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Enhancing Pan Bread Quality: Nutritional and Rheological Benefits of Partial Wheat Flour Replacement with Dahlia Tuber Powder (*Dahlia pinnata* L.)

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Abstract
This study investigates the potential of dahlia tuber powder (DTP) as a partial substitute for wheat flour in pan bread production, focusing on its nutritional, phytochemical, and rheological properties. The objective was to evaluate the effects of replacing wheat flour with 3%, 6%, 9%, and 12% DTP on the characteristics of the pan bread. Quantitative and qualitative analyses were conducted to assess the phytochemical content of DTP. The findings revealed that DTP is rich in essential nutrients, including ash, inulin, protein, and crude fiber. As the substitution level of DTP increased, significant enhancements in nutritional content were observed, with fiber, ash, and minerals such as calcium (Ca), potassium (K), phosphorus (P), iron (Fe), and zinc (Zn) increasing proportionately. Notably, pan bread samples containing DTP exhibited higher crude fiber and ash content while maintaining lower caloric values compared to control samples. Rheological assessments indicated improved dough stability and product conservation with DTP incorporation. However, specific volume decreased with higher DTP levels, particularly at the 12% substitution rate. Sensory evaluation revealed that pan bread with up to 9% DTP substitution was more acceptable compared to the 12% level. In conclusion, incorporating dahlia tuber flour into pan bread formulations not only enhances nutritional and rheological properties but also aligns with consumer preferences for healthier food options. Further research is recommended to explore the broader applications of DTP in various baked goods.
Keywords: Dahlia tuber powder, phytochemical contents, pan bread, mineral contents, rheological, physiochemical, sensory evaluation, Nutritional value.

Introduction

Bread is a staple food that is eaten worldwide **[1].** To avoid non-communicable diseases, customers are choosing to consume healthier foods these days. To enhance the diversity, accessibility, quality, and flavour of food goods like bread, markets and researchers are striving to improve technology for creating bread **[2]**. Spices and herbs are among the elements that could be utilized in bread manufacturing; these ingredients are important parts of human diets. They have been used to improve the flavour, colour, and scent of food as well as for medical purposes and as a preservative, antioxidant, and antibacterial since ancient times **[3].** Since cereals are a staple food for 95% of the population, they are thought to be the ideal fortification vehicle in developing nations. A staple food for most people, wheat flour accounts for over half of the total energy intake. All socioeconomic classes grow and eat cereals because they are relatively cheap **[4].** The genus Dahlia in the family *Asteraceae* contains 37 species; most of them are domesticated in Mexico **[5].** With over 20,000 types, ornamental plants are the most extensively disseminated in the globe when it comes to cut flowers and potted plants and using them as a structural element in garden design and building **[6, 7].** Nonetheless, evidence indicates that the plant's tuberous roots were utilized as a source of carbohydrates by prehistoric people, making them comparable to potatoes *(Solanum tuberosum* L.*)* **[8].** Currently, the prevalence of chronic illnesses, neurological disorders, cardiovascular disease, and certain types of cancer has increased due to the widespread consumption of foods high in calories but low in nutrition. **[8, 9, 10].**

Dahlia has been proposed as a source of inulin (with inulin content greater than 10%) for industrial production **[11].** Furthermore, dahlia inulin has been widely used in pharmacy as a drug carrier and as an adjuvant for vaccines **[12, 13].** Consequently, the extraction of inulin from dahlia tubers represents a real and significant area of research. Jerusalem artichokes, chicory, dahlias, and burdock roots are some examples of blooming plants that have high natural inulin content (15 g/100 g). Certain bacteria and fungi can also produce inulin **[14].** The inulin's degree of polymerization (DP) affects both its physiological properties and industrial processing of different forms **[15, 16].** The normal range of DP for inulin is 2 to 60. According to **[17],** long-chain inulin is characterized by having a mean DP value of no less than 23 (DP $\geq$ 23). The long-chain inulin solutions have more viscosity and durability than the solutions comprising each of the two types of inulin due to their DP being greater compared to solutions of short-chain and organic inulin. After high-speed shearing, a structure of gel with an even surface and homogenous particles starts to develop if the amount of long-chain inulin in the mixture is greater than 15g/100g. The emulsifying property of long-chain inulin with stable texture was regulated when it was added to food or medication, which significantly affected the rheological properties and changed the rheological properties of food products

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[18, 19, 20]. Inulin, a storage carbohydrate with a variety of nutritional and therapeutic applications, is one of the main components of dahlia tuberous roots **[6, 10].** According to **[21]**, it is a useful treatment for both acute and chronic intestinal diseases because of its prebiotic activity. Moreover, it raises the bioavailability of calcium and magnesium. Promising research suggests that it may help boost immunity, guard against digestive problems, and lower the risk of cancer. Additionally, its low-calorie content lowers the risk of high triglyceride concentrations and encourages the colon's healthy bacteria to grow **[7, 22].** A low-calorie ingredient called inulin enhances the nutritional value and rheological qualities of food. One of the most widely used methods nowadays for creating products that stand out for having ingredients that support health benefits is food fortification, which includes nutritious foods **[23].** Therefore, this study's goal was to evaluate how the rheological, physiochemical, and perceptual quality aspects of pan bread were affected when dahlia tuber powder (DTP) was substituted for wheat flour in different quantities.

Materials and Methods

Materials

Raw materials:

The tuber roots of *Dahlia pinnata* utilized in this study were procured from a commercial nursery located in El-Kantar El-Khayria, Al-Qalyubia government, Egypt. The Five Stars Co. Adabia in Suez, Egypt, provided 72% extraction of wheat flour. The following additional components were bought from the local market in Cairo, Egypt: instant active dry yeast, sugar (sucrose), shortening and salt (sodium chloride).

Chemicals:

All chemicals of analytical grade were supplied by El-Gamhouria Industrial Products and Drugs Company in Egypt, used in this study's analytical methods.

Methods:

Preparation of dahlia tuber powders:

The dahlia tuber powder was prepared using a modified version of **[24],** method. The goal of this step is to turn fresh dahlia tubers into flour so that they can be combined with other ingredients to make pan bread. To preserve the quality and consistency of the flour, the first step was to choose fresh dahlia tubers that were between six and eight months old. First, clean the fresh dahlia tubers with tap water to get rid of any remaining dust. Next, the tuber skin is peeled with a fruit peeler, and the tubers are sliced into slices with a traditional food slicer that has a thickness of ±1.5 cm. The resulting dahlia tuber slices were placed in salvers with holes and dried in an air oven with a motor fan for 10 to 12 hours at 50 to 55 degrees Celsius. Next, using a lab disc mill, the dehydrated flakes were ground until they were fine enough to pass through a 20-mesh sieve the same size as the wheat flour that was going to be blended. As directed by **[24],** the finished powders were sealed in polyethylene bags and kept dry at ambient temperature to prevent the absorption of moisture.

