Effect of Baking on Stability of Phenolic and Flavonoid Compounds and Quality of Tigernut Enriched Crackers

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Abstract: Tigernut is considered a good source of bioactive compounds as well as its health benefits and nutritive value. In the present study, tigernut tubers were dried, milled to produce tiger nut flour (TNF) and incorporated in crackers, replacing 10, 20, 30 and 40% of wheat flour to formulate samples TF1, TF2, TF3 and TF4. Total phenolic contents, physical, chemical and sensory characteristics of the produced crackers were determined. The phenolic and flavonoid compounds in TNF and TF4 were identified and quantified by HPLC. The results showed that TNF addition gradually increased the total phenolic contents of TF1, TF2, TF3 and TF4 samples to be 1.33, 1.39, 1.44 and 1.51 mg GAE/g, respectively compared to that of control sample (1.29 mg GAE/g). Pyrogallol, ellagic and benzoic were the predominant phenolic compounds, whereas luteo-6-arbinose-8-glucose and acacetin were the major flavonoid compounds in the tigernut crackers. The increase in TNF ratio led to an increase in the nutritional value but also negatively affected the physical properties of crackers by reducing spread ratio and breaking force. All crackers samples had satisfactory sensory acceptance except that contained 40% TNF.

Keywords**:** Tigernut, phenolic and flavonoid compounds, crackers.

INTRODUCTION

Cereal grains are the most important source of energy, dietary fiber, minerals, vitamins and many other bioactive compounds in the human diet. Unfortunately, cereal proteins are deficient in some essential amino acids such as lysine and threonine. Fortification of wheat flour with various sources of tubers, legumes, cereals and fruit flour to improve the nutritional values of bakery products was reported (Amir *et al*., 2013; Noorfarahzilah *et al*., 2014; Ogur, 2014).

Biscuits, the most popular bakery products, are very popular in daily diet for all consumers and normally made from soft wheat flours. It has many attractive properties such as the relatively long shelf-life, good eating quality and the possibility of using it in the feeding programs in the schools. The biscuits production has increased in recent years in several developing countries due to the increase of population (Pratima and Yadava, 2000; Ahmed *et al*., 2014; Youssef, 2015).

Tigernut (*Cyperus esculentus* L.) is a tuber crop, grown extensively in Mediterranean regions, cultivated for its edible tubers and belongs to family Cyperaceae. The tubers of tigernut are rich in carbohydrates, fat, dietary fiber, minerals (*i.e.* potassium, phosphorus, calcium, iron, zinc and copper), and vitamins (*i.e.* E and C). It has reported that tigernut contains moderate protein content with higher essential amino acids than that found in the protein standard recommended by the FAO/WHO (Bosch *et al.,* 2005; Oladele and Aina, 2007). Tigernut make up the short fall in wheat essential amino acids, because it contains significant amounts of lysine (2.92-6.24 mg/g dry weight) and threonine (1.82-4.09 mg/g dry weight), which make a composites of wheat flour and tigernut flour a balanced essential amino acid diet (Salau *et al.,* 2013; Aremu *et al.,* 2015). Tigernut extract is a natural antioxidant source comparable to BHA. It contained 197 mg GAE/100g of total phenolic compounds. Benzoic acid, ellagic acid, cholchecien, salicylic acids are the predominant phenolic compounds in it (Owon *et al.,* 2013).

Tigernut tubers are also considered rich source of high quality oil. However, tigernut oil is not used in food industries on a large scale compared to other vegetable oils despite its stability and similarity to olive oil in particular. It contains fatty acid profile similar to that of olive, avocado and hazelnut oil (Chinma *et al*. 2010; Ezeh *et al*., 2014). There is evidence that ancient Egyptians cultivated tigernut crop for its medicinal uses. Literature revealed that tigernut has many health benefits as its consumption can help prevent heart disease, thrombosis, activate the blood circulation and it can assist in reducing the risk of colon cancer (Zapata *et al*., 2012).

Many attempts have been reported to improve the nutritional values or the quality characteristics of some bakery products using tigernut flour such as cakes (Chinma *et al*., 2010), biscuits (Ahmed and Hussein, 2014), gluten-free rice bread (Demirkesen *et al*., 2013), and crackers and reduced the breakage of some of these products (Pareyt and Delcour, 2008).

