Original Research Article

Preparation and Evaluation of Breadsticks from Chufa Tubers as Substitute Wheat Flour.

Abstract

The influence of using tiger nut flour (TNF) substituted with wheat flour 72% extraction (WF) to improve the functional properties of breadsticks was explored. WF in the bread sticks preparation was substituted with four extents, 10, 20,30, and 40% with TNF. The breadsticks containing only WF was used as control. Prepared breadsticks were analyzed for their proximate composition, rheological properties, physical properties color, sensory attributes, texture profile. Arrival time, dough-development time, stability, elasticity and proportional number were significantly increased, however Water absorption, degree of softening, extensibility, and energy were decreased parallel with an increase of the WF substitution level using the TNF. Blending of TNF with WF resulted in a significant increase in fat, fiber and ash contents and in a decrease in protein content. The crust of bread sticks samples supplement with different levels of TNF had lower L* and b* values and the reduction increased as the fortification level increased. With the increase in the level of TNF in the formulation, the sensory attributes for color, taste, texture ,flavor, and overall acceptability of breadsticks increased. Measurement of bread sticks texture showed that hardness, cohesiveness, adhesiveness and chewiness values decreased when TNF content in the breadsticks formulation increased. The results shown that added10,20,30, and 40% TNF were the most superior for production of breadsticks with no adverse effect on the physical and sensory properties. The object of this study is to produce high nutritive breadsticks supplement with different levels of TNF.

Keywords: Breadsticks, tigernut flour , texture profile, sensory attribute.

1.Introduction

The sedge family includes the native tigernut, (*Cyperus esculentus* L.,) which grows only in northeast Africa **[1]**. It is a significant multipurpose crop, and its roots, which have a flavour and aroma, may contain essential oils. Its stems and leaves can be used as green feed and knitting materials **[2-4]**. The rich lipid, protein, carbohydrate, dietary fibre, and vitamin content of tigernut tubers is commonly used to produce edible oil, plant milk, and snack foods **[5-6]**. Tigernut tuber oil has been widely researched for its physical and chemical components stated **[7-8]**. Tiger nut flour was used in baked goods and for gluten-free bread with good baking and nutritional qualities since tiger nut is a rhizome rich in lipids, fiber, and carbohydrates [**9**].

The tuber is raised for its nutritional value and health advantages **[10]**. It has a good quantity of unsaturated fat, fiber, and a moderate amount of protein **[11]**. The tuber includes 45.73% carbohydrates, 5.08% protein, 14.80% crude fibre, 30.01% crude fat, and 2.23% ash **[12]**. According to **Ismaila et al, [13]** the protein concentrations of the black and yellow varieties were 10.25 and 7.90%, respectively. Tigernut includes 77.49–80.01% essential fatty acids and 31.32–34.03 mg/100 g essential amino acids **[14]** .

Tigernut oil is low in sterol and high in polyunsaturated fatty acids **[15]**. While the brown cultivar comprises 68.89% oleic, 13.33% palmitic, and 4.46% stearic, the black cultivar includes 77.71% oleic, 16.17% palmitic, and 11.87% linoleic **[16]**. Additionally, the oil contains important polyphenols as quercetin, sinapic, p-coumaric, ferulic, protocatechuic, gallic, syringic, and vanillic acids **[4]** .

Figure 1: Tigernut yellow (A), brown (B) and black (C) cultivars

Although the protein content is small, it has been reported to be beneficial for diabetics, people with digestive problems, and may even prevent heart disease when consumed [**17-18**]. This tuber contains dietary fiber that can help avoid gastrointestinal problems, colon cancer, and obesity [**19**]. Due to the presence of flavonoids, the tiger nut has a high antioxidant properties and can be used as a source of natural antioxidants [**20**].

The tiger nut contains a significant quantity of crude fat (22.14–44.92%). The oil's composition is similar to that of olive oil, which is considered as the best fat to consume [**21**]. In addition to the oil, it typically includes phenols, calcium, magnesium, potassium, vitamin E, and vitamin C [**22**]. When compared to other vegetable oils, this oil's superior oxidation stability is a result of its antioxidant activities [**23**]. Additionally, it includes alkaloids, saponins, and tannins that have anti-inflammatory and antibacterial properties [**24**].