Preparation of wheat flour /Dahlia tuber powder (WF/ DTP) blends

Dahlia tuber powder (DTP) in the amounts of 0, 3, 6, 9, and 12% was used in place of wheat flour. After each flour mixture was separately mixed and homogenized, it was sealed tightly until needed; it was stored at room temperature in polyethylene bags. Table 1 displays the blended powders that were produced.

Table 1: displays the blended powders that were produced

Substitution level (%)	Blended flour used	
	WF	DTP
100:0	100.0	0.00
97:3	97.0	3.00
94:6	94.0	6.00
91:9	91.0	9.00
88:12	88.0	12.00

WF: Wheat flour **DTP:** Dahlia tuber powder

Processing of Pan Bread:

Pan bread is made with the straight dough method following the **[25]** method. Egyptian Baking Technology Centre-Adapted manufacturing techniques were used to process pan bread. Three, six, nine, and twelve percent DTP were used in place of some of the wheat flour (72% extraction) in the pan bread recipe. **Table (2)** displays the pan bread recipe.

Table (2): Ingredient recipe of the processed pan bread

Ingredients	Weight (g)
* WF or WF/ DTP blends	100
Salt (sodium chloride)	2.0
Sugar	2.0
Instant active dry yeast	1.50
Shortening	1.50
Water	according to the mixolab test

*** WF:** Wheat flour **DTP:** Dahlia tuber powder

Pan bread was prepared as follows: The bulk dough was let sit for ten minutes after the ingredients were mixed for six minutes, at which point it was manually rounded out by turning it twenty times. A baking pan (19.0 × 9.5 × 7.0) that had been freshly oiled was filled with 300 g of prepared dough. The dough was proven for eighty minutes in a cabinet set to thirty ± 0.5°C and eighty percent relative humidity. Next, it was roasted at 250 degrees Celsius for 20 minutes in an electric furnace

(Sveba Dahlen, Fristad, Sweden). The cooked pan breads were left to cool for an hour at room temperature before being measured. They were then put in bags made of polyethylene and left at room temperature so that additional testing and sensory evaluations could be done.

Physical and Chemical Analysis:

Within an hour of baking, each produced pan bread loaf's average weight (g) was measured. The loaf's overall volume (cm^3) was determined by applying the safflower displacement method as described by **[26]** and the particular amount (cm^3/g) was calculated utilizing the subsequent method by following the procedure of **[27]. Specific volume (cm^3/g)** = Loaf volume (cm^3)/Loaf weight (g).

Mass loss during baking: The pan bread's and the raw dough's physical characteristics were ascertained by **[27],** and the mass loss during baking (% LM) was computed using the following equation:

$$LM\ (\%) = \frac{M\ \text{dough} - M\ \text{bread}}{M\ \text{dough}} \times 100$$

Where: M bread and M dough represent the mass and weight of the dough and bread, respectively.

The techniques described by the **[28]** were employed to ascertain the constant weight, water content, ether extracts, ash, crude fiber material, and gross chemical components of all pan bread tested samples and the examined beginning flour (wheat flour, dahlia tuber powder, or DTP). Based on differences in each examined sample, the carbohydrates were calculated using the following formula:

% carbohydrates = 100- the sum of % (crude protein + ether extract + ash + crude fiber).

The chemical analysis results represented the mean of the outcomes obtained for each examined parameter in triplicate samples.

Theoretical calculation of energy: The following formula was used to determine the pan bread's energy values (calories kcal per 100 g) theoretically using the [29] method:

Energy value (kcal per 100 g) **= (**quantity of protein (g) ×**4**+ quantity of carbohydrate (g) × **4**+ quantity of lipids (g) × **9)**.

The caloric value of Inulin = 1.25 Kcal /g **[30].**

Determination of inulin content:

The approach put forth by **[31]** was followed in the quantification of its content.

Determination of tested minerals: -

In wheat flour, dahlia tuber powder, and pan bread samples, the following mineral concentrations were discovered: Following a 1:1 (v/v) HCl acid: water ratio immersion, the resulting ash was filtered and calibrated to 100 milliliters in a volumetric flask. The mineral contents of iron (Fe), calcium (Ca), magnesium (Mg), and zinc (Zn) were measured using the method described by **[28].** Technique utilizing a Perkin Elmer Atomic Absorption Spectrophotometer (Varian Inc., Palo Alto, CA, USA, Model 2380). A CORNING 400 flame photometer (series No. 4889, UK) was used to measure the potassium (K) content. **[28];** states that phosphorus was ascertained using a spectrum analyzer and the molybdovandate technique.

Qualitative estimation of phytochemicals

The phytochemical screening of dahlia tuber powder was completed using the techniques explained by **[32].**

Quantitative estimation of phytochemicals

1-Estimation of total phenolic acids

The Folin-Ciocaleau approach **[33],** was used to ascertain the amounts of phenolic acids found in dahlia tuber powder. 50 µL of phenolic extraction should be divided across many test tubes. Fill each test tube to the 1 mL-1 mark with pure water. Fill every test tube, including the blank, with 0.5 mL-1 of Folin-Ciocalteu reagent (1 N). Let it stand at room temperature for five minutes after that. Lastly, fill each test tube containing the blank with 2.5 mL-1 of Na_2CO_3 (5%). After that, leave it for forty minutes at ambient temperature in the dark. The standard used was gallic acid, which was diluted in methanol. A spectrophotometer was used to measure the calibration curve's OD725 nm absorbance.

2. Estimation of total flavonoids

Total flavonoids were measured using the method described by **[34].** The aluminum chloride approach was employed to ascertain the amount of flavonoid concentrations of dahlia tuber powder. A 500 µL amount of the extract was poured into several test tubes. Pour in enough distilled water to fill each test tube (one milliliter). After that, fill each tube with 150 µL of sodium nitrate (5%) and let it stand at ambient temperature for five minutes. 150 µL of 10% $AlCl_3$ should be added to each test tube, and the tubes should be left at ambient temperature for a total of six minutes. Fill each test tube with 2 mL-1 of 4% NaOH. Add 5 mL-1 of distilled water to the test tube's capacity. The experiment tubes were appropriately vortexed and then permitted to come to room temperature to air out for fifteen minutes. A spectrophotometer was used to measure the standard dissolved in methanol at 510 nm, and the calibration curve of rutin was employed.

3-Estimation of total saponins

The total saponins were measured using the protocol described below. Dahlia tuber powder (20 grams) was combined using 200 cc of 20% ethanol. The suspension was constantly stirred over a hot water bath for four hours to bring the temperature up to 55°C. After filtering the mixture, 200 milliliters of 20 percent ethanol were used to remove the residue once more. In a water bath, the two extracts together were heated to within ninety degrees Celsius and brought to a boil at 40 milliliters. The concentrate was moved to a 250-milliliter separating unit, and then a funnel containing 20 mL of the solvent diethyl ether (DEA) was added, along with vigorous shaking. The layer of ether was eliminated, and the layer of water was reinstated. It was an appointment for the cleaning process. Ten milliliters of 5% sodium chloride water were used to wash sixty milliliters of the basic butanol extracts twice. Our method for cooking the leftover solution was a water bath. After evaporation, the sample was dried in an oven to a consistent weight. A percentage was computed for the saponin content as described by **[35].**

Rheological properties testing:

[27] states that Mixolab (Chopin, Tripettet Renaud, Paris, France) carried out the rheological investigations of dough.

