP as shown in Table (1). Total phenolics were reported as the most abundant ones, followed by polysaccharides, flavonoids, saponins, tannins, terpenoids, lutein, triterpenoids, anthocyanins and carotenoids. In a similar study, Habib *et al.* (2014) noticed that date seeds contain high levels of total polyphenols. Also, Ardekani *et al.* (2010) found that the DMSO extract of the "Zahedi" variety had the highest total phenolic content (3541 mg.100 g^{-1} dry plant) among of these 14 varieties and 5 organic solvents and indicates that polyphenols are the main antioxidants. The variation in total bioactive compounds content and subsequent antioxidant activity (AA) determined were noticed in the date seeds depending on many factors including variety/species, soil type, geographic location, agriculture management and the determination method parameters i.e. extraction methods, extraction medium etc., (Al-Farsi *et al.*, 2005; Khanavi *et al.*, 2009; Ardekani *et al.*, 2010; Khalid *et al.*, 2016; Nehdi *et al.*, 2018; Alharbi *et al.*, 2021 and Oladipupo Kareem *et al.*, 2021). In general, these data show that the DSP were an excellent source of many nutrients for humans (carbohydrates, fiber, protein, and ash), minerals (K, P, Mg and Fe) and, bioactive compounds and antinutritional (phenolics, flavonoids, lutein, polysaccharides, terpenoids, saponin and tannins).

Chemical composition of control and composite wheat flour:

Data in Table (2) showed the approximate chemical composition of control and composite wheat flour samples. Such data indicated that the mixing of DSP (5-20%) with wheat flour leads to a decrease in moisture, total protein and carbohydrate content by non-significant values while crude fat, crude fiber and ash were increased by significant values. The rate of increase in crude fat, crude fiber and ash as the result of DSP mixing levels was recorded dose-response manner. By the 20% of DSP mixing, crude fat, crude fiber, and ash were increased by 151.355, 249.61, and 17.71%, respectively. Conversely, the nutritional characteristics of both the control and composite flour samples may be influenced by such alterations in chemical composition (Table 3). These characteristics encompass total energy ($Kcal.100g^{-1}$), the daily energy requirements for an adult male (GDR/energy), as well as protein requirements (GDR/protein), along with the percentage fulfillment of daily energy (P.S./energy) and protein (P.S./protein) needs for an adult male. With the increasing DSP level addition up to 20%, to the wheat flour, the values of GDR/protein and P.S./protein in the composite samples were significantly ($p \leq 0.05$) altered. Data of this study are following that obtained by several authors who found that date seed powder (DSP) contains high levels of diverse essential nutrients. For example, Al-Farsi *et al*. (2007), found that the proximate composition of Omani date kernels was 2.3–6.4% protein, 5.0–13.2 fat, 0.9–1.8% ash and 22.5–80.2% dietary fiber. Subsequently, the addition of DSP to flour samples leads to a highly significant increase in their crude fat, ash and crude fiber. This property could have many food industrial, nutritional and therapeutic benefits. Insoluble fiber, which does not dissolve in water, plays a significant nutritional role since it helps to provide bulk to stool and aid in the movement through the digestive tract (Pereira *et al.*, 2004). Soluble fiber is known to assist in the reduction of blood glucose and cholesterol levels (Chandalia *et al.*, 2000; Al-Weshahy & Rao, 2012 and Elhassaneen *et al.*, 2023).

Table 2. Chemical composition of control and composite wheat flour

Component ($g.100g^{-1}$)	Wheat flour (WF, 85%)	Composite wheat flour					
		DSP (5%)		DSP (10%)		DSP (20%)	
		g/100g	% of change	g/100g	% of change	g/100g	% of change
Water	10.23±0.54^{a}	10.13±0.71^{a}	-0.98	10.08±0.32^{a}	-1.47	9.85±0.50^{a}	-3.71
Total Protein	10.84±0.41^{a}	10.59±0.46^{a}	-2.32	10.46±0.28^{a}	-3.51	10.07±0.21^{b}	-7.10
Crude fat	1.11±0.12^{c}	1.59±0.20^{bc}	43.24	1.95±0.09^{b}	75.68	2.79±0.30^{a}	151.35
Crude fiber	1.27±0.10^{c}	2.17±0.11^{bc}	71.18	2.92±011^{b}	129.92	4.44±0.20^{a}	249.61
Ash	0.96±0.09^{b}	1.02±0.09^{b}	6.25	1.06±0.08^{ab}	10.42	1.13±0.11^{a}	17.71
Carbohydrates	75.59±2.89^{a}	74.50±3.11^{a}	-1.44	73.53±1.98^{ab}	-2.73	71.72±2.56^{b}	-5.12

*Each value represents the mean of three replicates ±SD. Means with the superscript letters in the same raw were significantly different at $p \leq 0.05$.

Table 3. Nutritional evaluation of control and composite wheat flour

Factor	Wheat flour (WF, 85%)	Composite wheat flour					
		DSP (5%)		DSP (10%)		DSP (20%)	
		g/100g	% of change	g/100g	% of change	g/100g	% of change
Energy (Kcal/100g)	356 ±11.34^{a}	355 ±10.65^{a}	-0.30	354 ±14.98^{a}	-0.62	352 ±9.56^{a}	-0.97
G.D.R. (g) for protein (63 g)	581.18 ±15.09^{c}	595.01 ± 16.21^{b}	2.38	602.29 ±10.56^{ab}	3.63	625.62 ±17.93^{a}	7.65
G.D.R. (g) for energy (2900 Kcal)	815.27 ±13.67^{a}	817.70 ±9.10^{a}	0.30	820.34 ±15.98^{a}	0.62	823.23 ±10.65^{a}	0.98
P.S./ 80 g (One loaf, %) For protein (63g)	13.77 ±0.98^{a}	13.45 ±0.77^{a}	-2.32	13.28 ±1.01^{ab}	-3.51	12.79 ±0.65^{b}	-7.10
P.S./80 g (One loaf, %) For energy (63g)	9.81 ±0.78^{a}	9.78 ±0.45^{a}	-0.30	9.75 ±0.86^{a}	-0.62	9.72 ±0.43^{a}	-0.97

*Each value represents the mean of three replicates ±SD. Means with the superscript letters in the same raw were significantly different at $p \leq 0.05$.