Research on enhancing food products to produce proper nutrients, promote health, and prevent disease has been sparked by the rising demand for functional foods. The usage of omega-3 polyunsaturated fatty acids (omega-3 PUFA) is one of the most common in functional foods because of its nutritional benefits. Because of this, significant efforts have been made to raise the amount of omega-3 PUFA that people consume each day through their diet, which would finally enable them to reach their recommended daily allowance (RDA) [**25**].

Recent research efforts have focused on finding ways to enhance ordinary bread products with a variety of plant-based ingredients that are high in nutrition. In recent years, oilseeds have gained popularity in many recipes due to their higher protein content than cereals, high fibre content, high omega-3 and omega-6 essential PUFA content, and natural antioxidant components as tocopherol, beta-carotene, caffeic acid, chlorogenic acid, and flavonoids **[26]** .

The bakery products made using compound flour had a perfect quality, as they had some properties resembling wheat flour bread though the properties and texture of compound flour bakery differ from those made with wheat flour. With a better nutritional quality and shape . Wheat is considered to be nutritionally deficient due to the lack of certain essential amino acids like lysine and threonine in cereal proteins, in addition to being a source of calories and some other nutrients [**27**].

Some of the important quality criteria of bread are volume, texture and appearance, whereas smell and taste play a major role for producers and consumers. Bread contains about 300 volatile substances that are classified into several types, such as alcohols, esters, aldehydes, etc. The kind and concentration of the ingredients at the time of processing, yeast activity during fermentation, and fermentation conditions all interact in various ways to produce them (temperature, time, etc.) [**28-29**]. SO, this study aimed at producing breadsticks from blends of wheat, and tiger nut flour and evaluates its, sensory and proximate analysis.

2. Materials and methods

2.1 Raw Materials

Source of tubers: From the local markets in Tanta City, Egypt, chufa (tiger nut) tubers (*Cyperus esculentus*) were purchased. We bought wheat flour (72%ext) from the North Cairo Flour Mills Company in Egypt (2022). The Egyptian Sugar and Integrated Industries Company (ESIIC), Chemicals Factory, El-Hawamdia City, Giza, Egypt, provided active dry yeast (*Saccharomyces cerevisiae*). We bought shortening, salt (sodium chloride), and sugar (sucrose) at the local market in Egypt (2022).

Reagents:

All of the chemicals and reagents used in the present study's analytical procedures were of the analytical grade and were obtained from El-Gamhouria Trading Chemicals and Drugs Company in Egypt and Sigma-Aldrich Company for Chemicals in the USA.

Table 1.The basic formula used in the preparation of breadsticks.

Ingredients(g)	Control	B10	B20	B30	B40
Wheat flour(WF) 72%	100	90	80	70	60
Tiger nut flour (TNF)%	00	10	20	30	40
Sugar(sucrose) (g)	8.0	8.0	8.0	8.0	8.0
Fat (oil) (g)	10	10	10	10	10
Salt (g)	0.5	0.5	0.5	0.5	0.5
Dry yeast (g)	0.6	0.6	0.6	0.6	0.6

Tiger nut powder was substituted the base flour at different extents (10, 20, 30 and 40 %). The control dough was prepared form 100% Wheat flour.

B10= 90 g wheat flour+10 g Tiger nut flour B20= 80 g wheat flour+20 g Tiger nut flour

B30= 70 g wheat flour+30 g Tiger nut flour B40= 60 g wheat flour+40 g Tiger nut flour

The straight dough procedure was used for bread sticks making as follow: sugar, fat, salt and dry yeast, were added to each types of flour with warm water and oil, the ingredients were thoroughly mixed together manually. Dough was left to ferment for 30 min at room temperature

(30± 2ºC). Dough was divided into pieces and gives 10 min to rest. The pieces were fermented for half an hour at 30ºC and 90% relative humidity after being molded into their final form. Fermented snacks dough's were baked at 170 ºc for 30 min **[30].**

Proximate Analysis:

Moisture, protein, fat, crude fiber, and ash contents were determined using the methods outlined by **AOAC,** [**31**], whereas carbohydrate was estimated using the difference.