Therefore, the aim of this research was to determine the effect of tigernut flour addition on the crackers physico-chemical and sensory qualities, and the effects of baking on the contents of total phenolic content, phenolic and flavonoid compounds, of crackers samples prepared with tigernut flour.

MATERIALS AND METHODS

About five kilograms of each tigernut (*Cyperus esculentus* L.) tubers and wheat flour (72% extraction) were purchased from local market in Zagazig city, Egypt. The tubers were cleaned to get rid of dust, stone, pebbles, pests, mould and mites before washing with tap water. The tubers were dried in hot air oven at 50°C until constant weight, milled and sieved with a 0.45 mm mesh size sieve. Tigernut flour (TNF) was kept in

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sealed polyethylene bags and stored in the freezer at -18°C until further use or analysis.

Crackers preparation

Crackers were prepared according to the method and formula of AACC (2002) with some modifications that included: flour (225g), oil (20g), sugar (60g), salt (2.0g), baking powder (2.5g) and water (49g). Dry and liquid ingredients were mixed for 3 min, dough was rested for 10 min after that it was sheeted and laminated to a thickness of 5 mm and cut to circular shape. The crackers were baked in electric oven at 175 °C for 4 min and cooled to room temperature.

Physical properties

The color of cracker samples was analyzed using a color hunter-lab analyzer (Hunter Lab Color Flex EZ, USA). Three color values were recorded, L^*, a^* and b^* values as reported in the methods mentioned by (Abdel-Samie *et al*., 2010).

Spread ratio of cracker samples were measured following the AACC method (AACC, 2002). After 30 min of removing crackers from oven, six pieces were laid edge-to-edge and measured for diameter, rotated 90° and re-measured, average of the two measurements was divided by 6 as the single cracker sample diameter. Chosen six crackers was put on top of another and measured for thickness, rearranged and re-measured, average of two values were taken and divided by 6 to get the thickness of a single cracker sample.

Breaking force of crackers was measured following the method of (O'Brien *et al*. 2000) with some modifications. Three-point bend test was applied using texture analyzer (TA-TX2, Stable Microsystem, Surrey, England) equipped with a 25-kg load cell. Breaking force (Kg) was recorded as peak force using the force-in-compression mode. Crackers samples were placed on base beams stage with a separate distance of 4 cm. Three-point bending rig was used with the HDP/BS, knife-edge probe. Analysis conditions were: return-to-start cycle, pretest speed and test speed were 2 mm/sec, posttest speed was 10 mm/sec, trigger force was 20 g, and distance was 20 mm.

Chemical composition

Chemical composition of tigernut flour and prepared crackers including moisture, protein (N*6.25), fat, crude fiber, ash and minerals contents were analyzed as described in the official methods AOAC (2005). Carbohydrates percentage was calculated by difference (100 - (Fat + Moisture + Protein + Ash)) as indicated in the AOAC (2005) methods.

Total phenolics content (TPC)

The total phenolics content of the samples were determined using Folin-Ciocalteu method (Olanrewaju *et al*., 2015). The results were expressed as mg Gallic acid equivalent/g (mg GAE/g).

Phenolic and flavonoid compounds determination

The phenolic and flavonoid compounds in tigernut flour and tigernut crackers were analyzed according to the methods described by Goupy *et al*. (1999) and Mattila *et al*. (2000) using HPLC instrument (Hewlett Packard, Series 1050, USA) composed of column C18 hypersil BDS with particle size 5 µm. The separation was carried out using methanol and acetonitrile (80:20) as mobile phase, at flow rate of 1 ml/min. Quantification was carried out based on calibration with standards of phenolic and flavonoid compounds.
The estimated amount of phenolic compounds in crackers was calculated based on:
Estimated amount = Concentration of the compound X % TNF in Crackers on dry matter basis.

Sensory evaluation

The prepared crackers were sensory evaluated according to the method of Pertuzatti *et al*. (2015). It was presented to 20 panelists within the age range of 22-55 years of both sexes. Panelists were asked to evaluate quality attributes of crackers (aroma, color, texture, taste and overall acceptability) using nine points hedonic scale.