Consequently, fiber plays a significant role in lowering the risk of various diseases, such as cardiovascular conditions, breast cancer, diabetes, and constipation. In light of this, numerous studies indicate that increased fiber consumption may provide protective advantages by influencing a range of factors, including elevated blood pressure, high insulin levels, excess body weight, elevated triglycerides, and decreased HDL-c levels (McKeown *et al.,* 2002; Elhassaneen *et al.,* 2021; Abdelrahman, 2022; El-Hawary, 2022; Fayez, 2022; and Elhassaneen *et al.,* 2023, 2024a,b). Additionally, diets characterized by low-fiber and high-glycemic foods may elevate the risk of developing type 2 diabetes (Liu *et al.*, 2000; Fung *et al.*, 2002 and Schulze *et al.*, 2004). Moreover, Farvid *et al.* (2016) found that increased fiber intake correlates with a decreased risk of breast cancer. Generally, the fiber found in DSP is deemed equally effective as that derived from various plant sources (Elhassaneen *et al.,* 2021; 2022 a,b; Fayez, 2022 and Gad Alla, 2023). Therefore, nutrition specialists advocate for a gradual increase in fiber consumption rather than an abrupt change, and due to fiber's water-absorbing properties, fluid intake should correspondingly rise as fiber intake increases (Pereira *et al.,* 2004 and Elhassaneen *et al.,* 2023). Lastly, based on the findings regarding moisture content, the integration of DSP with wheat flour enhances its storage longevity and reduces susceptibility to microbial spoilage and enzymatic processes (Sawaya *et al.*, 1984).

Mineral composition of control and composite wheat flour:

Data in Table (4) showed the mineral content of control and composite wheat flour. From such data, it could be noticed that with the increase in DSP level mixing with the wheat flour, the value of all estimated minerals except Zn and Cu in the composite samples was significantly ($p \leq 0.05$) increased. The high significant increase takes this approach Mg > K > Na > Se > P > Fe > Ca > Mn which recorded 56.75, 43.76, 40.77, 30.00, 27.30, 25.00, 18.43 and 3.14% when compared with the control wheat flour samples. The reasons for the significant increase estimated in composite flour samples are due to the increased content of these minerals in DSP compared to what is found in wheat flour. In this context, Nehdi *et al.* (2018) and Alharbi *et al.* (2021) identified that DSP is comprised of various minerals, with potassium (K) being the predominant one. Other minerals such as calcium (Ca), copper (Cu), cobalt (Co), iron (Fe), magnesium (Mg), phosphorus (P), fluorine (Fl), selenium (Se), sodium (Na), and zinc (Zn) were documented in considerable quantities (Hinkaew *et al.,* 2021). Furthermore, Mahmud *et al.* (2017) observed that Barhi DSP possesses notable mineral content, with the highest concentration of K recorded at 239.1 mg/100 g, followed in decreasing order by Mg (176.39 mg/100 g), P (123.13 mg/100 g), Ca (38.94 mg/100 g), and Na (12.98 mg/100 g). Generally, magnesium is crucial for the optimal functioning of numerous bodily systems, including the heart, bones, muscles, and nerves. Additionally, epidemiological research indicates that diets rich in magnesium are typically abundant in other nutrients, which synergistically contribute to disease prevention, in contrast to supplements focusing solely on a single nutrient (Orchard *et al.*, 2014). The levels of potassium are integral to various physiological functions, which include resting cellular membrane potential, the conduction of action potentials in neuronal, muscular, and cardiac tissues, hormonal secretion and functionality, acid-base equilibrium, maintenance of systemic blood pressure, as well as fluid and electrolyte homeostasis (Mount & Zandi-Nejad, 2012; Malnic *et al.,* 2013 and Weiner *et al.,* 2014). Moreover, potassium significantly influences the regulation of local cortical monoaminergic levels of norepinephrine, serotonin, and dopamine, affecting sleep/wake balance and spontaneous activity (Dietz *et al.*, 2023). Calcium is the most prevalent mineral within the human body, primarily stored in bones and teeth, which confer structural integrity and hardness. The body requires calcium for muscular movement and for transmitting nerve signals between the brain and other body parts (IMUS, 2011 and Balk *et al.*, 2017). Phosphorus is essential for the formation of bones, teeth, and cell membranes.

Table 4. Mineral composition of control and composite wheat flour

Mineral	Wheat flour (WF, 85%)	Composite wheat flour					
		DSP (5%)		DSP (10%)		DSP (20%)	
		g/100g	% of change	g/100g	% of change	g/100g	% of change
Ca	18.56 ±1.55 [b]	20.28 ±2.04 [a]	9.28	21.01 ±0.87 [a]	13.18	21.98 ±0.59 [a]	18.43
K	124.89 ±4.11 [d]	139.15 ±3.21 [c]	11.42	153.41 ±7.14 [b]	22.84	179.54 ±11.21 [a]	43.76
Mg	27.56 ±2.15 [c]	31.98 ±3.07 [b]	16.04	35.13 ±2.27 [ab]	27.47	43.20 ±3.09 [a]	56.75
P	121.76 ±5.42 [c]	131.07 ±6.09 [bc]	7.65	140.38 ±10.34 [b]	15.29	155.00 ±11.21 [a]	27.30
Fe	1.88 ±0.11 [c]	1.98 ±0.20 [bc]	5.19	2.12 ±0.09 [b]	12.77	2.35 ±0.15 [a]	25.00
Zn	0.91 ±0.08 [a]	0.90 ±0.03 [a]	-1.21	0.89 ±0.05 [a]	-2.42	0.85 ±0.04 [a]	-6.59
Na	4.44 ±0.67 [c]	4.91 ±0.56 [bc]	10.59	5.33 ±0.31 [ab]	20.05	6.25 ±0.41 [a]	40.77
Mn	1.02 ±0.03 [a]	1.03 ±0.02 [a]	0.98	1.03 ±0.01 [a]	1.08	1.05 ±0.03 [a]	3.14
Cu	0.68 ±0.01 [a]	0.67 ±0.03 [a]	-1.91	0.65 ±0.02 [a]	-3.82	0.63 ±0.01 [a]	-7.65
Se	0.004 ±0.00 [b]	0.0043 ±0.00 [b]	7.50	0.0046 ±0.001 [b]	15.00	0.0052 ±0.001 [a]	30.00

*Each value represents the mean of three replicates ±SD. Means with the superscript letters in the same raw were significantly different at $p \leq 0.05$.