Determination of Total Polyphenolics

The total polyphenolics compounds (TPC) content was measured using the Folin Ciocalteu reagent and the procedure described by **[32]**. The concentration of polyphenolics was determined using a UV spectrophotometer (Varian, Melbourne, VIC, Australia). The absorbance was measured at 760 nm using gallic acid as a reference. The findings were expressed as mg of gallic acid equivalent per 100gDM.

Total Flavonoids Estimation

The method described by **Vuong et al,** [**33**] was used to estimate total flavonoids. The absorbance at 510 nm was measured using a UV spectrophotometer (Varian, Melbourne, VIC, Australia). Total flavonoids content was estimated as mg of quercetin equivalent (QE)/100g of dry sample using quercetin as a standard.

Determination of Minerals

According to the **U.S. EPA [34]** minerals were assessed in ash solution using ICP-OES Agilent 5100 VDV.

Rheological properties

The different blends' rheological properties were assessed using the Brabender Farinograph and Extensograph apparatus in accordance with **[35]**.

Color Determinations

The colour of the breadsticks was measured objectively. The CIE lab colour scale (Hunter, Lab Scan XE - Reston VA, USA) was used to measure the Hunter a*, b*, and L* parameters using a colour difference meter and a spectrocolourimeter (Tristimulus Colour Machine).

Texture Profile Analysis

Breadsticks' texture profiles were assessed using a penetrometer instrument, and the texture properties of breadstick blends were estimated using a TVT-300XP texture analyzer (Tex Vol Instruments AB, Viken, Sweden), according to **[35].**

Sensory Evaluation

Sensory attributes of the studied breadsticks with tigernut flour were carried out by twenty panelists to determine flavor, color, texture, overall acceptability and taste. Scores from one to ten were used to make the decision, with the following categories: excellent (10-9), very good (8-6), fair (5-4) and unacceptable (3-2) allowing to the methods outlined by **[36]**.

Statistical Analysis

SPSS software (version 26) was employed for the statistical analysis, and Duncan's multiple range tests were employed for mean comparison. To compare between means, Duncan's multiple range tests were performed at the ($P \leq 0.05$) level.

Chemical Composition of TNF and WF

The proximate analyze of raw materials used for the making of breadsticks is offered in Table 2. The found results exposed that the highest content of protein found in WF was 11.80%. While the lowest value was found in TNF 6%. Fat content were 28.50 and1.85% TNF and WH respectively.

TNF had the highest content of ash 4.60% followed by WF (0.50%). Fiber content was (8.50%and 0.45%) for TNF and WH respectively. WH had high available carbohydrate content 85.40. Whiles, TNF had the lowest value 52.40%. TNF and WH had high caloric values 498.79 and 415.36(kcal/100g). It has many nutrients that can be deeply explored and comprises 1.60–2.60% ashes, 3.28–8.45% proteins, 22.14–44.92% lipids, 8.26–15.47% fibers and 23.21–48.12% starch [**37**]. The findings harmony with **Martín-Esparza et al. [38]** showed that TNF contain 4.80%protein, 2.2% ash, 25.30%fat.

Data obtainable in Table 2 showed the mineral content of TNF and WF as mg⁄100g. The findings exposed that the mean value of minerals (K, P, Ca, Mg, Fe and Mn) in TNF was higher than that of WF. On the contrary, Zn levels are lower in TNF than WF. **Ismaila *et al*. [13]** described that Ca, P, K, Na, Zn,and Fe in both black and yellow cultivars.

Obtained Data in Table 2 presented total phenolic and total flavonoids content of TNF and WF as mg⁄100g. The results revealed that the mean value of total phenolic contents of TNF and WF was (210.50 and 155mg/100g), respectively, while total flavonoids were (170.30and 2.70mg/100g), respectively .

