



Evaluation of Breadsticks Prepared from Chufa Tubers as Partial Substitute of Wheat Flour

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The influence of using Tiger Nut (chufa tubers) flour (TNF) as a partial substitute of Wheat Flour 72% extraction (WF) to improve the functional properties of breadsticks was explored in this study. Substitution levels by TNF were 0 (control sample), 10, 20, 30 and 40%. Breadsticks were analyzed for their proximate compositions, rheological properties, color measurements, sensory attributes and texture profiles. Arrival time, dough-development time, stability, elasticity and proportional number were significantly increased, however, water absorption, degree of softening, extensibility and energy were decreased with increasing the level of TNF. Blending of TNF with WF resulted in a significant increase in fat, fiber and ash contents but protein content was decreased. The crust of breadsticks samples supplemented 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

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formulation, the sensory attributes for color, taste, texture, flavor and overall acceptability of breadsticks increased. Measurement of breadsticks texture showed that hardness, cohesiveness, adhesiveness and chewiness values decreased when TNF content in the breadsticks formulation increased. The results shown that added 10, 20, 30, and 40% TNF were the most superior for production of breadsticks with no adverse effect on the physical and sensory properties. The objective of this study is to produce high nutritive breadsticks supplemented 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 high 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].

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 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].



Fig. 1. Tigernut yellow (A), brown (B) and black (C) cultivars

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 bread 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 constituents, minerals, texture profile, physicochemical constituents

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 Four (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.

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 ($30 \pm 2^\circ\text{C}$). Dough was divided into pieces and gives 10 min to rest. The pieces were fermented for half an hour at 30°C and 90% relative humidity after being molded into their final form. Fermented snacks dough's were baked at 170°C 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.

2.2 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 100 gDM.

2.3 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.

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

Wheat flour was partially substituted by Tiger Nut powder at different extents (10, 20, 30 and 40 %). The control dough was prepared from 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

2.4 Determination of Minerals

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

2.5 Rheological Properties

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

2.6 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).

2.7 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].

2.8 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].

2.9 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.

2.10 Chemical Composition of TNF and WF

The proximate constitute of raw materials used for the making of breadsticks is offered in Table 2. The found results showed 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 and 1.85% 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%. While, 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 are in harmony with Martin-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 revealed 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 155 mg/100g), respectively, while total flavonoids were (170.30 and 2.70 mg/100g), respectively.

2.11 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 compositions of breadsticks made from mixtures comprising of WF and TNF. The mineral compositions 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 breadsticks 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 with 10, 20 and 30% tignut flour increases ash, fiber, fat and caloric value in pan bread.

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 ($p \leq 0.05$).

Table 3. Proximate compositions 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 ±0.10	76.33 ^b ±0.06	73.35 ^c ±0.07	70.56 ^d ±0.03	67.78 ^e ±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)					
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	89.24 ^b ±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 ≤ 0.05)

2.12 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 reduction. 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 investigation 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 [47,48].

2.13 Texture Characteristics of Breadsticks Prepared with Different Levels of TNF

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 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		

Table 5. Texture parameters of breadsticks

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 ($p \leq 0.05$).

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 \pm standard deviation

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 \pm 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

2.14 Sensory analysis of breadsticks

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 there is increase TNF the overall acceptability, odor, taste, and color were decreased in bread.

2.15 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].

This work confirms the great importance of applied science in bakery products [49-62].

3. CONCLUSION

TNF incorporation enhanced the nutritional, sensory and textural 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 also, the textural