It activates enzymes and maintains blood pH within a standard range, regulating the normal operations of nerves and muscles, including cardiac functions, and serves as a fundamental component of genetic material, being part of DNA, RNA, and ATP, the primary energy source for the body (Food and Nutrition Board/Institute of Medicine, 1997). On the other side, mixing DSP leads to an increase in the levels of some trace metals in composite flours including Fe, Se and Mn. All of these trace elements are essential to human health, playing crucial roles in the prevention and management of various diseases, including anemia, immunodeficiency, cancer, and atherosclerosis (Nielsen, 2000; Lipinski, 2005; Gharib *et al.*, 2022a and Elhassaneen *et al.,* 2023). Iron (Fe) primarily functions as a vital component of hemoglobin in erythrocytes, facilitating the transportation of oxygen from the lungs to the tissues throughout the body (Gharib *et al.,* 2022b). Furthermore, it is essential for the synthesis of deoxyribonucleic acid and significantly contributes to the overall functionality of the human immune system (Abbaspour *et al.,* 2014). Selenium (Se) serves a critical biological function as a cofactor for the reduction of antioxidant enzymes, including glutathione peroxidases and specific forms of thioredoxin reductase found in both animals and certain plants. The glutathione peroxidase enzyme family (GSH-Px) catalyzes reactions that eliminate reactive oxygen species (ROS), such as hydrogen peroxide and organic hydroperoxides (Schroeder *et al.,* 1970 and Elhassaneen *et al.,* 2024 a,b). Manganese (Mn) plays a significant role in lipid and lipoprotein metabolism and is involved in the pathogenesis of atherosclerosis, along with several other cardiovascular diseases (Li and Yang, 2018).

Bioactive compounds and dietary fiber content in wheat flour composite:

Table (5) showed the bioactive compounds and dietary fiber content in wheat flour mixed with Khalas date seed powder (DSP)**.** Such data indicated that the mixing of DSP (5-20%) with wheat flour leads to an increase all the assayed bioactive compounds except phytates. The rate of increase in all assayed bioactive compounds as the result of DSP mixing levels were recorded in a dose-response manner. By the 20% of DSP mixing level to wheat flour, the total phenolics, total carotenoids, total flavonoids, lutein, polysaccharides, terpenoids, triterpenoids, tannins, saponin and dietary fibers were increased by the rates of 3440.54, 10.40, 1667.56, 750.25, 1552.34, 2416.33, 3275.61, 4394.12, 6083.58 and 120.52%, respectively. In general, wheat flour mixed with the DSP is rich in all assayed bioactive compounds. All of these bioactive constituents play important roles in applications of food processing and human nutrition. Phenolics, flavonoids, and carotenoids have key biological functions in preventing and/or treating a variety of illnesses, including diabetes, cardiovascular disease, atherosclerosis, cancer, obesity, bone, anemia, and aging. The preceding effects of these chemicals are mostly attributable to their magical biological/antioxidant activities, which include powerful antioxidant effects, anti-inflammatory capabilities, and vasodilation (Elhassaneen & Sanad, 2009; Elhassaneen *et al.,* 2016 a,c, 2019, 2020, Abdelaal *et al.*, 2021; Gharib *et al.,* 2022a and Gad Alla, 2023). Polysaccharides are used as thickening and gelling agents, and emulsion stabilizers as well as exhibiting several biological activities including anticoagulant, antithrombotic, anti-inflammatory, anti-obesity, antiviral, anti-osteoporosis, antioxidant, hypocholesterolemic, hypolipidemic and antimicrobial activities (Burtin, 2003; Fitton, 2003; Fitton *et al.,* 2008; Bixler & Porse, 2011; El-Gamal, 2020; Abdelaal *et al.,* 2021; Elhassaneen *et al.,* 2020; 2021; 2023 and Gad Alla, 2023). Tannins exhibited antimicrobial, anti-inflammatory, antidiabetic, cardioprotective, antitumor, and antioxidant effects (Rajak *et al.*, 2023). It is utilized as a food preservative and packaging material in the food industry (Chung *et al.,* 1998 and Tong *et al.,* 2022). Terpenoids in composite wheat flour can offer a diverse range of potential health benefits. For example, saponins, amphipathic nature makes them active as surfactants with the potential to interact with elements of cell membranes, such as cholesterol and phospholipids, making them potentially valuable for the development of cosmetics and medications (Timilsena *et al.,* 2023). Also, saponins lower cancer risks, blood glucose response, and blood lipid levels in the body (Akpoghelie *et al.,* 2022). Triterpenoids, including ursolic acid, can act as precursors for the development of more potent bioactive derivatives, such as investigational antitumor agents (Ma *et al.*, 2005). Additionally, dietary fibers (DF), which increase in wheat flour due to DSP mixing, enhance human health by promoting a favorable intestinal environment that supports the proliferation of intestinal microflora, including probiotic strains, thus categorizing them as prebiotics (Camire *et al.*, 1993). Furthermore, Elbasouny *et al.* (2019) noted that these fibers are predominantly insoluble and possess the ability to bind bile acids. This binding of bile acids is thought to be one of the mechanisms through which specific dietary fiber sources contribute to the reduction of plasma cholesterol levels.