Table (3): Mixolab parameters used in Chopin + protocol

Settings	Values
Mixing speed	80 rpm
Dough weight	75 g
Tank temperature	30 °C
Temperature 1ed step	30 °C
Duration 1ed step	8 min
1ed temperature gradient	15 min – 4 °C /min
Temperature 2ed step	90 °C
Duration 2ed step	7 min
2ed temperature gradient	10 min – 4 °C /min
Temperature 3ed step	50 °C
Duration 3ed step	5 min
Total analysis time	45 min

The parameters displayed by a typical Mixolab curve are as follows:

Physical deterioration (Nm): Nm is the torque following a holding period at 30 °C; Nm is the torque distinction between C1.2 and C1.2; the variation in torque between C1.2 and C2 represents thermal weakening (Nm); The minimal torque generated Minimum consistency is achieved via dough passing under physical and thermal restrictions. (Nm); The pasting temperature (°C) is the temperature at which this increase in viscosity began; peak torque (Nm) = C3, the maximum torque produced during the heating stage; peak temperature (°C) equals the surrounding temperature at the viscosity peak; Following cooling to 50°C, the torque obtained is given by the following: After cooling to 50°C, the final torque (Nm) is equal to C5, the breakdown torque (Nm) is equal to C3 - C4, and the setback torque (Nm) is the torque difference between C5 and C4. Minimal torque (Nm) = C4.

Sensory evaluation of pan bread:

Twenty participants from Al-Azhar University's Faculty of Agriculture's Food Science and Technology Dept. and Egyptian Baking Technology Center, Giza, Egypt, evaluated the pan bread samples (control and different blends) after two hours of baking to determine consumer acceptance. According to **[36],** the tested pan brad samples were presented in a randomized manner, and each panelist was asked to indicate their preferences on several parameters, including shape, odor, taste, color (for crust and crumb), texture and overall acceptability of using a 9-point structured hedonic scale. The assessment was carried out in the afternoon, five hours after breakfast. Water was available for panelists to rinse their mouths following the evaluation of each sample during the panel test. Based on the acceptability of the pan bread samples to the senses, the best composite was determined.

Statistical analysis:

Three or more replicates of each experiment were conducted. Using an entirely random approach as outlined by **[37]**, the data was analyzed statistically utilizing the Statistics Package for Social Science
(SPSS) software (version 20.0, created by IBM Applications, Inc., Chicago, USA, 2018). Every result is shown as the average ± standard error (SE). The one-way analysis of variance (ANOVA) was used to conduct the statistical analysis at a significance level of 5%. Duncan then conducted repeated range tests ($p < 0.05$).

Results and Discussion

Proximate composition and caloric value of the raw materials:

The chemical composition of the analyzed samples is listed in Table **4.** Which included dahlia tuber powder (DTP) and wheat flour (72% ext.). According to the data obtained, the moisture content of dahlia tuber powder was 5.77 percent, and wheat flour was 11.14%. These findings are consistent with those of **[21, 38, 39].**

Table (4): Proximate composition of dahlia tuber powder (DTP) as compared with wheat flour

Compounds (g/100g)	Raw Material	
	WF	DTP
Moisture	11.14 ± 0.11^{a}	5.77 ± 0.15^{b}
Crude protein	10.12 ± 0.27^{a}	9.86 ± 0.19^{b}
Fat	0.75 ± 0.12^{a}	0.64 ± 0.23^{a}
Crude fiber	0.92 ± 0.17^{b}	5.65 ± 0.25^{a}
Ash	0.56 ± 0.09^{b}	6.23 ± 0.14^{a}
Carbohydrates	87.65 ± 0.52^{a}	37.79 ± 0.33^{b}
Inulin	ND	39.83 ± 0.16^{a}
Energy value (kcal/100g)	397.83 ± 0.22^{a}	246.14 ± 0.34^{b}

^{a,b,c} Means with different letters in the same row are significantly different ($P < 0.05$); **ND**: not detected. **WF:** Wheat flour **DTP:** Dahlia tuber powder

However, wheat flour had the highest crude protein content (10.12%) on a dry weight basis when compared to dahlia tuber powder (9.86%); these outcomes align with those of **[40, 41].** The lipid contents of DTP and wheat flour were 0.64% and 0.75%, respectively, according to dry weight. According to Table 4's data, the DTP had the highest crude fiber content (5.65%), while the lowest amount (0.92%) was discovered in wheat flour. It was also evident from the same Table that the ash content of DTP was approximately eleven times higher than that of wheat flour (0.56%). On a dry weight basis, it was discovered to be 6.23% in dahlia tuber powder. These findings align with those of **[40, 42].** However, the observed ash content of 6.23% in D. pinata is greater than what **[21]** found, that the ash content ranged between 2.86 and 4.29%. As can be seen from the results in the same Table, the main component in all tested samples was the amount of carbohydrates. This content was found to be higher in wheat flour (87.65%) and lower in dahlia tuber powder (37.79%). These results agree with the findings of **[42, 21]**.

Table **(4)** displays the inulin concentration, which was identified in dahlia tuber powder (DTP), which made up 39.83% of the sample, but was absent from wheat flour (WF). The outcomes from the studies conducted by **[22, 43, 44],** align with the present discoveries. Inulin at the roots of the dahlia plant ranges from 38% to 53%, as reported by **[31, 6, 22]**. The ability to maintain blood glucose levels makes it a desirable diet for diabetics, among many other benefits. Regarding the caloric value, based on the obtained data, it might be said that the calorie values differ noticeably from one another of dahlia tuber powder and wheat flour. The highest caloric value (kcal /100g) was found in wheat flour (WF), which had a caloric value of 397.83 kcal/100g as compared to dahlia tuber powder (246.14 kcal/100g). The results obtained here are consistent with those obtained by **[9, 5].** About this, it's vital to remember that dahlia tuber powder has a substantial amount of inulin (39.83%), which has a calorie content of 1.25 Kcal/g by nature, compared to 4.0 Kcal/g for carbohydrates. This could explain why dahlia tuber powder (DTP) has fewer calories than wheat flour **[30]**.A decent quantity of nutrients, such as dietary fiber, protein, ash, and inulin, can be found in dahlia tuber powder, based on the results of prior studies. Because of its low-calorie content and high fiber content, dahlia tuber powder has been shown to have protective effects against certain diseases **[9, 5].** It can also help prevent cancer and cardiovascular disease, improve digestibility in individuals with diabetes, lower blood lipid levels and reduce obesity **[31].** Moreover, dahlia tuber powder has a high nutritional value.