characteristics improved. TNF is a good choice for the making of supplemented breadsticks however TNF improved customer appreciation of breadsticks. Finally, it could make some breadsticks using ingredients like TNF and WF with high quality that are suitable for people.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Babiker EE, Özcan MM, Ghafoor K, Al Juhaimi FA, Ahmed IAM, Almusallam IA. Bioactive compounds, nutritional and sensory properties of cookies prepared with wheat and tigernut flour. *Food Chem.* 2021;349:129155. DOI:10.1016/j.foodchem.2021.129155
2. Duman E. Some physico-chemical properties, fatty acid compositions, macro-micro minerals and sterol contents of two variety tigernut tubers and oils harvested from East Mediterranean region. *Food Sci Technol.* 2019;39;Suppl 2:610-5. DOI:10.1590/fst.28018
3. Lasekan O. Volatile constituents of roasted tigernut oil (*Cyperus esculentus L.*). *J Sci Food Agric.* 2013;93(5):1055-61. DOI: 10.1002/jsfa.5846, PMID 22936608
4. Ozcan MM, Ghafoor K, Al Juhaimi F, Uslu N, Babiker EE, Ahmed IAM. Influence of germination on bioactive properties, phytochemicals and mineral contents of tigernut (*Cyperus esculentus L.*) tuber and oils. *J Food Meas Char.* 2021;15: 3580–3589:4-021-00929-3. DOI: 10.1007/s1169
5. Clemente-Villalba J, Cano-Lamadrid M, Issa-Issa H, Hurtado P, Hernández F, Carbonell-Barrachina ÁA et al. Comparison on sensory profile, volatile composition and consumer's acceptance for PDO or non-PDO tigernut (*Cyperus esculentus L.*) milk. *LWT Food Sci Technol.* 2021;140:110606. DOI:10.1016/j.lwt.2020.110606
6. Oluwajuyitan TD, Ijarotimi OS. Nutritional, antioxidant, glycaemic index and antihyperglycaemic properties of improved traditional plantain-based (Musa AAB) dough meal enriched with tigernut (*Cyperus esculentus*) and defatted soybean (*Glycine max*) flour for diabetic patients. *Heliyon.* 2019;5(4):e01504. DOI: 10.1016/j.heliyon.2019.e01504
7. Aljuhaimi F, Ghafoor K, Musa Özcan M, Miseckaite O, E Babiker E, Hussain S. The effect of solvent type and roasting processes on physico-chemical properties of tigernut (*Cyperus esculentusL.*) tuber oil. *J Oleo Sci.* 2018;67(7):823-8. DOI: 10.5650/jos.ess17281
8. Aljuhaimi F, Şimşek Ş, Özcan MM. Comparison of chemical properties of taro (*Colocasia esculenta L.*) and tigernut (*Cyperus esculentus*) tuber and oils. *J Food Process Preserv.* 2018;42(3): e13534. DOI:10.1111/jfpp.13534
9. Aguilar N, Albanell E, Miñarro B, Guamis B, Capellas M. Effect of tiger nut-derived products in gluten-free batter and bread. *Food Sci Technol Int.* 2015;21(5):323-31. DOI: 10.1177/1082013214535615
10. Asare PA, Kpankpari R, Adu MO, Afutu E, Adewumi AS. Phenotypic characterization of tiger nuts (*Cyperus esculentus L.*) from major growing areas in Ghana. *Sci World J.* 2020;2020:7232591, 1–11. DOI: 10.1155/2020/7232591
11. Rosell CM. Tiger nut powder as ingredient for obtaining gluten free foods based on noodle processing and extrusion technology. December; 2020.
12. Sabah MS, Shaker MA, Abbas MS, Moursy FI. Nutritional value of tiger nut (*Cyperus esculentus L.*) tubers and its products. *J Biol Chem Environ Sci.* 2019;14(1):301-18.
13. Ismaila AR, Sogunle KA, Abubakar MS. Physico-chemical and functional characteristic of flour and starch from two varieties of tiger-nut. *FUDMA J Agric Agric Technol.* 2020;6(1):91-7.
14. Ijarotimi OS, Oluwajuyitan TD, Ogunmola GT. Nutritional, functional and sensory properties of gluten-free composite flour produced from plantain (Musa AAB), tigernut tubers (*Cyperus esculentus*) and defatted soybean cake (*Glycine max*). *Croat J Food Sci Technol (Online).* 2019;11(1):1131-251. DOI:10.17508/cjfst.2019.11.1.16
15. Aremu M O, Ibrahim H, Aremu SO, Aremu SO. Lipid composition of black variety of raw and boiled tigernut (*Cyperus esculentus L.*) grown in North-East Nigeria. *Pak J Nutr.* 2016;15(5): 427-38. DOI: 10.3923/pjn.2016.427.438
16. Nina GC, Ukeyima M, M U. Effect of Stored Tiger Nut Oil Cultivars on the