Table 5. Bioactive compounds content of control and composite wheat flour

Component	Wheat flour (WF, 85%) Value	Composite wheat flour					
		DSP (5%)		DSP (10%)		DSP (20%)	
		Value	% of change	Value	% of change	Value	% of change
Total phenolics (mg gallic acid.100 g^{-1})	5.23 ± 0.11 [d]	51.47 ± 2.02 [c]	884.03	101.70 ± 1.76 [b]	1844.55	185.17 ± 2.11 [a]	3440.54
Total carotenoids (mg catechin.100 g^{-1})	3.27 ±0.09 [b]	3.38 ± 0.12 [ab]	3.36	3.51 ± 0.21 [a]	7.34	3.61 ± 0.30 [a]	10.40
Total flavonoids (mg RE.100 g^{-1})	2.54 ±0.05 [d]	19.98 ± 1.21 [c]	686.61	37.72 ±1.19 [b]	1384.96	44.90 ± 2.04 [a]	1667.56
Lutein (µg.100 g^{-1})	2.01 ±0.07 [d]	5.98 ±1.03 [c]	197.51	9.88 ± 1.23 [b]	391.54	17.09 ± 0.87 [a]	750.25
Polysaccharides (mg starch.100 g^{-1})	10.32 ± 1.02 [d]	49.39 ± 2.31 [c]	378.59	89.42 ± 3.29 [b]	766.48	170.52 ± 4.28 [a]	1552.34
Terpenoids (mg linalol.100 g^{-1})	0.98 ± 0.21 [c]	6.43 ± 0.32 [c]	556.43	12.09 ± 1.20 [b]	1133.67	24.66 ± 1.87 [a]	2416.33
Triterpenoids (mg ursolic acid.100 g^{-1})	0.41 ± 0.04 [b]	3.58 ± 0.72 [ab]	774.27	6.90 ± 1.21 [a]	1582.93	13.84 ± 2.09 [a]	3275.61
Tannins (mg catechine equivalent .100 g^{-1})	0.68 ±0.06 [d]	6.72 ± 0.45 [c]	888.24	17.34 ±2.76 [b]	2450.00	30.56 ± 3.17 [a]	4394.12
Saponin (mg .100 g^{-1})	0.67 ±0.07 [d]	10.96 ± 1.34 [c]	1535.82	21.57 ± 2.19 [b]	3119.40	41.43 ± 3.17 [a]	6083.58
Phytates (mg .100 g^{-1})	386.24 ±12.54 [a]	367.54 ± 11.87 [ab]	- 4.84	339.85 ± 8.54 [b]	-12.01	305.15 ± 9.04 [c]	-20.99
Dietary fiber (mg .100 g^{-1})	6.58 ±0.60 [c]	8.78 ±0.45 [b]	33.43	11.04 ±1.05 [ab]	67.78	14.51 ±1.38 [a]	120.52

*Each value represents the mean of three replicates ±SD. Means with the superscript letters in the same raw were significantly different at $p \leq 0.05$.

Additionally, high intake of DF has a positive influence on blood glucose profile and it is related to health complications, by altering the gastric emptying time and affecting the absorption of other simple sugars (Chandalia *et al.*, 2000 and Al-Weshahy & Rao, 2012). On the other side, the major concern about the presence of phytate in the diet is its negative effect on mineral uptake. Minerals of concern in this regard would include Zn^{2+}, $Fe^{2+/3+}$, Ca^{2+}, Mg^{2+}, Mn^{2+}, and Cu^{2+} (Lönnerdal, 2002 and Lopez *et al.*, 2002). Also, a negative effect of phytates on the nutritional value of protein was reported (Cheryan and Rackis, 1980). Finally, increasing the different bioactive constituents in wheat flour mixed with DSP could play important roles in applications of human nutrition as functional foods.

DPPH radical scavenging activity of aqueous control and composite wheat flour extracts:

Data in Figure (1) and Table (6) showed the free radical scavenging activity (RSA, %) of the aqueous control and composite wheat flour extract and standard (BHT). From such data, it could be noticed that DSP possessed the highest scavenging activity while wheat flour samples exhibited the lowest one. As the concentration of DSP increased to 20%, the RSA values in the samples demonstrated a statistically significant enhancement ($p \leq 0.05$) when compared to the control sample (wheat flour). At a concentration of 100 µg/mL, the RSA values for WF, DSP, WF+5% DSP, WF+10% DSP, and WF+20% DSP were recorded at 28.90, 83.54, 42.20, 47.99, and 57.02%, respectively, while the standard BHT exhibited an RSA of 90.89%. For the IC50 values, WF+5% DSP, WF+10% DSP, and WF+20% DSP were noted at 10.63, ND, 123.75, and 25.63 µg/mL, respectively, with the IC50 of BHT (the standard) being 8.13 µg/mL. The free radical scavenging efficacy of the various tested samples in relation to the standards is ranked as follows: standard (BHT) > WF+5% DSP > WF+10% DSP > WF+20% DSP > WF.

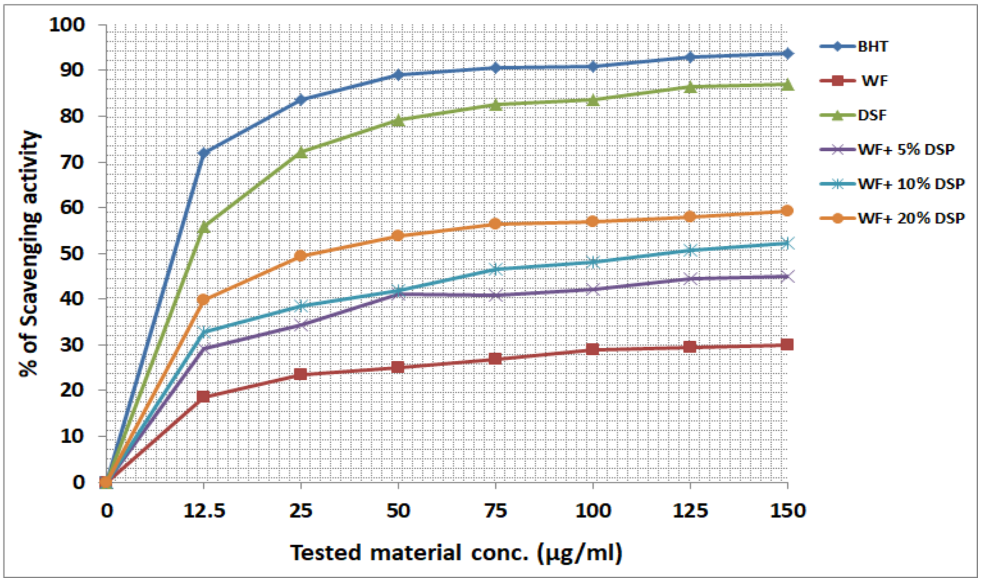

Figure 1. DPPH radical scavenging activity (%) of control, composite wheat flour and standard (BHT). Each value represents the mean value of three replicates.

Table 6. IC_{50} (DPPH) of control, composite wheat flour and standard (BHT)*

Tested Material	Butylated hydroxytoluene (BHT)	Wheat flour (WF)	Date seed powder (DSP)	WF+ 5% DSP	WF+ 10% DSP	WF+20% DSP
IC_{50} (µg/mL)	8.13±0.09 [d]	ND	10.63±0.46 [c]	ND	123.75±1.11 [a]	25.63±1.08[b]

*Each value represents the mean of three replicates ±SD. Values with different superscript letters in the same raw are significantly different at p≤0.05.