Table 2 Chemical Composition of TNF, and WF

Components	Tiger nut flour	Wheat flour 72%
Moisture	4.50^{b} ±0.05	8.80^{a} ±0.20
Crude protein%	6.00^{b} ±0.06	11.80^{a} ±0.04
Ether extract%	28.50^{a} ±0.45	1.85^{b} ±0.02
Ash%	4.60^{a} ±0.06	0.50^{b} ±0.01
Crude fiber%	8.50^{a} ±0.04	0.45^{b} ±0.01

*Available carbohydrates%	52.40^{b} ±0.45	85.40^{a} ±0.30
Caloric value (kcal/100g)	498.79^{a} ±0.40	415.36^{b} ±0.10
Total phenolic (mg /100 g)	210.50^{a} ±0.50	155^{b} ±0.50
Total Flavonoids (mg/ 100 g)	170.30^{a} ±0.50	2.70^{b} ±0.03
Minerals (mg/100 g)		
K	250^{a} ±2.50	123.30^{b} ±0.90
Ca	160^{a} ±3.50	18.00^{c} ±0.30
P	140^{a} ±2.50	130^{b} ±1.40
Mg	115^{a} ±0.50	109^{b} ±0.70
Fe	10.00^{a} ±0.10	1.90^{b} ±0.01
Mn	45^{a} ±0.01	1.40^{b} ±0.01
Zn	1.5^{a} ±0.03	4.20^{b} ±0.05

-Each value was an average of three determinations ± standard deviation.

- a, b ,c different superscript letters in the same rows are significantly different at LSD at ($p \leq 0.05$).

Proximate Composition of Breadsticks

Table 3 provides the proximate composition of bread sticks prepared from mixes containing WF and TNF. The proximate composition of blended bread sticks were affected significantly by blending with different extents of TNF. The protein content of bread sticks was significantly higher when blended with various TNF concentrations compared to the control (10.20%). Adding TNF to WF decreased the protein content of breadsticks to 09.53–08.23 respectively. Blending with different proportions of TNF significantly increased the fat content of bread sticks in comparison to control (10.04%). Enrichment of WF with TNF increased the fat content to 12.30–19.07 respectively. Fortification of WF with TNF significantly increased the ash content of breadsticks to 0.77–1.81 respectively in comparison to control 0.44%. Blending with different

Proportions of TNF significantly ($P \leq 0.05$) decreased the carbohydrate content of bread sticks in comparison to control (78.94%). Blending WF with TNF decreased the carbohydrate content to 76.33–67.78 % respectively.

Blending with different proportions of TNF significantly ($P \leq 0.05$) increased the energy content of bread sticks in comparison to control (456.84%). Blending WF with TNF increases the energy content to 463.96–485.18 kcal ⁄ 100g respectively. Blending with TNF significantly increased the energy content of blends as the TNF proportion increased.

Table 3 shows the mineral comprise of breadsticks made from mixtures comprising WF and TNF. The mineral composition of blended breadsticks was significantly impacted by blending with various TNF extents. The potassium, calcium, phosphorus, and sodium content of bread sticks were significantly higher after blending with various TNF ratios compared to the control. The iron content of breasticks increased to 2.24–4.31 when WF was replaced with TNF. On the contrary, Supplementing with different extents of TNF significantly ($P \leq 0.05$) reduced the Mg content of breadsticks in comparison to control (90.68 mg/100g). Substituting 30% TNF to WF enhances the flour's fiber, protein, ash, and oil absorption capacities as well as its antioxidant, amylopectin, and amylose contents. **[39-40]** showed that replacing wheat flour with10, 20 and 30% tigernut flour increases ash, fiber, fat and caloric value in pan bread.

Table 3 Proximate composition of breadsticks

components	Control	B10	B20	B30	B40
Crude protein%	10.20^{a} ±0.01	9.53^{b} ±0.02	9.22^{c} ±0.02	8.73^{d} ±0.04	8.23^{e} ±0.05
Ether extract%	10.04^{e} ±0.35	12.30^{d} ±0.60	14.56^{c} ±0.40	16.81^{b} ±0.50	19.07^{a} ±0.30
Ash%	0.44^{e} ±0.01	0.77^{d} ±0.02	1.12^{c} ±0.03	1.47^{b} ±0.05	1.81^{a} ±0.03
Crude fiber%	0.38^{e} ±0.03	1.07^{d} ±0.02	1.75^{c} ±0.05	2.43^{b} ±0.08	3.11^{a} ±0.07
*Available carbohydrates%	78.94^{a}	76.33^{b}	73.35^{c}	70.56^{d}	67.78^{e}