Statistical analysis

The obtained data were subjected to analysis of variance (ANOVA) using SAS software (SAS Institute, 1990). Differences between means were determined by the least significant difference test, and significance was defined at $P < 0.05$. All measurements were carried out in triplicates.

RESULTS AND DISCUSSION

Physical characteristics of the prepared crackers

Table (1) shows the color values of crackers surface in terms of chromatic coordinates. It was found that the control samples were lighter in color than those with tigernut addition. Lightness (L^*) value of the control sample was 68.02 whereas, it was 61.12, 57.22, 52.68 and 50.54 for TF1, TF2, TF3 and TF4 samples, respectively. Darker crackers (lower lightness) may be attributed to Millard reaction occurred in crackers with tigernut flour which contains higher sugar content than the wheat flour (Romani *et al*., 2009). Same trend of changes in lightness was also noted in b* values as control sample had the maximum value (27.49). The decrease in yellowness value was noted with the addition of TNF being 24.78, 23.68, 22.19 and 20.68 for TF1, TF3 and TF4 samples, respectively. On the other hand, TNF subistitution gradually increased the redness (a*) values of the prepared crackers from 0.4 for control samples to 3.0 for TF4 samples, which contained 40% of tigernut flour. These results are in accordence with those obtained by Zilic *et al*. (2016).

Table (1) demonstrates that the addition of tigernut flour to the crackers formula at 10, 20, 30 and 40% decreased the diameter of the prepared crackers from 4.77 cm for the control sample to 4.76, 4.70, 4.59 and 4.56 cm for TF1, TF2, TF3 and TFs4 samples, respectively. Thickness of crackers containing tigernut flour increased from 0.54 cm for control sample to 0.56, 0.57, 0.57 and 0.6 cm in TF1, TF2, TF3 and TF4 samples respectively. This may be due to the TNF high amounts of fiber (Bado *et al.,* 2015), allowing it to absorb more water, increase in volume, and increase in thickness. Changes in diameter and thickness were the reason that gave a reduction in spread ratio from 8.83 for control samples and gradually to 8.5, 8.25, 8.05 and 7.6 for TF1, TF2, TF3 and TF4 samples, respectively. On contrast, Ahmed and Hussein (2014) reported that the spread of the biscuits increased significantly when tigernut flour was increased in the formulation.

Lower breaking forces of crackers with tigernut flour was a reflective factor of the weaker gluten network in the tigernut containing crackers, giving a softer crackers with lower breaking forces. Breaking force of the control samples was the highest (5.43 Kg), compared to all tigernut flour containing crackers, which scored 5.22, 4.95, 4.70 and 4.63 Kg respectively for TF1, TF2, TF3 and TF4 samples respectively (Table 1).

Table (1): Effect of tigernut flour addition on some physical properties of the prepared crackers.

Samples	L* value	a* value	b* value	Diameter (cm)	Thickness (cm)	Spread %	Breaking forces (Kg)
Control	68.02* a	0.40 e	27.49 a	4.77 a	0.54 b	8.83 a	5.43 a
TF1	61.12 b	1.50 d	24.78 b	4.76 ab	0.56 ab	8.50 ab	5.22 b
TF2	57.22 c	2.09 c	23.68 c	4.70 bc	0.57 ab	8.25 b	4.95 c
TF3	52.68 d	2.63 b	22.19 d	4.59 bc	0.57 ab	8.05 bc	4.70 cd
TF4	50.54 e	3.00 a	20.68 e	4.56 c	0.60 a	7.60 d	4.63 d

*Means of triplicates. Means in the same column followed by the same letter have no significantly differences. TF1, TF2, TF3 and TF4 = replacement of 10, 20, 30 and 40% of wheat flour using tigernut flour.