Numerous studies have confirmed the successful application of the DPPH method for assessing the antioxidant properties and oxidative stability of various plant components, including date seeds (Aminzare *et al.*, 2019; Abdelaal *et al.*, 2021; Elhassaneen *et al.*, 2021, 2023 and Gad Alla, 2023). Various researchers have noted that the scavenging activity against free radicals is crucial in mitigating the detrimental effects of free radicals in a range of diseases, including obesity, cancer, cardiovascular disorders, diabetes, anemia, neurological conditions, and pulmonary diseases (Elbasouny *et al.*, 2019; Elhassaneen *et al.*, 2021; Abdelrahman, 2022; El-Hawary, 2022; Fayez, 2022; Gharib *et al.*, 2022b; Elhassaneen *et al.*, 2023 and Gad Alla, 2023). The findings from this investigation indicate that the combination of wheat flour with date seeds exhibited free radical scavenging capabilities, likely attributable to their substantial concentrations of various classes of bioactive compounds, including phenolics, carotenoids, flavonoids, polysaccharides, terpenoids, tannins, etc. Such compounds attack free radicals, which in turn delays the development of unpleasant flavors, retards lipid oxidation, and enhances color stability (Aminzare *et al.*, 2019). In addition, the use of DSP could provide many health benefits, such as antigen toxic activity; anti-inflammatory activity; protection against diabetes, liver diseases, and gastrointestinal disorders; and reduction of plasma triglycerides and total cholesterol levels (Rahmani *et al.*, 2014; Al-Rasheed *et al.*, 2015; Kchaou *et al.*, 2016 and Al-Alawi *et al.*, 2017).

Physical properties of date seed powder and wheat flour:

Data in Table (7) shows the WHC and OHC of DSP compared to wheat flour. Such data indicated that DSP recorded higher WHC and OHC being 7.96 ± 0.32 g $H_2O.g^{-1}$ and 4.89 ± 0.20 g $oil.g^{-1}$, respectively than wheat flour which recorded 6.74± 0.11 g $H_2O.g^{-1}$ and 2.41 ± 0.19 g $oil.g^{-1}$, respectively. Such data are in accordance partially with several authors who reported that the plant parts have high WHC is mainly attributed to high fiber content (Mashal, 2016; Sayed Ahmed, 2016 and Aly & Sadeek, 2018).

Table 7. Physical properties of date seed powder and wheat flour

Parameters	Date seed powder (DSP)	Wheat flour (WF, 85%)
Water holding capacity (WHC, g $H_2O.g^{-1}$)	7.96 ± 0.32 [a]	6.74± 0.11[b]
Oil holding capacity (OHC, g $oil.g^{-1}$)	4.89 ± 0.20[a]	2.41 ± 0.19 [b]

Each value represents the mean of three replicates ±SD. Mean values with different superscript letters in the same row were significant different at p≤0.05.

The higher WHC recorded in DSP could be attributed to the higher fiber content which holds more water compared to wheat flour. In a similar study, Ashoush and Gadallah (2011) reported that mango peel powder was higher than that mango kernel powder being 5.08 and 2.08 g water/g, respectively indicating that the higher fiber content in mango peel powder holds more water compared to mango kernel powder. Also, this observation agrees with that reported by several authors applied with different plant parts including potato peels, brown algae, prickly pear etc., (Ajila *et al.*, 2010; Elhasssaneen *et al.*, 2016a,b; Mashal, 2016; Aly & Sadeek, 2018 and Fayez, 2022).

Effect of DSP mixing on the rheological parameters of wheat flour bread:

1. Farinograph parameters:

Data in Table (8) and Figure (2) showed all farinograph parameters of wheat and wheat flour mixing with DSP. The addition of DSP to dough enhanced water absorption, arrival time, dough development time, dough stability, and farinograph quality number by 9.38 to 40.94, 13.67 to 102.88, 2.01 to 28.92, 4.99 to 52.91 and 5.43 and 21.81%, respectively. Thus, the rate of increase in all farinograph parameter levels was exhibited in a dose-dependent manner. Such data are in accordance partially with that obtained by Aly and Sadeek (2018) who reported that the incorporation of plant powder other DSP i.e. quinoa powder by 10 and 20% in dough increased its all farinograph parameters for cake dough. Also, Sayed-Ahmed (2016) discovered that the addition of plant-derived by-products, specifically 5% of potato peel, cauliflower, onion, and mango peel powder, into dough resulted in enhanced water absorption. This increase in dough water retention can be attributed to the elevated dietary fiber content present in the by-products, which significantly differed from the control. The elongation of dough development time and stability with a 5-20% incorporation of these by-products can be linked to their substantial dietary fiber and pectin content, functioning as food hydrocolloids. Dough stability serves as a critical parameter for assessing dough strength. The integration of these by-products into flour samples demonstrated considerably extended stability periods compared to the control samples (wheat flour). This effect was notably pronounced with the addition of 5 to 20% of the by-products to the wheat flour. Such an outcome may be ascribed to the influence of by-product incorporation on the protein quality and dietary fiber content of the flour, particularly regarding its binding properties (El-Sheikh, 1999; Elhassaneen *et al.*, 2016c; Mashal, 2016; Aly & Sadeek, 2018 and Swilm, 2022). Ultimately, the farinograph quality number (FQN) of the dough exhibited a statistically significant variance between the control sample and the dough containing 5–20% of the by-products.