	±0.10	±0.06	±0.07	±0.03	±0.05
Caloric value (kcal/100g)	456.84^{e} ±0.50	463.96^{d} ±0.80	471.03^{c} ±0.90	478.06^{b} ±0.50	485.18^{a} ±0.30
Minerals (mg/100 g)					
K	124.58^{e} ±01.70	133.31^{d} ±2.20	142.03^{c} ±3.30	150.76^{b} ±2.40	159.49^{a} ±1.60
Ca	13.56^{e} ±1.27	25.76^{d} ±2.80	37.97^{c} ±1.90	50.17^{b} ±2.10	58.98^{a} ±1.56
P	110.17^{e} ±0.01	111.02^{d} ±0.01	111.86^{c} ±0.08	112.71^{b} ±0.07	113.56^{a} ±0.04
Mg	90.68^{a} ±0.10	89.24b ±0.07	87.80^{c} ±0.05	86.36^{d} ±0.09	84.91^{e} ±0.04
Fe	1.53^{e} ±0.09	2.22^{d} ±0.07	2.92^{c} ±0.09	3.61^{b} ±0.06	4.31^{a} ±0.10
Mn	1.19^{e} ±0.07	4.88^{d} ±0.04	8.58^{c} ±0.10	12.27^{b} ±0.20	15.97^{a} ±0.30
Zn	3.56^{a} ±0.03	3.30^{b} ±0.02	3.10^{c} ±0.01	2.87^{d} ±0.04	2.64^{e} ±0.01

- B10= 90 g wheat flour+10 g Tiger nut flour B20= 80 g wheat flour+20 g Tiger nut flour
- B30= 70 g wheat flour+30 g Tiger nut flour B40= 60 g wheat flour+40 g Tiger nut flour

-Each value was an average of three determinations ± standard deviation.

- a, b ,c different superscript letters in the same rows are significantly different at LSD at ($p \le 0.05$).

Rheological Characteristics Parameters of Breadsticks Dough:

The farinograph and extensograph parameters of WF, and its blends with TNF are obtainable in Table 4. With increasing extents of TNF replacement, the data showed that wheat flour's ability to absorb water gradually reduced. The reduce in water absorption of the WF dough is maybe caused by the higher fat contents of TNF than WF. The distribution of gluten and the formation of the network structure of the mixed dough were both significantly influenced by the water absorption. It was found that there was an inverse relationship between millet flour addition ratio and water absorption, which may be because wheat flour had more fibre and polysaccharides that absorbed more water **Rosell *et al.* [41]** indicated that the increased amount of hydroxyl groups present in the fibre structure and allowing for more water interactions through hydrogen bonding is the primary reason of the differences in water absorption. The dough's "development time" is the interval between the addition of water and when it reaches its "point of greatest torque". The water hydrates the components of the flour during this mixing period, and the dough develops.

The farinograph data indicated that the addition of TNF increased dough development time; this may be because the presence of the aforementioned plant sources delayed the hydration and formation of gluten. Based on the quantity and quality of the dough's gluten, dough stability time is a significant indicator of the dough's strength, so it could be noticed that, the stability time of the control sample was 9.00 min, which increased by adding TNF to breadsticks reached about 9.5, 8.5, 9.5, and 20 min for B10, B20, B30, and B40, respectively.

Saha *et al.* [42] showed similar farinographic properties in their investigates on impact of millet type on dough rheology. Additionally, a reduction in water absorption was noted in a mixture of wheat and proso millet by **[43]**. When the amount of sorghum was increased, **Carson and Sun [44]** found that the composite flour's ability to absorb water and its dough stability significantly reduced. The addition of sorghum caused a weakening of the dough, which may have been produced by a reduction in wheat gluten content (dilution effect) and competition for water between the proteins in sorghum and wheat flour **[45-46]**.

Concerning the extensograph characteristics, the results presented in the same table show that the resistance to extension of blends significantly increased the elasticity of breadsticks to 410–460 respectively in comparison to control 370 B.U. The process of dough formation, from the initial addition of water to flour up to the formation of compact dough with desired qualities (consistency, resistance to deformation, stability), according to **Bojanska et al.** [47] exposed that the process goes through various phases during which fluidity, firmness, and elasticity gradually change. The dough development time is dependent on the quantity and quality of gluten, the size of the flour granules, and the degree of milling. Dough stability describes the amount of time during which dough maintains its maximum consistency, and high dough stability is regarded as good from the point of view of future baking use. According to **[47-48]**.

