Rheological, Nutritional, and Sensory Properties of Corn Crackers Enriched with Buckwheat Flour

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ABSTRACT

Corn crackers are primarily made from corn flour, often supplemented with wheat flour to enhance processing and functional properties. This study investigated the use of whole grain buckwheat flour (WBF) as a substitute for wheat flour in corn cracker formulations at three different levels: 10%, 20%, and 30%. The objective was to evaluate the chemical composition, rheological properties, physical characteristics (color and texture), and sensory attributes of the resulting crackers. The moisture, protein, fat, ash, fiber, and carbohydrate contents of the whole grain buckwheat flour were 9.72%, 13.53%, 2.97%, 1.91%, 11.37%, and 70.60%, respectively. Crackers fortified with buckwheat flour showed higher levels of protein, fat, fiber, and ash compared to the control sample. Regarding rheological properties, the incorporation of WBF into the dough increased the Mixolab parameters, including water absorption (from 0.36% to 5.05%), dough development time (from 6.06% to 36.36%), and dough stability (from 10.81% to 48.64%). As the proportion of buckwheat flour increased, there was a notable reduction ($p \leq 0.05$) in both the lightness (L) and redness (a*) values. Conversely, a significant increase ($p \leq 0.05$) in yellowness (b*) values was recorded, ranging from 24.86 to 27.32 in the crackers. According to the study findings, substituting 20% of wheat flour with whole grain buckwheat flour produced nutritionally enriched crackers with desirable physical and sensory qualities.*

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Keywords: Wheat flour, chemical composition, Mixolab, and texture analysis, sensory qualities.

INTRODUCTION

In Egypt, Crackers are a widely appreciated bakery item, valued for their crisp texture and extended shelf life. Traditionally crafted from leavened or unleavened dough using wheat flour, oil, water, and various additives, their recipes have evolved to enhance both their taste and nutritional content **(Barut *et al.*, 2024).** Cereal products play a vital role in the human diet, serving as key sources of carbohydrates, proteins, fats, dietary fiber, B vitamins, and various minerals. Whole grains, in particular, are a fundamental component of numerous processed food items **(Okarter and Liu 2010)**.

Corn (*Zea mays L.*) ranks as the second most extensively grown cereal crop around the world and is considered one of the most cost-effective cereals to produce. Flour and food products derived from corn can be regarded as both staple and functional foods. Corn flour is a nutritious ingredient, abun-dant in protein, carbohydrates, and fiber. It also boasts essential vitamins and minerals such as potassium, calcium, zinc, iron, phosphorus, thia-mine, and niacin. Additionally, corn flour is inherently gluten-free **(Ragaee *et al.*, 2006; Kumari, 2019).**

Buckwheat belongs to the *Polygonaceae* family and is part of the *Fagopyrum genus*, which consists of 22 species. Among these, the most widely cultivated types are common buckwheat (Fagopyrum escul-entum Moench) and Tartary buckwheat (*Fagopyrum tata-ricum (L.) Gaertn.*). These species are cultivated world-wide because of their remar-kable adaptability **(Zhang *et al.*, 2021).** Buckwheat is an excellent source of essential bioactive compounds and boasts a well-balanced nutri-tional profile **(Joshi *et al.*, 2020; Huda *et al*., 2021).**

Buckwheat flour is a highly nutritious ingredient commonly used in preparing noodles, pasta, bread, pancakes, biscuits, Crackers, Baladi bread, etc. (**Wójtowicz *et al.*, 2013; Eren and Akkaya,**

2024; Hussein *et al.*, 2024a; Hussein *et al.*, 2024b). The nutritional composition of buckwheat typically ranges from 5.7% to 16.4% protein, 3.4% to 7.4% fat, 10% to 21.5% fiber, and 67.8% to 81.4% carbohydrates, depending on its origin and variety **(Jha *et al.*, 2024).**

Buckwheat stands out as a promising smart food due to its remarkable stress resistance and nutritional benefits. Its rich composition of bioactive compounds contributes to strong antioxidant, antimicrobial, anti-glycemic, and anti-cancer properties, alongside other health-enhancing qualities. These attributes underscore its potential for use in nutraceutical and pharmaceutical applications **(Jha *et al.*, 2024).**

Consumer demand for healthy snacks has been increasing, making snack crackers a favorable option due to their potential for high quality and enhanced nutritional value. Additionally, crackers serve as a versatile medium for incorporating various nutrient-rich ingredients, offering opportunities for greater diversity in nutrition. **(Mihiranie et al., 2021).**