Table 8. Farinograph parameters of the control and composite wheat flour

Treatment	Water absorption (WA, %)	Arrival time (AT, min)	Dough development time (DDT, min)	Dough stability (DS, min)	Farinograph quality number (FQN)
Control wheat flour (CWF)	41.45 ±1.23 [c]	1.39 ±0.09 [c]	2.49 ±0.12 [c]	3.61±0.22 [c]	129 ±3 [c]
CWF + 5% DSP	45.34 ±2.43 [bc]	1.58 ±0.06 [bc]	2.54 ±0.11 [bc]	3.79 ±0.30 [bc]	136 ±2 [bc]
CWF + 10% DSP	51.97 ±3.09 [ab]	1.92 ±0.04 [ab]	2.78 ±0.13 [ab]	4.12 ±0.41 [b]	145 ±1.0 [b]
CWF + 20% DSP	58.42 ±2.54 [a]	2.82 ±0.03 [a]	3.21 ±0.29 [a]	5.52 ±0.33 [a]	157 ±4.0 [a]
As a percent of control (%)					
Control wheat flour (CWF)	0.00	0.00	0.00	0.00	0.00
CWF + 5% DSP	9.38	13.67	2.01	4.99	5.43
CWF + 10% DSP	25.38	38.13	11.65	14.13	12.40
CWF + 20% DSP	40.94	102.88	28.92	52.91	21.71

Each value represents the mean of three replicates ±SD. Mean values with the different letters in the same column are significantly different at level p≤0.05. CWF, (Control wheat flour); DSP, Date seed powder.

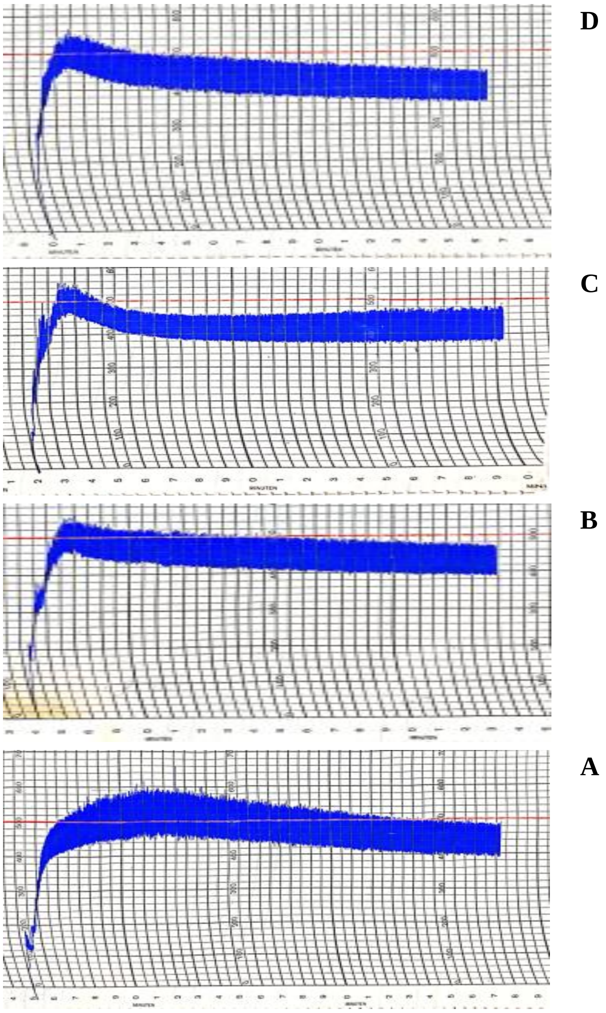

Figure 2. Farinograph parameters of the control and composite wheat flour. A: CWF (Control wheat flour); B: CWF + 5% DSP; C: CWF + 10% DSP; D: CWF + 20% DSP; DSP: Date seed powder.

This indicates an enhancement in dough quality following the incorporation of the by-products, as evidenced by a notable increase in the FQN value relative to the control sample.

2. Extensograph parameters:

Data in Table (9) and Figure (3) showed all extensograph parameters of wheat and wheat flour mixing with DSP. Mixing DSP into dough increases extensibility, relative resistance to extension, proportionate number, and energy. The rate of increase in all extensograph parameters levels was exhibited in a dose-dependent manner. Such data are in partial accordance with that reported Aly and Sadeek (2018) who reported that the mixing of quinoa powder in dough increased all extensograph parameters. Also, Sayed-Ahmed (2016) reported the mixing of plant parts by-products (potato peel, onion skin and cauliflower leaf powder) in dough increased all parameters by different rates. Furthermore, the influence of quinoa powder on enhancing the extensibility of wheat flour can be attributed to the modification of viscosity, which in turn impacts the gluten network (Abdel Hamid *et al.*, 1986). In addition, multiple studies have indicated that various plant by-products, including potato and onion peels, cauliflower leaves, and prickly pear peel, exhibit antioxidant properties that effectively inhibit the oxidation process, a factor known to reduce dough extensibility (Elhassaneen *et al.*, 2016a,b; Mashal, 2016; Sayed Ahmed, 2016 and Aly *et al.*, 2017). Lastly, data derived from rheological investigations has suggested that to elevate the quality of baked goods such as bread, the incorporation of DSP at levels of up to 20% into the dough is advisable.

Table 9. Extensograph of the control and composite wheat flour

Treatment	Extensibility (mm)	Relative resistance to extension (BU)	Proportional number	Energy (cm^2)
Control wheat flour (CWF)	152.33±2.98 [c]	463.25±7.10 [c]	2.29±0.09 [b]	95±2 [c]
CWF + 5% DSP	162.24±1.90 [b]	490.59±5.67 [bc]	2.62±0.06 [ab]	108±3 [b]
CWF + 10% DSP	170.76± 3.11 [ab]	504.33±4.61 [b]	2.94±0.11 [a]	118±3 [ab]
CWF + 20% DSP	178.38±2.65[a]	521.97±2.95 [a]	3.16±0.13 [a]	126±4 [a]
		As a percent of control (%)		
Control wheat flour (CWF)	0.00	0.00	0.00	0.00
CWF + 5% DSP	6.51	5.90	14.41	13.68
CWF + 10% DSP	12.10	8.87	28.38	24.21
CWF + 20% DSP	17.10	12.68	37.99	32.63

Each value represents the mean of three replicates ±SD. Mean values with the different letters in the same column are significantly different at level p≤0.05. CWF, (Control wheat flour); DSP, Date seed powder.