Table 4. Rheological Parameters characteristics of breadsticks dough

Farinograph characteristics					
Blends	Water Absorption (%)	Arrival time (min)	Dough development (min)	Stability (min)	Degree of softening (B.U)
Control	59.50	1.5	2.0	9.00	60
B10	55.00	1.5	2.0	9.50	50
B20	52.00	1.5	2.0	8.50	60
B30	49.00	2.0	3.0	9.50	30
B40	45.00	2.0	13.0	20.0	20
Extensograph characteristics					
Control	Elasticity (B.U)	Extensibility (mm)	Proportional number	Energy (cm^2)	
Control	370	115	3.22	72	
B10	410	110	3.73	78	
B20	290	40	7.25	17	
B30	410	55	7.45	34	
B40	460	60	7.67	46	

B10= 90 g wheat flour+10 g Tiger nut flour
B20= 80 g wheat flour+20 g Tiger nut flour
B30= 70 g wheat flour+30 g Tiger nut flour
B40= 60 g wheat flour+40 g Tiger nut flour

<u>Texture characteristics of bread sticks prepared with different levels of TNF</u>

Table 5 shows the textural characteristics of breadsticks made from blends containing WF and TNF. The textural parameters of blended breadsticks were significantly affected by supplementing with different extents of TNF. The hardness N of breadsticks was significantly lowered when blended with various concentrations of TNF compared to the control (39.96N). The cohesiveness of breadsticks was reduced to 1.36-0.92N when WF was substituted with TNF. Blending with different extents of TNF significantly decreased the adhesiveness content of breadsticks in comparison to control (0.50 mj). Replacement of WF with TNF increased the adhesiveness content to 0.40–0.10mj respectively.

Blending with different extents of TNF significantly ($P \leq 0.05$) decreased the chewiness of breadsticks in comparison to control (141.30mj). Blending WF with TNF decreased the chewiness to 130.80–85.20mj respectively. Blending with TNF significantly decreased the texture parameter of blends as the TNF proportion increased. The findings agree with **Martín-Esparza et al. [38]** showed that adding TNF to dough of pasta a significant decrease ($p<0.05$) in the hardness, cohesiveness and adhesiveness.

Table 5.Texture parameters of bread sticks

Samples	Control	B10	B20	B30	B40
Hardness (N)	39.96^{a} ±0.50	37.30^{b} ±0.20	35.66^{c} ±0.25	31.96^{d} ±0.30	26.25^{e} ±0.40
Cohesiveness	2.42^{a} ±0.01	1.36^{b} ±0.03	1.25^{C} ±0.04	1.18^{d} ±0.05	0.92^{e} ±0.04
Adhesiveness (mJ)	0.50^{a} ±0.01	0.40^{b} ±0.02	0. 30^{c} ±0.01	0.20^{d} ±0.04	0.10^{e} ±0.02
Chewiness (mJ)	141.30^{a} ±0.05	130.80^{b} ±0.05	105.40^{c} ±0.02	95.01^{d} ±0.10	85.20^{e} ±0.06

B10= 90 g wheat flour+10 g Tiger nut flour B20= 80 g wheat flour+20 g Tiger nut flour
B30= 70 g wheat flour+30 g Tiger nut flour B40= 60 g wheat flour+40 g Tiger nut flour
-Each value was an average of three determinations ± standard deviation.
- a, b ,c different superscript letters in the same rows are significantly different at LSD at ($p \leq 0.05$).

Sensory analysis of bread sticks

Table 6 shows the sensory qualities of breadsticks produced from blends containing WF and TNF. The sensory characteristics of blended breadsticks was impacted by the TNF and WF blending significantly ($p\leq 0.05$). Addition of TNF increased the color value to 8.90–9.40 respectively in comparison to control (8.60).Furthermore addition of TNF increased the taste value to 9.10–9.45 respectively in comparison to control (8.35).Similarly. Supplementing WF with TNF significantly ($P \leq 0.05$) increased flavor value to 8.80–9.25 respectively in comparison to control (8.15). Also, Replacement of WF with TNF blends significantly ($P \leq 0.05$) increased the texture score of the breadsticks from 8.15 in control to 9–9.30 in blended breadsticks respectively. Blending WF with TNF significantly ($P \leq 0.05$) increased overall acceptance value to 8.60–9.10. These findings did not quite match those reported by **Hussein, et al., [40]** who found that when increase TNF the overall acceptability, odor, taste, and color were decreased in bread.