Consumers today are increasingly seeking food products that not only offer great taste but also provide functional benefits. These include enhancing natural immunity, supporting disease prevention or therapy, boosting physical performance, and promoting mental well-being. A growing trend has emerged around functional foods, with buckwheat-based products gaining particular interest. **(Ekielski *et al*., 2007; Sedej *et al*., 2011).** The addition of buckwheat protein extracts has been shown to reduce cholesterol levels in both the blood and liver, making it potentially beneficial for managing high blood pressure, obesity, and constipation. Compounds found in buckwheat positively influence intestinal microflora and contribute to strengthening blood vessels. Animal studies have demonstrated its effectiveness in alleviating symptoms related to gallstone disease (cholelithiasis) **(Chłopicka, 2008; Yoo *et al*., 2012).**

This study aimed to produce corn crackers by substituting wheat flour with 10%, 20%, and 30% whole grain buckwheat flour. The objective was to assess the chemical and rheological properties, as well as the sensory quality of the resulting corn crackers.

MATERIALS AND METHODS

Materials:

- Wholegrain Buckwheat (*Fag-pyrum esculentum*) was obtained from the Environmental Studies & Research Institute, Sadat City University, Menoufia, Egypt.

- Corn flour (*Zea mays* L), wheat flour (72%), baking powder, Thyme, salt, and Paprika were obtained from the local market in Zagazig, Egypt. Chemicals were purchased from El-Ghomhorya Company for Trading Drugs, Chemicals, and Medical Instruments (Zagazig branch), Zagazig City, Egypt.

Methods

Preparing the buckwheat flour

Wholegrain buckwheat was cleaned, tempered, milled with a Quadrumat Junior flour mill (Model MLV-202, Switzerland), packed in plastic bags, and kept in the refrigerator until use

Crackers preparation

The crackers were prepared following the prescribed method by **Shalaby and El-Sayed (2020)** with a few modifications. the ingredients for the corn cracker dough were added in the quantities listed in Table 1. All ingredients and water as required were mixed for 3-4 minutes in a kitchen blender. The dough was placed in polyethylene bags and left at room temperature for 30 minutes. Afterward, it was hand-shaped to a thickness of approximately 5 mm and then cut into triangles, and then baked at 210 °C for 10 minutes. After cooling for 30 minutes at room temperature, the corn crackers were packaged in polyethylene bags until use.

Chemical analysis

Moisture, crude protein, ash, fat, and total dietary fiber content in raw materials and different cracker samples were determined by the official methods described in **AOAC (2010).** The total carbohydrate content was calculated by difference as described by **Guzman *et al.*, (1999**) using the following equation: Total carbohydrates = Total Solids (TS) − (Fat + Protein + Ash + fiber).

Nutritional evaluation

The energy value of different samples was calculated according to **Chaney (2006)** using the following equation:

Energy values (Kcal/100g) = 4 (protein % + carbohydrate %) + 9× fat %

The amount of cracker samples needed to meet the daily protein (50 g) and energy (2000 kcal) requirements for Adults and Children ≥ 4 years was determined using **FDA (2020**). Additionally, the percentage satisfaction of daily requirements for protein and energy fulfilled by consuming 100 g of the cracker samples was calculated

Rheological analysis of dough

The rheological properties of various raw materials were assessed using the Chopin Mixolab (Villeneuve-la-Garenne, France) method No. 54–60.01 and the Chopin+ protocol such as described in **AACCI. (2010)**. A standard Mixolab curve was generated, providing key parameters including, water absorption (WA), which measures the percentage of water needed for the dough to reach a torque of 1.1 Nm, dough development time (DDT, min), representing the duration needed to reach maximum torque at 30 °C, and stability (min), or the time interval during which dough consistency decreases by less than 11% of its peak value during mixing, and mechanical weakening (Nm) was quantified as the torque difference between two specific points, C1 and C2.

Texture analysis

The samples underwent texture analysis using a texture analyzer TA-TX2 (Stable Microsystem, Surrey, England) equipped with a 25 kg load cell. The hardness (N), adhesiveness (mJ), springiness (-), fracturability (N), and chewiness (N) were measured; the peak breaking force (N) of each sample was measured using a force-in-compression method. Cracker samples were positioned on base beams set 5 cm apart. Testing was conducted using a three-point bending rig equipped with an HDP/BS knife-edge probe. The analyzer operated in a return-to-start cycle, with both pre-test and test speeds at 2 mm/s, and a post-test speed of 10 mm/s. The trigger force was set at 20 g, with a test distance of 20 mm (Abdel-Samie et al., 2010).