Minerals content (mg/100 g) on dry weight basis of the raw material flour used in prepared tested pan bread samples:

Major macro and microelements (bio-elements) such as calcium (Ca), magnesium (Mg), phosphorus (P), iron (Fe), and zinc (Zn) were determined for both WF and DTP. Table (5) presents an examination of the mineral concentration of the WF and DTP samples. According to the findings, the wheat flour had the lowest concentrations of iron (1.69 mg/100 g), zinc (0.98), phosphorus (168.35 mg/100 g), magnesium (96.54 mg/100 g) and calcium (49.20 mg/100 g). Consequently, the mineral content of wheat flour was less than that of the reference pattern from the recommended daily allowances **[45].** These results are in line with those of **[46],** who found that wheat flour had the following dry weight basis concentrations: 2.66 mg/100 g of iron, 41.76 mg/100 g of calcium, 87.92 mg/100 g of magnesium, and 2.15 mg/100 g of zinc.

Table (5): Mineral content (mg/100 g) on dry weight basis of the raw material flour used in prepared tested pan bread samples

Mineral content (mg/100g)	Raw Material		RDA* (mg/day)
	WF (mg/100g)	DTP (mg/100g)	
Macro elements			
Calcium (Ca)	49.20 ± 0.23^{b}	198.76 ± 0.34^{a}	**800-1200**
Phosphorus (P)	168.35 ± 1.19^{b}	262.83 ± 0.37^{a}	**800-1200**
Potassium (K)	134.77 ± 0.86^{b}	179.87 ± 0.22^{a}	**2000-4000**
Microelements			
Magnesium (Mg)	96.54 ± 0.16^{b}	261.77 ± 0.19^{a}	**280-350**
Zinc (Zn)	0.98 ± 0.11^{b}	3.25 ± 0.18^{a}	**10-12**
Iron (Fe)	1.69 ± 0.29^{b}	11.44 ± 0.24^{a}	**8-10**

^{a,b,c} Means with different letters in the same row are significantly different ($P < 0.05$)**;**

WF: Wheat flour **DTP:** Dahlia tuber powder *** Recommended Dietary Allowances of Minerals- [45]**.

Furthermore, it was clear from the same Table that, in comparison to wheat flour, DTP had the greatest mineral concentration. Phosphorus (P) was determined to be 262.83 mg/100g in DTP, whereas the concentrations of Mg, Ca, K, Fe, and Zn were 261.77, 198.76, 179.87, 11.44, and 3.25 mg/100g on a dry weight basis, respectively. These results agree with those of **[21],** who found that dahlia tubers had varying mineral contents. In comparison to wheat flour, the macro-element phosphorus (P) was found to have the highest content (262.83 mg/100 g), followed by calcium (198.76 mg/100 g) and potassium (179.87 mg/100 g). Within the microelements, magnesium was only found at high levels (261.77mg/100g), while the other elements, iron (Fe) and zinc (Zn), were presented in trace amounts (11.44 and 3.25 mg/100g), respectively.

The preliminary phytochemical screening of dahlia tuber powder

Table (6) illustrated that the preliminary phytochemical screening of dahlia tuber powder showed that phenols, tannins, flavonoids, saponins, carbohydrates, amino acids, glycosides, and quinine were present in dahlia tuber powder. While alkaloids, anthraquinone, phlorotannins, cardiac glycosides, sterols, and diterpenes were absent.

Table (6): Phytochemical screening of dahlia tuber powder

Tests	Dahlia tuber powder
Carbohydrates	+
Amino acids	+
Phenol	+
Tannins	+
Phlobatannins	-
Flavonoids	+
Saponins	+
Alkaloids	-
Glycosides	+
Quinone	+
Diterpenes	-
Sterols	-
Cardiac glycosides	-
Anthraquinone	-

(+) mean present, (-) mean absent.

Phytochemicals, also known as phytonutrients, are biologically active compounds found in plant-based diets. Although they are not essential for human survival since the body cannot produce them, recent research has highlighted their health-protective properties and the underlying mechanisms behind these benefits, particularly their antioxidant capacity. Polyphenols, the most abundant antioxidants in the diet, can be found in various foods and beverages, including tea, coffee, wine, fruits, vegetables, cereals, dry legumes, and chocolate **[47].** These compounds play a crucial role in maintaining overall health and well-being by neutralizing harmful free radicals and reducing oxidative stress in the body.

The available data indicates that polyphenols may have a part in preventing diabetes, neurological illnesses, and cancer in addition to helping to prevent cardiovascular disease and osteoporosis **[47].** Flavonoids are a diverse group of polyphenolic antioxidants that are mostly present in fruits, vegetables, tea, wine, and beer as O-glycosides. **[48].** A number of these metabolites are important for human nutrition, particularly when it comes to the prevention and management of different illnesses, because of their antioxidant, antiviral, anti-inflammatory, anti-pain, and anti-cancer potential.

Phytochemical constitutes of dahlia tuber powder

The total contents of phenolic acids, flavonoids and saponins are shown in Table **(7).** Flavonoids, phenolic acids, and saponins were found to be concentrated at 27.43±0.76 mg RT/g of dry weight, 6.58±0.59 mg GA/g of dry weight, and 0.62±0.12 mg /100 g of dry weight, respectively, according to the results.

Table (7): Quantitative of phytochemical compositions of dahlia tuber powder

Parameters	Units	Dahlia tuber powder
Total flavonoids	mg RTE /g	27.43
Total phenolic acids	mg GAE /g	6.58
Total Saponins	mg /100 g	0.62

Because some polyphenols, like tannins, have negative effects that affect protein and amino acid accessibility, absorption of minerals, and the activities of enzymes that break down food, nutritionists have historically seen polyphenols as anti-nutrients **[49]**. The discovery of certain polyphenols' antioxidant properties has recently refocused our understanding of the health advantages these substances offer **[50].** Dietary phenolics can be classified into three main groups: polyphenols (which include hydrolyzable and compressed tannins), phenolic compounds (which in turn include hydroxybenzoic and hydroxycinnamic acids) and flavonoids, which are the best-known group. Plants defend themselves against phenols that cause damage caused by oxidation. They have also been thoroughly investigated as putative guards of mammalian antioxidants **[51].** To potentially ameliorate diseases**, [52]** highlights the current interest in increasing the regular consumption of plant phenolic such as tannins and flavonoids, as well as minerals with antioxidant properties including the antioxidant vitamins C and E, b-carotene, and carotenoids. The inclusion of antioxidant phytonutrients in food presents a problem for the food business. Fruits, vegetables, seeds, flowers, and some beverages like wine, beer, soy beverages, and black and green teas contain flavonoids. These kinds of substances are therefore taken as supplements, though they can also be taken as part of a regular diet. In vitro, these compounds exhibit a range of biological activities, including the induction of programmed cell death as well as anti-oxidant and anti-inflammatory properties, which may account for their possible health-promoting qualities **[53].** The majority of the current focus on flavonoids as substances that promote health is attributed to their potent antioxidant capabilities.