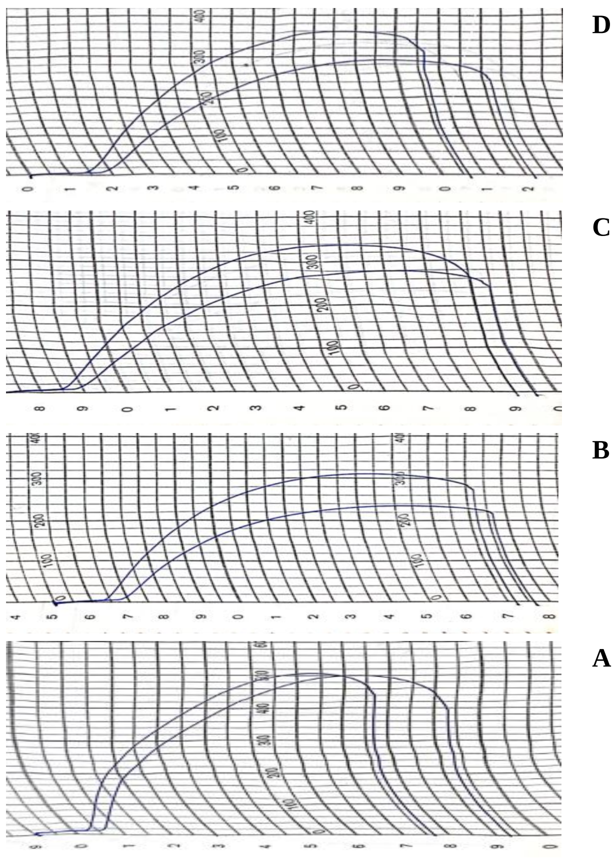

Figure 3. Extensograph parameters of the control and composite wheat flour. A: CWF (Control wheat flour); B: CWF + 5% DSP; C: CWF + 10% DSP; D: CWF + 20% DSP; DSP: Date seed powder.

Sensory evaluation of Balady bread incorporated with DSP:

The outcomes of the sensory assessment of Balady bread integrated with DSP, concerning attributes such as appearance, color, texture, flavor, mouthfeel, and overall acceptability, are presented in Table (10) and Figure (4). No statistically significant differences were observed in color, taste, flavor, mouthfeel, and overall acceptability between the control and DSP-enhanced Balady bread at the 5% and 10% incorporation levels. However, at the higher DSP incorporation level of 20%, the sensory evaluation parameters yielded slightly significant results

($p \leq 0.05$). In a related study**,** Broyart *et al.* (1998) indicated that the initial acceptance of baked goods is significantly affected by color, which may also serve as an indicator of the baking process's completion. The preferred color of bread is primarily a result of the Maillard browning reaction occurring during baking. Nevertheless, in DSP-fortified Balady bread, the color may also be partially attributed to the phenolic compounds and carotenoids present in DSP, which contribute a yellowish/brownish hue to the final product.

Table 10. Sensory evaluation of Balady bread incorporated with DSP

Treatment	Crust appearance	Crust colour	Texture	Taste and Flavor	Mouth feel	Overall acceptability
Control Balady bread (CBB)	9.12±0.21[a]	8.51±0.51 [a]	8.43±0.19 [a]	8.92±0.17 [a]	9.14±0.08 [a]	9.19±0.24 [a]
CBB + 5% DSP	9.01±0.14 [ab]	8.40±0.39 [a]	8.20±0.24 [a]	8.85±0.10 [a]	8.77±0.12 [ab]	9.02±0.44 [a]
CBB + 10% DSP	8.03±0.30 [b]	7.85±0.35 [ab]	7.85±0.18 [ab]	8.73 ±0.24 [a]	8.48±0.28 [b]	8.63±0.39 [ab]
CBB + 20% DSP	7.78±0.42 [b]	7.77±0.47 [b]	7.04±0.25 [b]	8.65±0.34 [a]	8.19±0.29[c]	8.13±0.39 [b]

[*] Each value represents the mean of ten replicates ±SD. Mean values with the different letters in the same column are significantly different at $p \leq 0.05$. CBB, (Control Balady bread); DSP, Date seed powder.