Color measurements

The *L**, *a**, and *b** color parameters of different samples were analyzed using the Hunter Lab Color Analyzer (Color Flex EZ spectrophotometer, USA) according to **Monnier *et al*. (2019).** *ΔE* was determined as a color change index based on the following equation $\Delta E = \sqrt{(\Delta a^2 + \Delta b^2 + \Delta L^2)}$, where $\Delta a = a - a_0$, $\Delta b = b - b_0$, and $\Delta L = L - L_0$

Sensory evaluation

Twenty panelists from the Food Science Department staff at the Faculty of Agriculture, Zagazig University in Egypt, were chosen to carry out a sensory evaluation of the crackers. The crackers were presented to the panelists on coded plates, arranged in a random sequence. The panelists evaluated the samples based on their acceptability in terms of color, taste, odor, crispness, and overall acceptance. The assessment utilized a nine-point hedonic scale, with ratings spanning from 1 (extremely dislike) to 9 (extremely like), as described by **Bustos *et al.* (2011).**

Statistical Analysis

The data was statistically analyzed using SPSS software, version 25. A one-way ANOVA was carried out, followed by a post-hoc

Duncan test to determine statistical significance. The findings are presented as the mean ± standard deviation, with p-values deemed significant when $p \leq 0.05$, according to **Bailey (1995).**

RESULTS AND DISCUSSION

The chemical composition of the raw material and corn crackers partially replaced with 10, 20, and 30% whole grain buckwheat flour is presented **in Table 2**. The chemical analysis showed a significant increase ($P \leq 0.05$) in protein, fat, ash, and fiber contents in the product crackers as the level of WBF increased, while moisture and carbohydrate contents significantly ($P \leq 0.05$) decreased compared to the control. This is likely due to whole buckwheat flour having notably higher levels of protein, fat, fiber, and ash, which reach 13.53, 2.97, 11.37, and 1.91%, respectively, when compared to wheat flour. These results are close to the findings documented by **Hussein *et al.*, (2024),** who found that protein was (14.90%) and fiber was (12.51%). **Hadnadev *et al.*, (2011)** reported that ash of whole grain buckwheat flour was 1.97%**.** The fat content of corn crackers with different percentages of buckwheat flour was higher than control because buckwheat flour tends to retain oil during baking **(Rufeng *et al.*, 1995 and Kaur *et al.*, 2015).** Due to the increase of protein with increasing buckwheat flour, the grams consumed of crackers to meet the daily requirement for Adults and Children ≥ 4 years (GDR) of protein decreased to 465.98±11.20g compared to the control 491.16±0.84g, and P.S.%/100g of crackers increased significantly.

The GDR values for energy were decreased significantly because of the caloric values by increasing the buckwheat flour ratio. So, the percent satisfaction for energy of the daily needs was increased from 17.76±0.01% for the control sample to 17.88±0.16% for crackers with 30% buckwheat flour, **as shown in Table 3.**

Color plays a crucial role as a quality criterion in the food industry and is often the first attribute assessed by consumers when determining product acceptance and making purchasing decisions. The data **at Table 4** indicated the changes in color values (*L**, *a** and *b**) of corn cracker with addition different percentage of buckwheat flour and observed that there was a significant decrease ($p \leq 0.05$) in lightness (*L**) and redness (*a**) values with the increase in buckwheat level. Control corn crackers (C) had the highest lightness and redness (63.19 and 16.70, respectively). While T_3 had the lowest lightness and redness (59.11 and 10.92, respectively). A significant increase ($p \leq 0.05$) was observed in yellowness (*b**) value and ranged from 24.86 to 27.32 for crackers. The yellow appearance of the snacks was noted across all samples, attributed to the carotenoids naturally present in corn and buckwheat. These findings agree with those of **Wójtowicz *et al.* (2013),** who reported lower *L** values and higher *b** values with an increased addition of buckwheat to corn snacks.

The rheological properties of the samples were analyzed using the Mixolab Chopin protocol. The key parameters obtained from the Mixolab curves are summarized **in Table 5 and Figure 1**. These parameters include water absorption, dough development time, dough stability, and mechanical weakening, all of which provide valuable insights into the dough's behavior during mixing at a constant temperature of 30 °C. These measurements collectively characterize the dough's performance during the processing stage. The findings of the current study demonstrated that as the proportion of wholegrain buckwheat flour in the blend increased, there was a gradual rise in water absorption (WA), dough development time (DDT) and stability (S) of the blended flours, The longer dough development time could be attributed to a slower rate of water absorption and delayed gluten formation, likely caused by the higher fiber content.