Chemical composition of the prepared crackers

Proximate chemical composition of control and TNF added crackers is presented in Table (2). Crackers moisture content changed from 3.08 for control sample to 4.63 for the sample containing 40% of TNF (TF4). Increament of moistre contents in final products of crackers containing TNF may be attributed to the high content of crude fiber (5.5%) in tigernut flour (Bamishaiye and Bamishaiye, 2011) comparing to wheat flour. Tigernut flour contains lower protein content than that in wheat flour, that is why TNF gradual addition to formula cause a decrease in protein from 9.4% for the control samples to 9.07, 8.77, 8.44 and 7.95% for TF1, TF2, TF3 and TF4 samples, respectively. The fat content increased in prepared crackers from 20.84% for control crackers to 25.32, 27.41, 30.91 and 34.11% for TF1, TF2, TF3 and TF4 samples, respectively. This may be atributed to the high fat content (32-35%) in tigernut flour (Oladele and Aina, 2007). Fiber content increased in crackers from 0.81 in the control samples to 1.43 in TF4 samples, in which 40% of TNF was added. Ash increased as well from 0.53 for the control samples to 0.69, 0.90, 1.27 and 1.43 in TF1, TF2, TF3 and TF4 samples, respectively. Carbohydrate contents of crackers decreased with the addition of tigernut flour from 56.34% for the control samples, and proportionally to 48.43% for TF4 samples. Similar results were reported by Ahmed and Hussein (2014).

Table (2): Effect of tigernut addition on chemical composition (% dry weight) of the prepared crackers.

Samples	Moisture	Protein	Fat	Fiber	Ash	Carbohydrate
Control	3.08* e	9.40 a	20.84 e	0.81 e	0.53 e	65.34 c
TF1	3.70 d	9.07 b	25.32 d	1.22 d	0.69 d	60.00 a
TF2	4.03 c	8.77 c	27.41c	2.14 c	0.90 c	56.75 b
TF3	4.34 b	8.44 d	30.91 b	2.97 b	1.27 b	52.07 d
TF4	4.63 a	7.95 e	34.11 a	3.45 a	1.43 a	48.43 e

*Means of triplicates. Means in the same column followed by the same letter have no significantly differences. TF1, TF2, TF3 and TF4 = replacement of 10, 20, 30 and 40% of wheat flour using tigernut flour.

Minerals

According to Bado *et al*. (2015) and Ekeanyanwu and Ononogbu (2010) tigernut was reported as a rich source of minerals. Potassium, phosphorus, magnesium, ferrous and zinc were analyzed and their results are shown in Table (3). From presented data, addition of tigernut flour in 10, 20, 30 and 40% in crackers formula increased potassium content from 1586.3 mg/kg for the control sample to 1863.3, 2109.7, 2416.7 mg/kg in the crackers containing 10, 20, and 30% TNF, highest potassium contents (2963.3 mg/kg) was obtained by TF4. The control sample had the lowest phosphorus content (1143 mg/kg) whereas, the highest content was found in the TF4 samples with a content of 1923.3

mg/kg. Adding tigernut flour increased magnesium content from 395.0 mg/kg for the control sample to 1106.7 mg/kg for TF4. Ferrous content also increased from 26.5 mg/Kg for the control sample to 54.8 mg/Kg for TF4 Samples. Zinc content increased from 44.3 mg/Kg for the control sample to 211.7 mg/kg for TF4 samples. Tigernut flour addition to the crackers formula caused an increase in its minerals content due to the high minerals contents of tigernut flour; 4860-6080 mg/kg of potassium, 1230-2290 mg/kg of phosphorus, 600-1000 mg/kg magnesium, 40-120 mg/kg of ferrous, 10-40 mg/kg zinc. These results are in harmony with those of Chinma *et al*. (2011).

Table (3): Effect of tigernut addition on minerals content (mg/Kg) of the prepared crackers.

Samples	K	P	Mg	Fe	Zn
Control	1586.3* e	1143.3 e	395.0 e	26.5 e	44.3 e
TF1	1863.3 d	1396.7 d	576.3 d	31.2 d	64.3 d
TF2	2109.7 c	1553.7 c	766.7 c	40.6 c	110.0 c
TF3	2416.7 b	1776.7 b	916.7 b	48.2 b	178.7 b
TF4	2963.3 a	1923.3 a	1106.7 a	54.8 a	211.7 a

*Means of triplicates. Means in the same column followed by the same letter have no significantly differences.TF1, TF2, TF3 and TF4 = replacement of 10, 20, 30 and 40% of wheat flour using tigernut flour.