Effect of substituted wheat flour with varying degrees of dahlia tuber powder (DTP) on the rheological characteristics of pan bread doughs:

A three-dimensional viscoelastic structure with gas-retaining properties is created during the initial mixing process because of the distribution of the material, disruption of the initially spherical protein particles, hydration of the flour compounds, and stretching and alignment of the proteins **[54, 55, 56].** The characteristics that define the first part of the mixolab curve are as follows: dough stability, dough growth (C1), dough absorbing of water (WA), the growth of the dough time, and C2 value. This segment is linked to the breakdown of proteins caused by physical and thermal constraints. The rheological characteristics of produced dough samples were evaluated using the Mixolab apparatus by partially replacing wheat flour with dahlia tuber powder in different ratios (3, 6, 9, and 12%). Table **(8)** and Figure **(1)** present the acquired data.

Table **(8)** and Figure **(1)** statistics show that the wheat flour utilized for the control sample had a moisture content of 10.4%. Other flour blends using dahlia tuber powder have a moisture content ranging from 10.7% to 11.3%. The proportion of water in the flour-blended samples increased from 3% to 12% after dahlia tuber powder was introduced to wheat flour **(Table 8).**

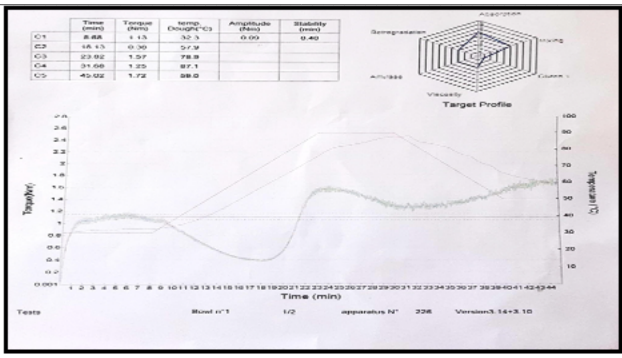
Table (8): Effect of partial replacement of wheat flour (WF) by different levels of dahlia tuber powder (DTP) on mixolab parameters.

Mixolab parameters		(Control)	Dahlia tuber powder substitution levels			
			3%	6%	9%	12%
Moisture content %		10.40	10.70	10.70	11.30	11.10
Water absorption %		59.10	55.60	52.50	49.80	45.80
Stability (min.)		8.48	9.70	10.72	12.15	11.97
Dough development (C1)	Formation time (min.)	5.68	6.53	5.60	8.87	1.62
	Torque (Nm.)	1.13	1.13	1.12	1.11	1.08
	Dough temperature (°C)	32.30	32.00	32.10	32.30	30.90
Protein breakdown (C2)	Formation time (min.)	18.13	17.83	19.55	20.35	20.73
	Torque (Nm.)	0.38	0.35	0.33	0.34	0.30
	Dough temperature (°C)	57.90	56.50	61.10	65.20	66.20
Starch gelatinization (C3)	Formation time (min.)	23.82	24.40	29.02	23.00	34.17
	Torque (Nm.)	1.57	1.59	1.60	0.67	1.64
	Dough temperature (°C)	78.90	79.90	85.40	75.40	83.10
Amylase activity (C4)	Formation time (min.)	31.68	33.13	33.05	30.00	34.48
	Torque (Nm.)	1.25	1.33	1.51	1.68	1.60
	Dough temperature (°C)	87.10	85.60	85.40	87.00	82.10
Starch gelling (C5)	Formation time (min.)	45.02	45.03	45.03	45.03	45.03
	Torque (Nm.)	1.72	1.86	1.94	2.59	2.20
	Dough temperature (°C)	59.00	58.60	58.40	58.80	56.80

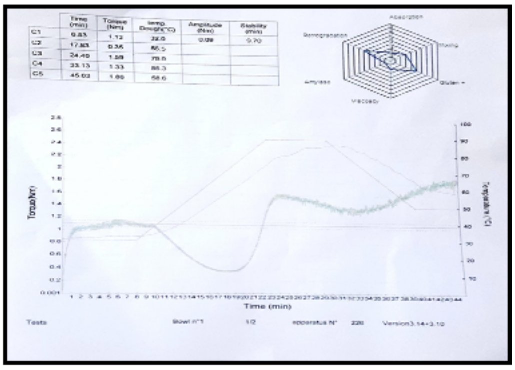
Based on the obtained results, it was possible to show that water absorption, in contrast to the reference sample, decreased from 55.6 to 45.8% and that it decreased gradually as the replacement of dahlia tuber powder (DTP) increased from 3 to 12% in pan bread dough. This outcome could be the result of a lower protein percentage in the dough as well as the fact that dahlia tuber powder (DTP) contains inulin rather than starch, even though starch and protein are typically associated with the pasting qualities of wheat flour. These findings are consistent with those of **[57],** who discovered that short-chain inulin had a greater impact on water absorption than long-chain inulin, most likely as a result of the lubricating properties of sugars and oligosaccharides **[58]**. Also discovered that the kind of inulin utilized had a substantial impact on the degree of decrease. These findings align with the findings of **[59].** The dough time for development (min) in blended samples, including dahlia tuber powder (DTP) rose as the replacement level was raised from 3 to 12%, as shown in Table (8) and Fig. (1). according to **[58].** The inulin content of these blends may be the reason for the delayed hydration rate and gluten development, which results in an extended dough development time.

The most significant indicator of dough strength is dough stability. Proteins lacking in sulfhydryl groups have been linked to dough stability; these proteins typically cause the dough to soften or degrade **[60].** When comparing the dough stability (min) of the blends to the control sample, which increased from 9.70 to 12.15 (min) as the level of DTP increased, it was evident from the previously obtained results of Table **(**8) and Fig. (1) That the dough stability (min) increased gradually as the partial replacement of DTP increased from 3 to 12% in blends. These findings, which are primarily attributable to DTP's higher inulin content, may increase dough stability as DTP addition levels in dough blend increase. When inulin was added to wheat flour, the resulting dough became stronger; this effect was more pronounced when the flour was weaker. These findings suggest that inulin might be able to partially substitute wheat flour without adversely affecting the quality of the dough, noticing this effect on dough strength**.** The data from **[58, 61]** coincide with the current findings.

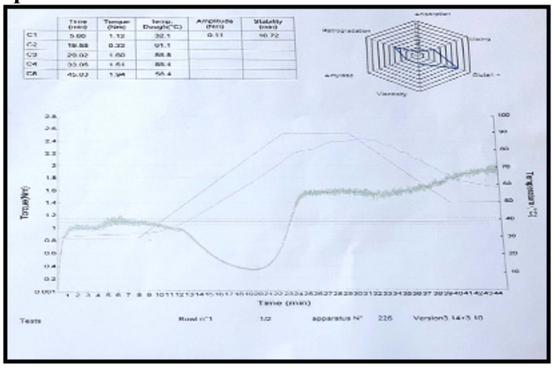
When comparing flour blends to the control sample, the amylase activity (C4) and starch gelling (C5) increased proportionately as the partial substitution of dahlia tuber powder (DTP) increased from 3 to 12%. On the other hand, the amount of starch gelling (C5) raised more between 1.86 and 2.59 (Nm) and the amylase activity (C4) raised gradually, going from 1.33 to 1.68 (Nm), as the rate of replacement elevated from 3 to 12% of DTP in the combines when compared to 1.25 and 1.72 (Nm) in the control sample.