These findings agree with **Hussein *et al.* (2024a),** when wheat biscuit was fortified with local buckwheat enhanced the arrival time, dough stability, dough development time, and weakening were enhanced compared to the control. Non-wheat flours such as whole-grain buckwheat, corn, amaranth, and soybean showed much higher water absorption. Meanwhile, rice flour and BWF had notably longer dough development times, as reported by **Hadnadev *et al.* (2011)**. The addition of WBF to dough enhanced water absorption, dough development time, stability time, and weakening by 0.36 to 5.05, 6.06 to 36.36, 10.81 to 48.64, and 6.25 to 27.5 %, respectively. The rise in water absorption is attributed to the fiber-rich fraction's capacity to absorb more water. Additionally, the stability time might be influenced by the dough's stiffness and stickiness, as noted by **Ibrahim *et al.* (2013).**

Texture profile analysis (TPA), the texture of snacks significantly influences their quality and how well they are received by consumers **(Szczesniak in 2002)**. For cracker samples, texture was assessed using a cutting test, which measured the maximum cutting force needed to permanently deform the sample. As illustrated in Fig. 2, an increase in cutting force was observed for crackers with a higher buckwheat content (30%). **Table 6 highlights** selected texture attributes of corn crackers enriched with buckwheat**.** Hardness is recognized as being influenced by the compressive strength of the cracker. The results showed a notable increase in hardness and a significant decrease in fracturability, both correlating with the amount of buckwheat flour added, with a significance level of $p \leq 0.05$. This increase in hardness could be attributed to the higher dietary fiber content, which is known for its significant water-absorbing capacity. These findings align with **Shalaby and El-Sayed (2020)**, who found that incorporating more tangerine and pea peels into crackers leads to increased hardness. Increasing the dietary fiber content in crackers can negatively affect their texture and crispness, which is a crucial consideration in cracker production **(Dokic *et al.*, 2015)**. WBF enhanced the springiness of the experimental samples' compared to the control by 30%.

Table 7 provides data on the sensory evaluation of corn cracker samples enriched with whole-grain buckwheat flour. Regarding odor, no significant differences were observed among all crackers products. However, significant differences were identified in color and taste between the control crackers and those containing 30% WBF. The taste and color of the control crackers showed no significant difference compared to those containing 10% and 20% WBF. T3 showed the lowest color score, which is supported by colorimetric measurements (Table 4). The crispness scores revealed a notable difference when comparing the control sample with the cracker product. Crackers with 30% WBF (T3) received lower scores compared to all other samples. In contrast, crackers containing 10% and 20% WBF (T1 and T4) achieved higher scores for both taste and crispness. The study concluded that corn crackers enriched with buckwheat achieved good acceptability when the buckwheat content did not exceed 20%. The findings also indicated that increasing the level of buckwheat flour in the crackers led to greater hardness. The findings align with the observations noted by **Wójtowicz *et al.* (2013).** Sensory evaluation indicated that replacing wheat flour with buckwheat flour (up to 20%) yielded acceptable results in snack development**.**

CONCLUSION

Corn crackers enriched with whole grain buckwheat flour exhibited enhanced nutritional value. The findings revealed that all experimental cracker samples were rated as acceptable; however, those containing up to 20% buckwheat flour demonstrated the best overall quality. Increasing the concentration of whole grain buckwheat flour beyond this level negatively affected the baking performance, color, and texture of the crackers. Notably, the samples with 20% buckwheat flour showed no significant changes in their sensory attributes while providing higher protein and fiber content compared to the control crackers. Therefore, incorporating 20% buckwheat flour is recommended to improve the quality of corn crackers and help mitigate raw material shortages. In conclusion, the use of corn crackers supplemented with 20% buckwheat flour is recommended to achieve optimal nutritional benefits.