Total phenolic content (TPC)

Total phenolic contents of tigernut flour was reported to be high (1.97 mg GAE/g) (Owon *et al*., 2013). Control sample (only wheat flour) had the lowest TPC (1.29 mg GAE/g) among all samples. Gradual increase in the TNF proportions to the crackers formula increased the TPC to reach 1.33, 1.39, 1.41 and 1.51 mg GAE/g for TF1, TF2, TF3 and TF4 samples, respectively (Table 4). These results are within the range of values obtained by Zapata *et al*. (2012).

Table (4): Total phenolic contents of the prepared crackers.

Samples	TPC (mg GAE/g)
Control	1.29*e
TF1	1.33d
TF2	1.39c
TF3	1.44b
TF4	1.51 a

*Means of triplicates. Means in the same column followed by the same letter have no significantly differences.TF1, TF2, TF3 and TF4 = replacement of 10, 20, 30 and 40% of wheat flour using tigernut flour, GAE = gallic acid equivalent.

Phenolic and flavonoids compounds

Table (5) showed the concentration of phenolic compounds arranged descendingly according to its concentration in crackers samples. Chromatographic analysis showed that e-vanillic, pyrogallol, benzoic and ellagic acids were the major phenolic compound in tigernut flour (TNF), and the highest level was that ofe-vanillicacid (60.57 mg/Kg flour). Whereas the predominant phenolic compound in TF4 crackers samples was pyrogllol acid in an amount of 195.39 mg/Kg crackers, and it contained considerable amounts of ellagic, benzoic, e-vanillic and salycilic.

e-vanillic, ferulic, vanillic and alpha-coumaric suffered loss as it showed lower concentrations in TF4 crackers samples comparing to the estimated concentrations; e-vanillic decreased from 24.23 to 11.19 mg/kg, ferulic decreased from 2.66 tp 1.4 7 mg/kg, vanillic decreased from 1.96 to 1.4 mg/kg, for the estimated and the detected concentrations of phenolics in TF4 crackers samples, respectively. Whereas pyrogallol, ellagic and benzoic, increased after baking. However, it is noted that, p-coumaric, gallic, 4-amino-benzoic and cinnamic were very low in TNF and showed high levels in TF4 crackers, thus, these compounds are probably produced during maillard reaction during baking process.

As for flavonoid compounds; Luteolin.6-arbinose 8-glucose represented 37.64% of the total flavonoids compounds followed by acacetin which represented 18.2% of the flavonoids compounds in TF4 crackers samples. Hisperidin, Apigenin.6-rhamnose 8-glucose, Apigein.6-glucose 8-rhamnose and Apigenin.6-arabinose 8-glactose were all present in TF4 within the range of 4.06-11.29% with a concentration of 11.90-33.12 mg/kg crackers. Whereas luteolin.6-arbinose 8-glucose, Apigenin. 6-glucose, Hisperetin and Apig. 6-glucose 8-rhamnose were in higher amounts in TNF than other flavonoid compounds in it (Table 6).

Only Apigeginin.6-glucose 8-rhamnose and kaempferol.3,7-dirhamnoside did not resist the baking temperature as Apigeginin. 6-glucose 8-rhamnose decreased from 37.41 to 15.56 mg/kg, kaempferol.3,7-dirhamnoside decreased from 4.37 to 1.34 mg/kg for estimated and detected concentrations in TF4 crackers, respectively. While the detected concentrations of acacetin, quercetin, hisperetin, apegnin, and apiginin.7-glucose in TF4 crackers samples showed higher concentrations comparing to the estimated amounts. Quercetin-3-O-glucoside was detected in the 40% added TNF (TF40) crackers although it was not detected in the TNF, which shows it may be formed during baking process through maillard reaction.

The high increase in some detected phenolics concentrations comparing to its estimated concentrations might also be due to an increased extractability of phenolics and flavonoids after baking, which make these compounds more avaliabe to be extracted and also make it more easy to human body to use.

These results are in harmony with those reported by Zilic *et al*. (2016) who stated that applied baking conditions has great potential to release phenolic compounds. While Gerard and Roberts (2004) reported that thermal processes cause a degradation of phenolic compounds when temperature increased from 40°C to 70°C. Rupasinghe *et al.* (2008) reported that baking affect all phenolic compounds in muffin fortified with apple skin powder (ASP) except for quercetin and phloretin aglycones which were very low in ASP. The auther conclouded that some flavonoid compounds seem to be produced during the baking process due to the thermohydrolysis or deglycosylation of the glycosides of quercetin and phloretin.