Table 6. Sensory evaluation of breadsticks

Sample	Color (10)	Taste (10)	Flavor (10)	Texture (10)	Overall acceptance (10)
Control	8.60^{c} ±0.05	8.35^{c} ±0.03	8.15^{e} ±0.20	8.15^{c} ±0.05	8.20^{e} ±0.21
B10	8.90^{b} ±0.10	9.10^{b} ±0.09	8.80^{c} ±0.25	9.00^{b} ±0.07	8.60^{d} ±0.12
B20	8.95^{b} ±0.05	9.35^{a} ±0.10	9.25^{b} ±0.05	9.30^{a} ±0.20	8.85^{c} ±0.22
B30	9.40^{a} ±0.03	9.45^{a} ±0.05	9.40^{a} ±0.05	9.40^{a} ±0.19	9.30^{a} ±0.18
B40	9.30^{a} ±0.05	9.35^{a} ±0.07	9.25^{b} ±0.10	9.30^{a} ±0.18	9.10^{b} ±0.22

- a, b, c different superscript letters in the same columns are significantly different at LSD at ($p \leq 0.05$).

-The mean value was an average of 20 determinations ± standard deviation.

Crust and crumb colors of breadsticks

The perception of the breadsticks' acceptability is significantly influenced by color. Table 7 displays the L^*, a^*, and b^* values for breadsticks fortified with TNF at different levels of fortification. The positive "b^*" value indicated yellowness, the "L^*" value indicated lightness, and the "a^*" value indicated the intensity of the redness. The results showed an increase in a dark tone with a decrease in L^* in both the crust and the crumb, an increase in yellowness with a decrease in b^* and an increase in TNF in breadsticks for the crust color, but the results were the opposite for the crumb color, where increased b^* values meant the yellowness increased. The white plain wheat flour's color tone has changed significantly as a result of the addition of TNF.

In general, all supplement bread samples had darker crust and crumb compared to the control. These results could be due to the high fiber and phenolic acid comprises of TNF that accelerate the formation of Maillard reaction products during the baking process **[36].**

Table 7. Crust and crumb colors of breadsticks

Sample	**Crust color**			**Crumb color**		
	L	***a***	***b***	***L***	***a***	***b***
Control	55.48^{a}	2.60^{e}	29.62^{a}	75.58^{a}	5.14^{a}	25.57^{a}
B10	53.28^{b}	2.78^{d}	28.10^{b}	72.14^{b}	4.62^{b}	24.10^{b}
B20	52.54^{c}	3.84^{c}	26.47^{c}	59.63^{c}	3.70^{c}	23.17^{c}
B30	51.80^{d}	5.52^{b}	25.68^{d}	58.95^{d}	2.15^{d}	22.92^{d}
B40	49.08^{e}	5.33^{a}	24.10^{e}	55.17^{e}	1.44^{e}	21.82^{e}

-Means with different letter in the same row are significantly different at LSD at ($p \leq 0.05$).
- Each value was an average of three determinations ± standard deviation.
L (lightness), *a* [(chromaticity on a green (-) to red (+)], *b* [(chromaticity on a blue (-) to yellow (+)], 90 = yellow, 180 = bluish to green, and 270 = blue scale; *L* = 100 for lightness and *L* = 0 for darkness.

Conclusion

TNF incorporation enhanced the nutritional, sensorial and texture characteristics of breadsticks. Blended breadsticks were softer and firmer as compared to the breadsticks from WF. TNF further enhanced the nutritional value and color properties of breadsticks but the textural characteristics improved. TNF is a good choice for the making of supplemented breadsticks however TNF improved customer appropriate of breadsticks. To end, it could make some breadsticks using ingredients like TNF and WF with high quality that are appropriate for customers.

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