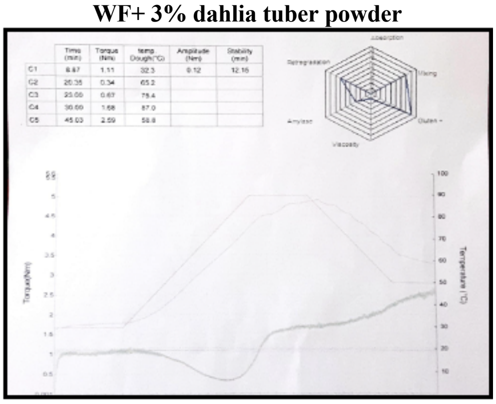
Control sample



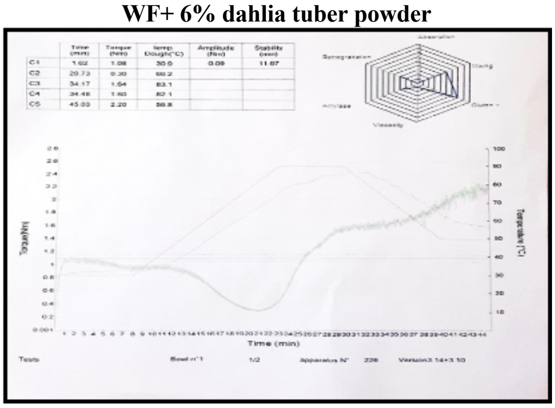
WF+ 3% dahlia tuber powder



WF+ 6% dahlia tuber powder



WF+ 9% dahlia tuber powder



WF+ 12% dahlia tuber powder

Fig. (1): Mixolab profiles of pan bread dough as affected by partial replacement of wheat flour by dahlia tuber powder (DTP).

Effect of replacement wheat flour with dahlia tuber powder (DTP) on pan bread sample quality criteria:

Chemical composition of pan bread

The results of the chemical structure analysis of pan bread prepared using wheat flour (72 ext.) as well as its blends—made with dahlia tuber powder (DTP) with replacement levels 3, 6, 9, and 12% of WF by DTP—are shown in Table **(9).**

Table (9): Chemical composition (%) of pan bread prepared by substituting wheat flour (WF) with dahlia tuber powder (DTP) (on dry weight basis)

Chemical Composition (%)	Control sample	Wheat flour substitution levels with DTP (%)			
		3%	6%	9%	12%
Moisture	35.61±0.17[c]	34.48±0.29[d]	35.76±0.29[c]	36.09±0.22[b]	37.31±0.32[a]
Crude protein	11.38±0.15[a]	11.07±0.19[b]	10.83±0.22[c]	10.76±0.21[c]	10.42±0.27[d]
Fat	2.26±0.14[a]	1.98±0.13[b]	1.87±0.16[b]	1.62±0.15[c]	1.40±0.13[d]
Crude fiber	0.93±0.11[e]	1.91±0.10[d]	2.38±0.19[c]	2.92±0.18[b]	3.80±0.11[a]
Ash content	0.87±0.17[d]	2.05±0.11[c]	2.13±0.25[c]	2.47±0.27[b]	3.19±0.29[a]
Carbohydrates*	84.56±0.23[a]	82.99±0.21[b]	82.79±0.18[b]	82.23±0.31[c]	81.19±0.41[d]
Energy value (kcal/100g)	404.10±0.34[a]	394.06±0.38[b]	391.31±0.54[c]	386.54±0.38[d]	379.04±0.23[e]

[a,b,c] Means with different letters in the same row are significantly different ($P < 0.05$); *Carbohydrates were calculated by difference.

When the closest content of the formulation, such as dahlia tuber powder (DTP) was compared from 3 to 12%, as indicated in Table (9), the proportions of crude fiber and ash were significantly (p <0.05) higher than the contents of the control sample. On the other hand, the protein, fat and carbohydrate content of the DTP-containing test samples dropped over time as the amount of dahlia tuber powder increased. These results corroborate those of **[40, 41],** who demonstrated that dahlia tuber has less protein than wheat flour in terms of both ether extract and protein.

Table (9) demonstrates that the crude fiber and ash content of the pan bread samples produced increased significantly (p <0.05) when varying doses of DTP were partially substituted for wheat flour as compared to the control sample. According to **[62]**, eating a high-fiber diet lowers the risk of developing cardiovascular disease, diabetes, obesity, and high blood pressure, among other conditions. As may be predicted, the control sample had the greatest amount of carbohydrates and the lowest levels of nutrients such as ether extract, fiber, and ash.

Table **(9)** illustrates how the pan bread samples with 3, 6, 9, and 12% of carbohydrates, respectively, showed a progressive decline in carbohydrates, reaching 82.99, 82.79, 82.32, and 81.19%, compared to 84.56% in the control sample. These results are consistent with those of **[63]** who found that raising the fiber or inulin content of wheat flour used to make pan bread reduced the amount of carbohydrates in the flour. compared to the samples used as controls, which had the smallest amounts of ash and crude fiber in the subject matter and the highest value of calories, Table **(9)** clearly shows that pan dough samples that included dahlia tuber powder (DTP) at all replacement levels (3, 6, 9, and 12%) had the greatest amounts of nutrients, such as ash and crude fiber content, and the lowest value of calories. Crude fiber, which has a high-water absorption rate and the ability to form viscous aqueous solutions, is another ingredient found in large quantities in dahlia tuber powder. Consequently, the final product can continue to be fresh for an extended amount of time **[64].**

Last but not least, prior research on the approximate composition of dahlia tuber powder (DTP) indicates that it is a good source of ash, crude fiber, and protein. Its high nutritional content is complemented by new ingredients and natural products whose composition offers protection against specific diseases, offering further health benefits. Colonic bacteria can readily ferment it, and it has a high capacity to hold onto water to form a gelatinous mass. This mass provides significant lubrication and a large volume of stool by slowing stomach emptying and increasing the viscosity of the gastrointestinal contents **[65]**.

Effect of replacement wheat flour (WF) by dahlia tuber powder (DTP) on the mineral content of pan bread produced:

Table **(10)** displays the mineral content of the examined batches with DTP concentrations of 3, 6, 9, and 12% as well as the control sample, which is made up of wheat flour (72% ext.). Compared to the sample under control, the amount of DTP added increased the mineral content of the examined sample.