Table (5): Phenolic compounds in tigernut flour and the prepared crackers containing 40% TNF (TF4).

Phenolic compounds	Concentration (mg/kg)			
	TNF	TF4 crackers		
		Estimated	Detected	Detected%
Pyrogallol	46.72	18.69	195.39	56.41
Ellagic	9.7	3.88	50.26	14.51
Benzoic	11.34	4.54	42.64	12.31
e-vanillic	60.57	24.23	11.19	3.23
Salycilic	7.04	2.82	8.85	2.56
P-coumaric	1.32	0.53	6.39	1.84
Epicatechein	2.95	1.18	4.78	1.38
Catechol	2.24	0.90	4.01	1.16
Catechein	7.65	3.06	3.33	0.96
Gallic	0.65	0.26	3.28	0.95
Protocatchuic	2.24	0.90	2.36	0.68
Chlorogenic	2.83	1.13	2.3	0.66
Iso-ferulic	2.83	1.13	1.97	0.57
Coumarin	1.88	0.75	1.94	0.56
Ferulic	6.65	2.66	1.7	0.49
Vanillic	4.91	1.96	1.4	0.40
4-amino-benzoic	0.32	0.13	1.24	0.36
Cinnamic	0.27	0.11	1.02	0.29
Alpha-coumaric	5.82	2.33	0.62	0.18
3,4,5-methoxy-cinnamic	0.47	0.19	0.55	0.16
Caffeine	1.25	0.5	0.51	0.15
Caffeic	0.55	0.20	0.38	0.11
Reversetrol	0.38	0.15	0.25	0.07

TNF= Tigernut Flour, TF4= crackers prepared with 40% substituted wheat flour using TNF. Detected %= Detected compound/ summition of the total detected*100.

Table (6): Flavonoids compounds in tigernut flour and the prepared crackers containing 40% TNF (TF4).

Flavonoid Compounds	Concentration (mg/kg)			
	TNF	TF4 crackers		
		Estimated	Detected	Detected %
Luteolin.6-arbinose 8-glucose	166.27	66.51	110.43	37.64
Acacetin	11.7	4.68	53.41	18.20
Hisperidin	34.20	13.68	33.12	11.29
Apigenin.6-rhamnose 8-glucose	26.89	10.76	17.84	6.08
Apigenin.6-glucose 8-rhamnose	93.53	37.41	15.56	5.30
Apigenin.6-arabinose 8-glactose	5.52	2.21	11.9	4.06
Narengin	6.14	2.46	8.63	2.94
Hisperetin	4.08	1.63	8.51	2.90
Luteolin.6- glucose 8- arbinose	17.11	6.84	6.03	2.06
Rutin	3.86	1.54	4.65	1.58
Quercetin	0.87	0.35	3.15	1.07
Quercetrin	3.79	1.52	2.72	0.93
Apigenin.7-glucose	1.2	0.48	2.45	0.84
Apigenin.7-O-neohespiroside	2.44	0.98	2.27	0.77
Rosmarinic	1.17	0.47	2.15	0.73
Quercetin-3-O-Glucoside	--	--	2.01	0.69
Luteolin.7-glucose	3.29	1.32	1.91	0.65
Kaempferol	1.57	0.63	1.69	0.58
Rhamnetin	1.16	0.46	1.58	0.54
Kaempferol.3,7-dirhamoside	10.92	4.37	1.34	0.46
Naringenin	1.32	0.53	0.80	0.27
Apegnin	0.21	0.08	1.24	0.42

TNF= Tigernut Flour, TF4= crackers prepared with 40% substituted wheat flour using TNF. Detected %= Detected compound/ summition of the total detected*100.