- quality Properties of Fried Plantain Chips. J Nutr Food Process. 2020;3(3):1-4. DOI: 10.31579/2637-8914/029
17. Adejuyitan JA. Tigernut processing: its food uses and health benefits. Am J Food Technol. 2011;6(3):197-201. DOI: 10.3923/ajft.2011.197.201
 18. Ogunlade I, Adeyemi Bilikis A, Aluko Olanrewaju G. Chemical compositions, antioxidant capacity of Tiger nut (*Cyperus esculentus*) and potential health benefits. Eur Sci J. 2015;11:217-24.
 19. Viuda-Martos M, López-Marcos MC, Fernández-López J, Sendra E, López-Vargas JH, Pérez-Álvarez JA. Role of fiber in cardiovascular diseases: A review. Compr Rev Food Sci Food Saf. 2010;9(2):240-58. DOI: 10.1111/j.1541-4337.2009.00102.x
 20. Jing S, Wang S, Li Q, Zheng L, Yue L, Fan S et al. Dynamic high pressure microfluidization-assisted extraction and bioactivities of *Cyperus esculentus* (*C. esculentus* L.) leaves flavonoids. Food Chem. 2016;192:319-27. DOI: 10.1016/j.foodchem.2015.06.097
 21. Touria L, Wafae L, Francesco C, Farida S. Sets of internal and external factors influencing olive oil (*Olea europaea* L.) composition: a review. Eur Food Res Technol. 2022;21:3947.
 22. Ezeh O, Gordon MH, Niranjana K. Tiger nut oil (*Cyperus esculentus* L.): A review of its composition and physico-chemical properties. Eur J Lipid Sci Technol. 2014; 116(7):783-94. DOI: 10.1002/ejlt.201300446.
 23. Nina GC, Ukeyima M, Ogori AF, Hleba L, Hlebova M, Glinushkin A et al. Investigation of physiochemical and storage conditions on the properties of extracted tiger nut oil from different cultivars. J Microbiol Biotechnol Food Sci. 2020; 9:988-93.
 24. Vega-Morales T, Mateos-Díaz C, Pérez-Machín R, Wiebe J, Gericke NP, Alarcón C et al. Chemical composition of industrially and laboratory processed *Cyperus esculentus* rhizomes. Food Chem. 2019; 297:124896. DOI: 10.1016/j.foodchem.2019.05.170
 25. Konieczka P, Czauderna M, Smulikowska S. The enrichment of chicken meat with omega-3 fatty acids by dietary fish oil or its mixture with rapeseed or flaxseed—effect of feeding duration. Anim Feed Sci Technol. 2017;223: 42-52. DOI: 10.1016/j.anifeedsci.2016.10.023
 26. Martinez MM, Gomez M. Current trends in the realm of baking: when indulgent consumers demand healthy sustainable foods. Foods. 2019;8(10): 8–10:8100518. DOI: 10.3390/foods
 27. Dhingra S, Jood S. Organoleptic and nutritional evaluation of wheat breads supplemented with soybean and barley flour. Food Chem. 2002;77(4):479-88. DOI: 10.1016/S0308-8146(01)00387-9.
 28. Birch AN, Petersen MA, Hansen ÅS. The aroma profile of wheat bread crumb influenced by yeast concentration and fermentation temperature. LWT Food Sci Technol. 2013;50(2):480-8. DOI: 10.1016/j.lwt.2012.08.019
 29. Birch AN, Petersen MA, Arneborg N, Hansen ÅS. Influence of commercial Baker's yeasts on bread aroma profiles. Food Res Int. 2013;52(1):160-6. DOI: 10.1016/j.foodres.2013.03.011
 30. El-Hadidy GS, Eman AY, Abd El-Sattar AS. effect of fortification breadsticks with milk thistle seeds powder on chemical and nutritional properties. Asian Food. Sci J. 2020;17(2):1-9. DOI: 10.9734/AFSJ/2020/v17i230187
 31. AOAC. Association of official of analytical chemists. Official methods of analysis. 18th ed, Pub. by the A.O.A.C. 2005, Arlington, Virginia. USA; 2020.
 32. Thaipong K, Boonprakob U, Crosby K, Cisneros-Zevallos L, Hawkins Byrne DH. Comparison of ABTS, DPPH, FRAP, and ORAC assays for estimating antioxidant activity from guava fruit extracts. J Food Compos Anal. 2006;19(6-7):669-75. DOI: 10.1016/j.jfca.2006.01.003
 33. Vuong QV, Hirun S, Chuen TLK, Goldsmith CD, Bowyer MC, Chalmers AC et al. Physicochemical composition, antioxidant and anti-proliferative capacity of a lilly pilly (*Syzygium paniculatum*) extract. J Herb Med. 2014;4(3):134-40. DOI: 10.1016/j.hermed.2014.04.003
 34. U.S. EPA. Method 200.7: Determination of Metals and Trace Elements in Water and Wastes by Inductively Coupled Plasma-Atomic Emission Spectrometry. Revision 4.4. Cincinnati; 1994.
 35. AACC International Methods approved of the American Association of Cereal Chemists. 11th Ed. American Association