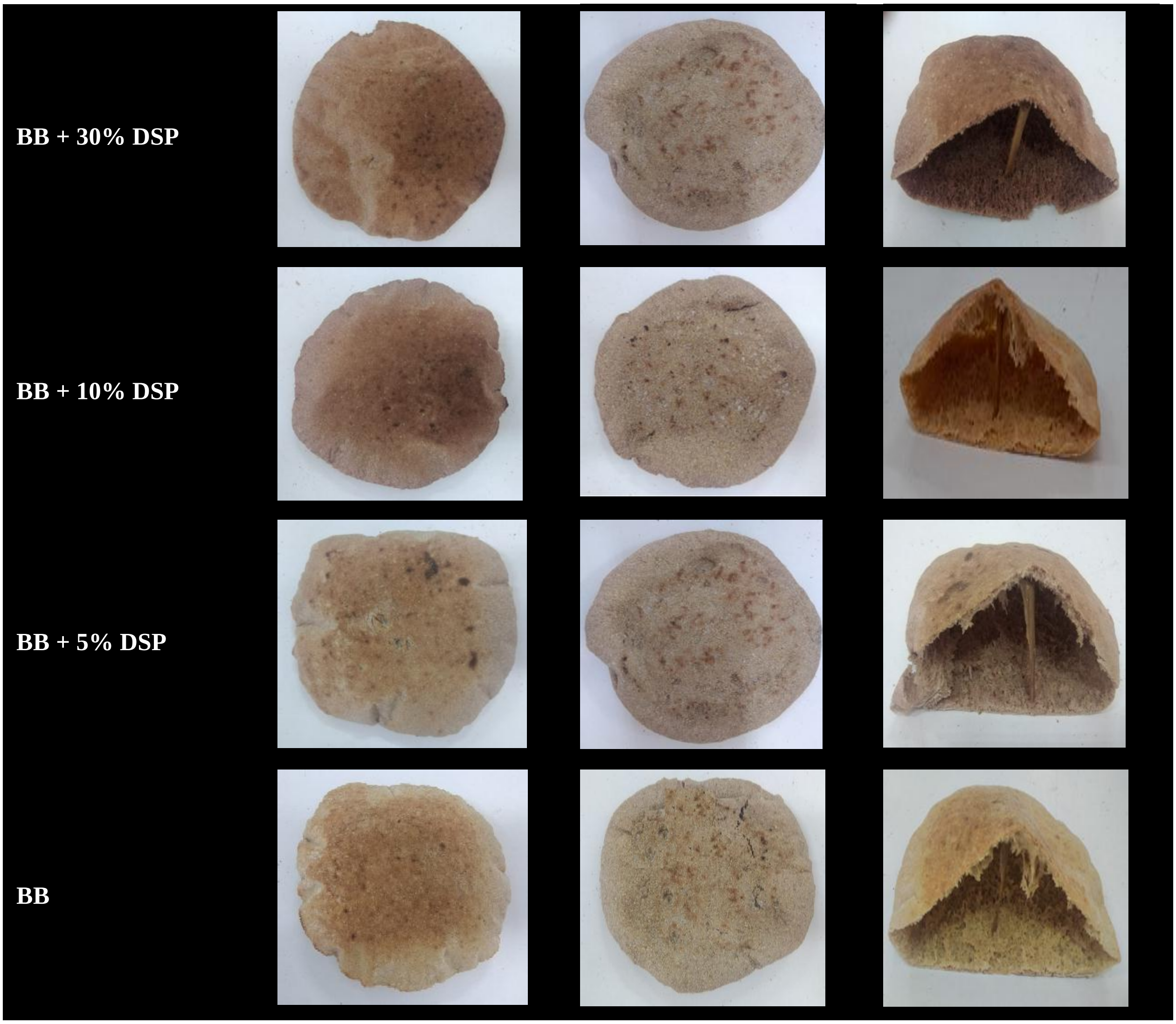

Figure 4. Photos of Balady Bread (BB) mixed with date seed powder (DSP)

Comparable findings were reported by Brannan *et al.* (2001), who noted that an increase in flour leads to greater visual lightness in muffins, characterized by more yellowness and brownness rather than being dark or yellow-green, resulting in higher scores for aroma, texture, and color acceptability. Furthermore, no significant differences were detected in taste and flavor between the control and DSP-infused bread, likely due to the nature of DSP not imparting any distinct flavor. Additionally, there was no significant difference in overall acceptability among the control and DSP-enhanced breads up to the 10% level, which may be attributed to the close similarity in color and taste/flavor to commercially available bread types, such as bran wheat bread.

Data of the sensory evaluation with the chemical, physical and biological properties of the bread incorporated with DSP recommended for the use of such products as an important functional food and could be potentially applied to many therapeutic nutrition applications.

CONCLUSION

The chemical analysis of DSP indicated that it serves as an excellent source of protein, dietary fibers, minerals, energy, and various categories of bioactive compounds. The integration of DSP with Balady bread flour enhanced the rheological properties of the dough, including farinograph and extensograph parameters, thereby improving their baking characteristics. Balady bread samples fortified with DSP exhibited elevated levels of dietary fiber, minerals, and total bioactive compounds compared to the control bread. Moreover, the increase in bioactive compounds within the bread samples resulted in significant enhancements in their biological activities, such as antioxidant and scavenging properties. The incorporation of DSP into Balady breads up to 20% did not substantially affect their quality or sensory evaluation parameters.

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الملخص العربي

تاثير خلط مسحوق نوى التمرمع دقيق القمح على الخواص الريولوجية ومحتوى المغذيات والمركبات النشطة بيولوجيا والنشاط المضاد للأكسدة للخبز البلدى المصرى

نيفين سيوفى اسماعيل، يوسف عبد العزيز الحسانين، هبة مصطفى الخولي

تهدف الدراسة الحالية إلى تحديد التركيب الكيميائي والتقييم الغذائي ومحتوى المركبات النشطة بيولوجيًا لمسحوق نوى تمر الخلاص (DSP). كما أن التطبيق في تصنيع الخبز البلدي المصري عن طريق استبدال دقيق القمح جزئيًا بمسحوق نوى التمر الخلاص سيكون ضمن نطاق هذا البحث. أوضحت النتائج أن محتويات الرطوبة والبروتين الكلي والدهون الخام والألياف الخام والرماد والكربوهيدرات الكلية في مسحوق نوى التمركانا ٨,١١ و ٦,٦٢ و٩,٠٣ و١٧,٣٥ و١,٧١ و ٥٧,١٨٪ على التوالي. كما أظهر تحليل المعادن لمسحوق نوى التمر أنه غني بالعديد من العناصر المختلفة حيث سجل البوتاسيوم أعلى مستوى يليه الفسفور والمغنيسيوم والكالسيوم والصوديوم والحديد والمنجنيز والنحاس والزنك والسيلينيوم. اما بالنسبة للمركبات النشطة بيولوجيًا في مسحوق نوى التمر، كانت المركبات الفينولية الكلية هي الأكثر وفرة، تليها السكريات المتعددة والفلافونويد والسابونين والتانينات والتربينويدات واللوتين والتراى تربينويدات والأنثوسيانين والكاروتينات. كما أدى خلط نوى الدقيق (٥–٢٠%) مع دقيق القمح إلى زيادة جميع المعادن التي تم تحليلها باستثناء الزنك والنحاس، وجميع المركبات النشطة بيولوجيًا باستثناء الفيتات ونشاط إزالة الجذور الحرة (النشاط االمضاد للاكسدة). بالنسبة للخواص الريولوجية، أدى دمج نوى التمر في العجين إلى زيادة جميع مقاييس الفارينوجراف بما في ذلك امتصاص الماء ووقت الوصول ووقت تطوير العجين واستقرار العجين ورقم جودة الفارينوجراف بمعدل ٩,٣٨ إلى ٤٠,٩٤ و١٣,٦٧ إلى ١٠٢,٨٨ و٢,٠١ إلى ٢٨,٩٢ و٤,٩٩ إلى ٥٢,٩١ و٥,٤٣ و٢١,٨١٪ على التوالي. كما زادت جميع مقاييس الإكستنسوجراف بما في ذلك قابلية التمدد والمقاومة النسبية للتمدد والعدد النسبي والطاقة. كما تم تسجيل معدل زيادة في جميع المركبات والمقاييس التي تم تحليلها نتيجة لخلط نوى التمر بطريقة الاستجابة للجرعة. وبناءا على تلك النتائج، يمكن أن يمثل مسحوق نوى التمر دورا استراتيجية هامة من خلال المساهمة في سد الفجوة الغذائية وتحسين معايير الجودة، كبديل جزئي للدقيق. لذلك، أوصت الدراسة الحالية بتضمين مثل هذا الناتج الثانوى (نوى التمر) في العديد من تطبيقات التصنيع الغذائى والتغذية العلاجية.

الكلمات المفتاحية: التركيب الكيميائي، المعادن، نشاط إزالة الجذور الحرة، الفارينوجراف، الإكستنسوجراف، التقييم الحسي.