Sensory evaluation of crackers

The effect of adding tigernut flourat different levels (10-40%) on the acceptability of the prepared crackers is presented in Table (7). Data showed that, the addition of 10 - 30% of TNF did not sgnificantly affect the color, taste, aroma, texture and overall acceptability of cracker samples.wherease, samples containing 40% TNF obtained lower scores in all tested sensory attributes. All tigernut cracker samples had an acceptable scores in the range of 5.8-7.8 for all tested parameters. As for color, the scores decreased from 8.4 for control samples to 5.8 for the TF4 samples. Taste scores also decreased from 8.2 for control samples to 6.2 for TF4 samples. Results also showed that control sample was harder than tigernut cracker samples, that can be attributed to the increasing of oil and fiber contents in tigernut crackers. Dilluted gluten network, as tigernut flour is a gluten free component, can also contribute to the decrease in hardness. The texture scores were in good agreement with the results of the breaking force of crackers (Table 1).

The dark color, different flavor, and special aroma of tigernut flour was the reason behind the decrease of color, taste and aroma scores in the tigernut crackers. Overall aceptability was an overall opinion of panelists which is based on all other parameters, so, overall acceptability also decreased with the addition of tigernut flour in crackers. This results are in agreement with those obtained by Ahmed *et al*. (2014).

Table (7): Effect of tigernut addition on sensory evaluation of crackers.

Samples	Color	Taste	Aroma	Texture	Overall acceptability
Control	8.40* a	8.2 a	8.0 a	8.2 a	8.4 a
TF1	7.60 ab	7.8 ab	7.4 ab	7.2 ab	7.4 ab
TF2	7.0 bc	6.8 bc	7.0 ab	7.2 ab	7.1 b
TF3	5.8 c	6.6 bc	7.0 ab	7.0 b	6.8 b
TF4	5.8 c	6.2 c	6.6 b	6.8 b	6.7 b

*Means of triplicates. Means in the same column followed by the same letter have no significantly differences.TF1, TF2, TF3 and TF4 = replacement of 10, 20, 30 and 40% of wheat flour using tigernut flour.

CONCLUSION

Proportional increase of tigernut flour into the crackers formula caused an increased fat, fiber, ash, total phenolic contents, whereas protein content decreased. Pyrogallol, ellagic, benzoic, p-coumaric, gallic, and cinnamic showed to increase during baking while e-vanillic, ferulic and alpha-coumaric decreased during baking. Acacetin, quercetin and apegenin showed an increase in detected concentrations compared to the estimated concentrations in tigernut crackers. The sensory analysis showed good overall acceptability scores of the prepared crackers of different levels (10-40%), color, taste, aroma and texture of all crackers samples were acceptable for consumer.

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تأثير عملية الخبز علي ثبات المركبات الفينولية والفلافونويدية وخصائص جودة المقرمشات المدعمة بحب العزيز

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يعتبر حب العزيز مصدر جيد للمركبات الحيوية علاوة علي فوائده الصحية والتغذوية. في هذه الدراسة تم طحن درنات حب العزيز وإضافتها إلي المقرمشات باستبدال ١٠، ٢٠، ٣٠، ٤٠٪ من دقيق القمح لتكوين العينات TF1, TF2, TF3, TF4. تم قياس المحتوي الكلي للمركبات الفينولية ومحتوي المركبات الفينولية والفلافونويدية وكذلك تم تقدير الخواص الفيزيائية والكيماوية والحسية للمقرمشات الناتجة. وأوضحت النتائج أن إضافة دقيق حب العزيز أدي إلي زيادة تدريجية في محتوي الفينولات الكلية في العينات TF1, TF2, TF3, TF4 لتصبح ١.٣٣ و١.٣٩ و ١.٤٤ و ١.٥١ مجم حامض جاليك/جم علي التوالي مقارنةً بالكنترول (١.٢٩جم حامض جاليك/جم). وكانت الأحماض الفينولية السائدة هي الـ Benzoic, pyrogallol, ellagic بينما كانت الـ acacetin وluteo-6-arbinose-8-glucose هي المركبات الفلافونويدية السائدة في المقرمشات المدعمة بدقيق حب العزيز. أدي زيادة معدل إضافة دقيق حب العزيز إلي ارتفاع القيمة الغذائية للمقرمشات الناتجة في حين أدي أيضا إلي انخفاض معدل الفرد وقوة الكسر. وكانت جميع عينات المقرمشات مقبولة حسياً فيما عدا تلك المحتوية علي ٤٠٪ دقيق حب العزيز والتي حصلت علي درجات منخفضة في جميع الصفات الحسية المختبرة.