- of Cereal Chemists. St. Paul, MN: INC; 2012.
36. De Renzo DJ. Bakery products yeast leavened. Vol. 20. Noyes Data Corporation; 1975.
 37. Adel AAM, Awad AM, Mohamed HH, Iryna S. Chemical composition, physicochemical properties and fatty acid profile of Tiger Nut (*Cyperus esculentus* L.) seed oil as affected by different preparation methods. *Int Food Res J.* 2015;22:1931-8.
 38. Martín-Esparza ME, Raigón MD, Raga A, Albors A. Functional, thermal and rheological properties of high fibre fresh pasta: effect of Tiger Nut Flour and xanthan gum addition. *Food Bioprocess Technol.* 2018;11(12):2131-41. DOI: 10.1007/s11947-018-2172-8
 39. Bamigbola YA, Awolu OO, Oluwalana IB. The effect of plantain and tigernut flours substitution on the antioxidant, physicochemical and pasting properties of wheat based composite flours. *Cogent Food Agric.* 2006;2(1):1-19. DOI:10.1080/23311932.2016.1245060
 40. Hussein AS, Fouad M, El-Shenawy M. Production of functional Pan Bread from Mixture of Tiger Nut Flour, Milk Permeate and Hard Wheat Flour. *Egypt J Chem.* 2022;65(3):509-17.
 41. Rosell CM, Rojas JA, Benedito de Barber C. Influence of hydrocolloids on dough rheology and bread quality. *Food Hydrocoll.* 2001;15(1):75-81. DOI: 10.1016/S0268-005X(00)00054-0
 42. Saha Supradip GA, Singh SRK, Bharti N, Singh KP, Mahajan V, Gupta HS. Compositional and varietal influence of finger millet flour on rheological properties of dough and quality of biscuit. *Food Sci Technol.* 2011;44(3).
 43. Lorenz K, Dilsaver W. Rheological properties of food application of proso millet flours. *Cereal Chem.* 1980;57:21-4.
 44. Carson LC, Sun XS. Breads from white grain sorghum: rheological properties and baking volume with exogenous gluten protein. *Appl Agric Eng.* 2000;16:423-9.
 45. Deshpande SS, Rangnekar PD, Sathe SK, Salunkhe DK. Functional properties of wheat-bean composite flours. *J Food Sci.* 1983;48(6):1659-62. DOI: 10.1111/j.1365-2621.1983.tb05054.x
 46. Rao SJ, Rao GV. Effect of incorporation of sorghum flour to wheat on chemical, rheological and bread characteristics. *J Food Sci Technol.* 1997;34:251-4.
 47. Bojňanská T, Tokár M, Mocko K, Balková H, Frančáková H, Ivanišová E et al. Evaluation of new varieties of summer wheat *Triticum aestivum* L. considering selected parameters of technological quality. *J Microbiol Biotechnol Food Sci.* 2013:1281-92.
 48. Skendi A, Papageorgiou M, Biliaderis CG, Biliaderis CG. Effect of barley β -glucan molecular size and level on wheat dough rheological properties. *J Food Eng.* 2009;91(4):594-601. DOI: 10.1016/j.jfoodeng.2008.10.009