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Table 1: Ingredients of the prepared corn crackers mixture (g)

Ingredient (%)	C	T1	T2	T3
CF	70	70	70	70
WF 72%	30	20	10	-
WBF	-	10	20	30
Thyme	1.5	1.5	1.5	1.5
Paprika	2	2	2	2
baking powder	1	1	1	1
Salt	2	2	2	2

CF: corn flour; WF: wheat flour; WBF: wholegrain buckwheat flour

Table 2: Chemical analysis of raw material and corn crackers enriched with whole grain buckwheat flour

Samples		Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Fiber (%)	Carbohydrate (%)
CF		10.50 $\pm 1.^{51ab}$	9.77 $\pm 0.91^{b}$	2.41 $\pm 0.1^{a}$	1.12 $\pm 0.12^{ab}$	2.18 $\pm 0.25^{b}$	74.02 $\pm 12.55^{a}$
WF		11.3 $\pm 1.71^{a}$	11.20 $\pm 1.98^{a}$	0.80 $\pm 0.00^{b}$	0.59 $\pm 0.01^{c}$	0.61 $\pm 0.08^{c}$	75.50 $\pm 14.01^{a}$
WBF		9.72 $\pm 1.48^{c}$	13.53 $\pm 1.26^{a}$	2. 97 $\pm 0.02^{a}$	1.91 $\pm 0.20^{a}$	11.37 $\pm 0.22^{a}$	70.60 $\pm 10.12^{b}$
Crackers	C	10.73 $\pm 1.62^{a}$	10.18 $\pm 1.41^{c}$	1.94 $\pm 0.21^{b}$	1.08 $\pm 0.14^{d}$	1.80 $\pm 0.08^{d}$	74.27 $\pm 10.23^{a}$
	T_1	10.55 $\pm 1.63^{a}$	10.39 $\pm 1.31^{b}$	2.11 $\pm 0.30^{b}$	1.16 $\pm 0.00^{c}$	2.90 $\pm 0.07^{c}$	73.93 $\pm 9.84^{ab}$
	T_2	10.3 7 ± 1.44^{b}	10.60 $\pm 1.53^{ab}$	2.26 $\pm 0.12^{a}$	1.33 $\pm 0.23^{b}$	3.70 $\pm 0.21^{b}$	73.37 $\pm 8.74^{b}$
	T_3	10.02 $\pm 1.23^{c}$	10.73 $\pm 2.11^{a}$	2.35 $\pm 0.15^{a}$	1.45 $\pm 0.11^{a}$	4.49 $\pm 0.31^{a}$	72.99 $\pm 4.55^{b}$

Values denoted by different letters (a–d) within the same column indicate a statistically significant difference at $p \le 0.05$. *Control: 70% CF +30 WF;* ***T_1****: 70% CF + 20 % WF +10% WBF;* ***T_2****: 70% CF + 10 % WF +20% WBF;* ***T_3****: 70% CF + 0 % WF +30% WBF*

Table 3 Nutritional evaluation of corn crackers enriched with whole grain buckwheat flour

Samples	C	T_1	T_2	T_3
Energy (Kcal/100g)	355.26 ±2.01^{b}	356.22 ±3.80^{b}	356.27 ±4.01^{ab}	357.65 ±3.09^{a}
GDR (g) for protein(50g)	491.16 ±0.84^{a}	481.23 ±5.28^{ab}	471.70.15 ±4.79^{b}	465.98 ±11.20^{c}
GDR (g) for energy (2000 Kcal)	562.97± 1.02^{a}	561.45 ±2.14^{ab}	561.37 ±1.89^{ab}	559.21 ±3.17^{b}
P.S.% of protein (50g)	20.36 ±0.25^{ab}	20.78 ±0.09^{ab}	21.20 ±0.02^{a}	21.46 ±0.13^{a}
P.S.% of energy (2000 Kcal)	17.76 ±0.01^{a}	17.81 ±0.13^{a}	17.81 ±0.09^{a}	17.88 ±0.16^{a}

Values denoted by different letters (a–c) within the same column indicate a statistically significant difference at p ≤ 0.05. Control*: 70% CF +30 WF;* ***T_1****: 70% CF + 20 % WF +10% WBF;* ***T_2****: 70% CF + 10 % WF +20% WBF;* ***T_3****: 70% CF + 0 % WF +30% WBF*

Table 4: Color attributes of corn crackers enriched with whole grain buckwheat flour

Samples	Color parameter			Δ *E*
	*L**	*a**	*b**	
C	63.19±0.01^{a}	16.70±0.01^{a}	24.86±0.00^{b}	-
T_1	62.96±0.01^{a}	16.58±0.01^{a}	26.09±0.00^{ab}	0.79
T_2	60.10±0.01^{b}	14.68±0.00^{ab}	26.73±0.00^{a}	8.56
T_3	59.11±0.00^{c}	10.92±0.01^{c}	27.32±0.00^{a}	28.05

Values denoted by different letters (a–c) within the same column indicate a statistically significant difference at p ≤ 0.05.