Table (10): Mineral content of pan bread produced by using different replacement levels of wheat flour (WF) with dahlia tuber powder (DTP)

Mineral content (mg/100g)	Control sample	Wheat flour substitution levels with DTP (%)				RDA* (mg/day)
		3%	6%	9%	12%	
Macro elements						
Calcium (Ca)	17.42±0.17^{d}	18.13±0.27^{c}	18.68±0.33^{b}	19.87±0.42^{a}	19.88±0.26^{a}	800-1200
Phosphorus (P)	137.88±0.32^{e}	154.37±0.50^{d}	161.55±^{c}	178.98±^{b}	205.28±0.47^{a}	800-1200
Potassium (K)	114.75±0.44^{e}	117.47±0.25^{d}	122.56±^{c}	125.33±^{b}	129.98±0.55^{a}	2000-4000
Microelements						
Magnesium (Mg)	67.10±0.22^{d}	75.83±0.17^{c}	76.07±0.32^{c}	82.87±0.23^{b}	88.25±0.21^{a}	280-350
Iron (Fe)	2.23±0.19^{e}	3.18±0.15^{cd}	3.36±0.12^{c}	3.73±0.17^{b}	3.97±0.11^{a}	8-10
Zinc (Zn)	5.77±0.18^{c}	5.83±0.11^{c}	6.28±0.27^{b}	6.33±0.21^{b}	6.67±0.15^{a}	10-12

^{a,b,c} Means with different letters in the same row are significantly different (P < 0.05); * **Recommended Dietary Allowances of Minerals- [45]**

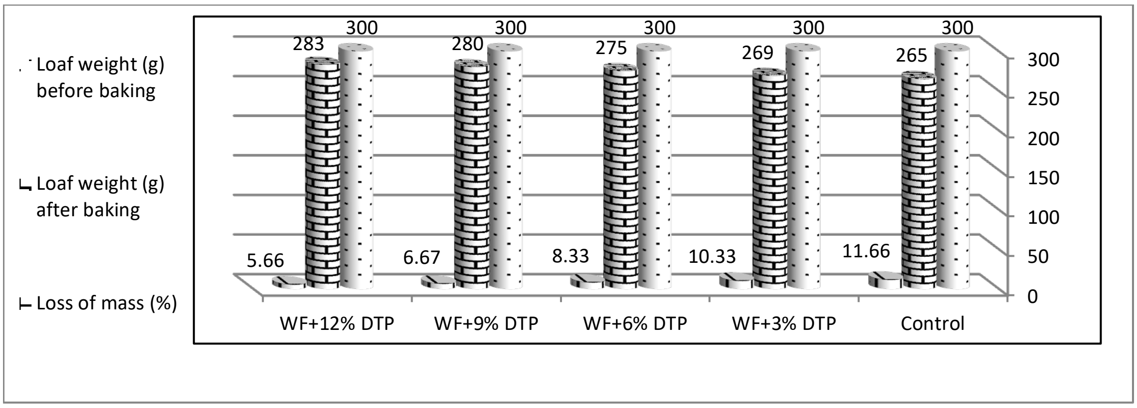
The results are shown in Table (10), where all tested minerals (Ca, P, K, Mg, Zn, and Fe) had significantly (p <0.05) higher levels at replacement levels of 3 to 12% in comparison to the control sample (the lowest mineral content was recorded for (Fe) percent, which was at 3%). It needs to be supplemented to meet the daily needs of most components. In contrast, the Zn content of the pan bread sample infused with DTP was somewhat higher than that of the control sample, which was produced with only 72% wheat flour. Consequently, one may consider the combined pan bread to have higher levels of fiber, proteins, and minerals. These findings are consistent with those of **[66]** who demonstrated that the high fiber, protein, and fat content of dahlia flour make it a possible addition to bakery goods' nutritional value. The facts above lead one to the conclusion that dahlia tuber powder ought to be utilized in bakery goods since it can improve the nutritional content of pan bread created and potentially aid in the nourishment of both adults and children who consume bread.

Effect of replacement wheat flour with different levels of dahlia tuber powder on the physical properties of pan bread produced:

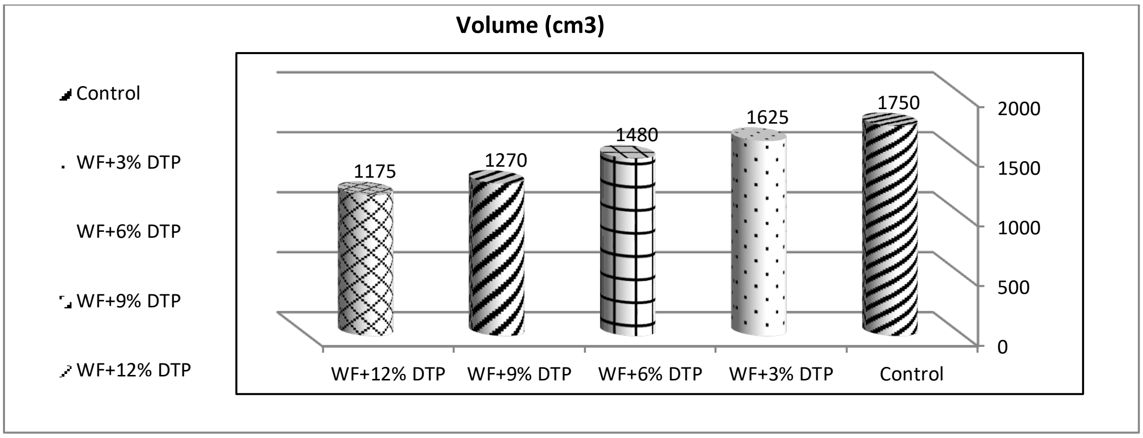
The outcomes of partial substitution of wheat flour at levels 3, 6, 9, and 12% for dahlia tuber powder (DTP) are Fig. (2) Together with the physical characteristics of the resulting pan bread. The acquired data showed that the loaf's weight after cooking (g) rose progressively as the DTP additive levels increased, compared to the control sample (265g). In contrast, when the additive amount was raised from 3.0 to 12.0%, it increased in pan bread samples from 269 to 283g. In comparison to the control sample (11.66%), the weight change of the pan bread sample (%) dropped from 10.33 to 5.66 %. The data obtained indicates that the partial substitution of wheat flour with DTP resulted in a reduction in the volume of pan bread as compared with the initial pan bread sample.

The decrement rate in those volumes was gradually raised by boosting the replacement amount of DTP from 3% to 12% when compared to a loaf volume of pan bread having 3% and 12% of DTP, respectively, to the control sample (1750). Furthermore, the loaf volume steadily dropped as the pan bread formula's replacement amount of DTP grew; this declining rate was more pronounced in the samples containing 12% DTP. These reductions may be due to the neutralization of gluten and the high fiber content of DTP. The results obtained align with the research conducted by **[67, 68],** which indicated that the presence of fiber increased the weight and decreased the volume of the loaf. Moreover, **[69]** showed that the bread enriched with date pits may have had lower gluten content as a result of the pits' rapid water absorption, which could have contributed to the decreased volume. As a result, less water is available for the production of gluten.