 49. El-Dreny EG, El-Hadidy GS. Utilization of young green barley as a potential source of some nutrition substances. *Zagazig. J Agric Res.* 2018;45(4):1333-44.
 50. El-Hadidy GS. Preparation and Evaluation of Pan Bread Made with Wheat flour and psyllium Seeds for Obese Patients. *Eur J Nutr Food Saf.* 2020;12(8):1-13.
 51. El-Hadidy GS, Eman AY, Abd El-Sattar AS. Effect of Fortification Breadsticks with Milk Thistle Seeds Powder on Chemical and Nutritional Properties, *Asian Food Sci ,J.* 2020;17(2):1-9.
 52. El-Hadidy GS, El-Dreny EG. Effect of addition of doum fruits powder on chemical, rheological and nutritional properties of toast bread, *Asian Food Sci J.* 2020;16(2):22-31.
 53. El-Hadidy GS, Rizk EA, El-Dreny EG. Improvement of nutritional value, physical and sensory properties of biscuits using quinoa, naked barley and carrot. *Egypt. J Food Sci.* 2020;48(1):147-57.
 54. El Hadidy GS, Rizk EA. Influence of coriander seeds on baking Balady bread. *J Food Dairy Sci.* 2020; 9 (2):69-72.
 55. El-Dreny EG, El-Hadidy GS. Preparation of Functional Foods Free of Gluten for Celiac Disease Patients. *J. Sus. Agric Sci.* 2020;46(1):13-24.
 56. El-Hadidy GS, Nassef SL, El-Satta ASA. Preparation of some functional bakeries for celiac patients. *Curr Chem Lett.* 2022;11(4):393-402. DOI: 10.5267/j.ccl.2022.5.002.
 57. El-Hadidy GS, Shaban HH, Mospah WM. Production and evaluation of gluten-free crackers from rice, lentil, and quinoa flour for celiac disease patients. *J Food Res.* 2022;11(3):1-47.
 58. El-Hadidy GS, Shaban HH, Mospah WM. Gluten-free crackers preparation. *Eur J Nutr Food Saf.* 2022;14(7):24-34. DOI: 10.9734/ejnf/2022/v14i730513

59. El-Hadidy GS, ElMeshad W, Abdelgaleel M, Ali M. Extraction, identification and quantification of bioactive compounds from globe artichoke (*Cynara cardunculus* var. *scolymus*). Sains Malays. 2022;51(9): 2843-55.
60. Nassef SL, El-Hadidy GS, Abdelsattar AS. Impact of defatted chia seeds flour addition on chemical, rheological, and sensorial properties of toast bread. Egypt J Agric Sci. 2023;73(4):55-66.
DOI: 10.21608/ejarc.2023.174785.1008.
61. El-Hadidy GS, Nassef L, El-Dreny G. Chemical and biological evaluation of bakeries produced from golden berries. Eur J Nutr Food Saf. 2023;15(2): 1-13.
DOI: 10.9734/ejnfs/2023/v15i21290.
62. Shaban H, Nassef S, Elhadidy G. Utilization of garden cress seeds, flour, and tangerine peel powder to prepare a high-nutrient cake. Egypt J Agric Res. 2023;101(1):131-42.
DOI: 10.21608/ejar.2023.176562.1309.

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