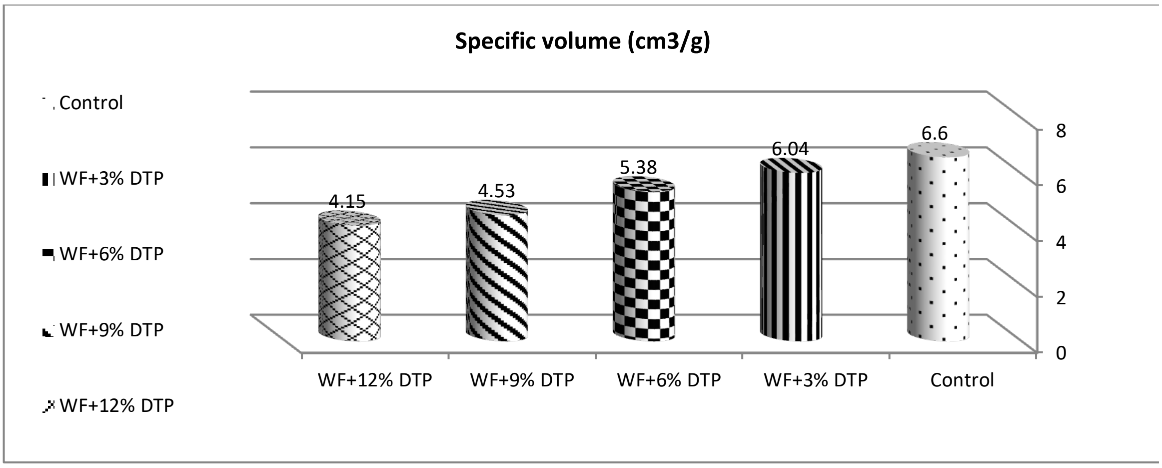
Fig. (2) further demonstrates that when wheat flour was partially substituted with varied degrees of DTP, the specific amounts of pan bread generated steadily decreased in comparison to the control bread. Furthermore, it was observed that the particular amount of pan bread produced at its lowest point—4.15 cm3/g—when 12% DTP was used in place of wheat flour, as opposed to 6.60 cm3/g for the control pan bread. According to these results, dough blends were significantly weakened by the fiber content of DTP, probably as a result of the diluted gluten **[68].** This observation is consistent with the results of **[70]** they discovered that bread made with 10% more inulin had a lower quality. Additionally, inulin decreased the bread's volume and specific volume. This could have been due to a delayed gelatinization that promoted more dough expansions during baking.



(a): Effect of replacement wheat flour by different levels of dahlia tuber powder on loaf weight (g) of pan bread produced



(b): Effect of replacement wheat flour by different levels of dahlia tuber powder on loaf volume (cm^3) of pan bread produced



(c): Effect of replacement wheat flour by different levels of dahlia tuber powder on specific volume (cm^3/g) of pan bread produced

Fig. (2) a, b and c: Physical characteristics of produced pan bread by using different replacement levels of dahlia tuber powder

Effect of substituted wheat flour by varied percent of dahlia tuber powder (DTP) on sensory evaluation of pan bread samples:

Evaluating food products with the senses is essential to defining their quality. The consumer also has a big say in what products are chosen **[71]** listing taste, texture, odor, and surface color as some of the essential characteristics linked to quality. Pan bread's organoleptic Comparing it to the control sample at various DTP levels allowed for the evaluation of quality parameters, including physical appearance, crusted color, crumbs texture, color, flavor, and overall acceptability. Table **(11)** presents the findings.

Table (11): Sensory evaluation of pan bread prepared from wheat flour (WF) and substituted wheat flour by varied percent of dahlia tuber powder (DTP)

Treatment / sensory properties	Control sample	Wheat flour substitution levels with DTP (%)			
		3%	6%	9%	12%
Shape	8.70±0.12[a]	8.65±0.16[a]	8.40±0.22[ab]	7.56±0.19[c]	5.70±0.18[d]
Odor	8.70±0.15[a]	8.60±0.43[a]	8.30±0.19[ab]	7.40±0.15[c]	6.31±0.24[d]
Taste	8.60±0.17[a]	8.50±0.22[a]	8.13±0.15[b]	7.20±0.17[c]	6.62±0.13[d]
Crust color	8.66±0.11[a]	8.56±0.31[a]	8.45±0.19[a]	7.54±0.22[b]	5.90±0.27[c]
Crumb color	8.73±0.13[a]	8.50±0.36[ab]	8.30±0.25[b]	7.65±0.34[c]	5.75±0.19[d]
Crumb texture	8.70±0.16[a]	8.60±0.43[a]	8.50±0.32[a]	7.54±0.12[b]	6.10±0.22[c]
Overall acceptability	8.80±0.19[a]	8.70±0.21[a]	8.50±0.11[ab]	7.60±0.36[c]	6.20±0.23[d]

[a,b,c] Mean followed by different letters in the same row are significantly different ($P < 0.05$) ; **DTP**: dahlia tuber powder

The obtained results showed that there were no substantial variations between the control pan bread sample and the one under scrutiny comprising DTP at levels 3 and 6% concerning most sensory attributes. Conversely, the pan bread samples with 9 and 12% DTP showed lower judgment scores than the control pan bread. The panelists found the pan bread samples with 9% DTP to be somewhat acceptable. These findings are consistent with those of **[72],** who observed that the addition of inulin to bread resulted in a comparatively dark crust color. Contrarily, **[73]** discovered that the crust or crumb of bread did not darken when inulin was added at levels of 5% to 25%.

Overall, the results indicated that pan bread made with dahlia tuber powder in place of some wheat flour had acceptable and good sensory qualities but less than overall acceptability when compared to the control sample made with 100% wheat flour, especially when a percentage of 12% was included. However, when percentages of dahlia tuber powder were substituted up to 12%, the resulting pan bread lost its sensory appeal. The degree of ingredients and bread preparation methods may have an impact on the sensory qualities, customer preferences, and general acceptability in this regard **[74].**

Conclusion

The above result showed that dahlia tuber powder is rich in phytochemicals and was successfully incorporated into bakery products (pan bread) by partially replacing wheat flour. Replacing wheat flour with dahlia tuber powder from 3 to 12% resulted in pan bread with good sensory acceptability and high nutritional value as compared to the control sample. Nutrients like dietary fiber, ash, fats, and minerals increased noticeably as a result of substitution. When dahlia flour is added to pan bread, it can serve as a beneficial addition to a daily diet that typically lacks these ingredients. Functional foods are those that offer health benefits in addition to the traditional nutrients they contain. Furthermore, up to 9% of the wheat flour substituted with dahlia tuber powder produced acceptable sensory scores, according to the results. In light of the current findings, it is advised that efforts be focused on using dahlia tuber powder, which is a good and readily available source of numerous nutrients that improve the nutritional quality of pan bread.

Author Contributions: Conceptualization, **Sameh M. Ghanem** and **Nashaat N. Mahmoud**; methodology, **Muhammed I. Haggag**, and **Ali H. Foda**; software, [1]**Mokhtar M. Salama**; investigation, **Nashaat N. Mahmoud**, **Hamdy A. Zahran** and **Sameh M. Ghanem**; data curation **Nashaat N. Mahmoud**; writing—original draft preparation, [1]**Mokhtar M. Salama and Hamdy A. Zahran;** writing—review and editing, **Ali H. Foda** and **Muhammad I. Haggag;** visualization **Sameh M. Ghanem**; monitoring, **Nashaat N. Mahmoud**, After reading the finalized version of the manuscript, all writers have given their approval.

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