L (0, black; 100, white), a* (−a*: greenness, +a*: redness), b* (−b*, blueness; +b*, yellowness.*

Control*: 70% CF +30 WF;* ***T_1****: 70% CF + 20 % WF +10% buckwheat;* ***T_2****: 70% CF + 10 % WF +20% buckwheat;* ***T_3****: 70% CF + 0 % WF +30% buckwheat*

Table 5: Rheological properties of dough with different percentages of wholegrain buckwheat flour

Samples	Mixolab parameters			
	WA %	DDT (min)	ST (min)	Weakening (UF)
C	55.40 ± 1.01^{c}	3.38 ± 0.24^{bc}	3.70 ± 0.68^{c}	80 ± 2.22
T_1	55.60 ± 1.17^{c}	3.51 ± 0.91^{bc}	4.10 ± 0.71^{bc}	85 ± 3.12
T_2	56.40 ± 0.92^{b}	4.09 ± 0.35^{ab}	4.72 ± 0.41^{ab}	91 ± 2.98
T_3	58.20 ± 1.90^{a}	4.50 ± 0.82^{a}	5.50 ± 0.92^{a}	102 ± 5.12
As a percent of control (%)				
C	0.00	0.00	0.00	0.00
T_1	0.36	6.06	10.81	6.25
T_2	1.80	21.21	27.56	13.75
T_3	5.05	36.36	48.64	27.5

C: control; WA: water absorption; DDT: dough development time; ST: stability time

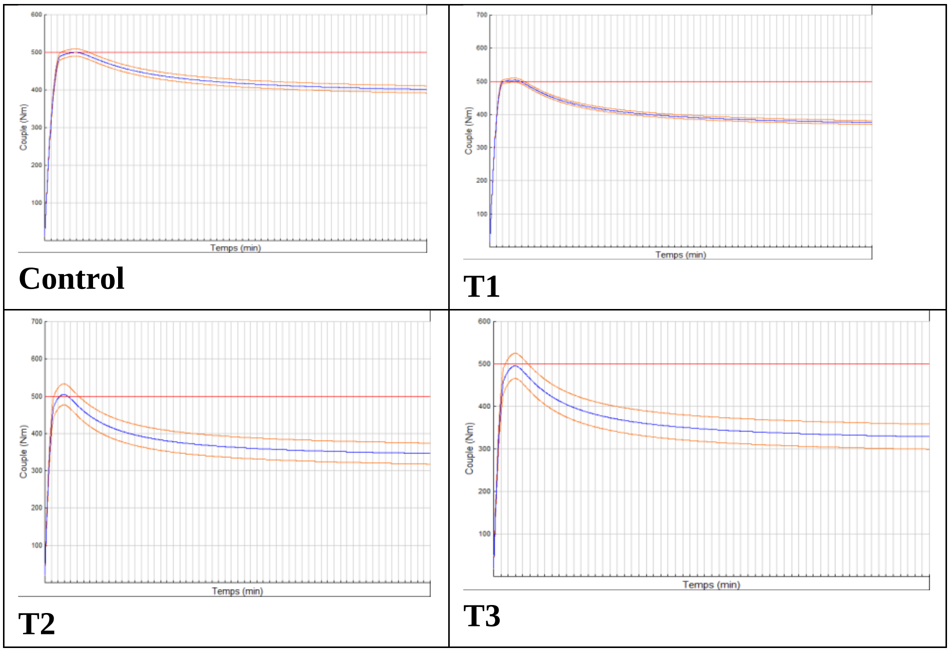
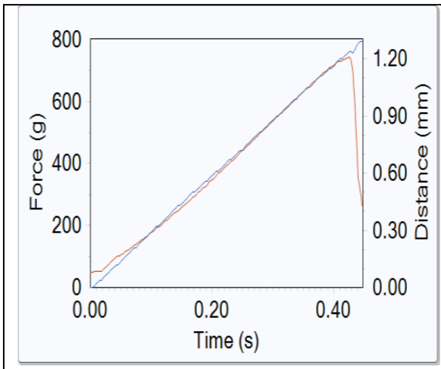


Figure 1. Mixolab parameters of corn cracker enriched with wholegrain buckwheat flour. Control*: 70% CF +30 WF;* ***T_1****: 70% CF + 20 % WF +10% buckwheat;* ***T_2****: 70% CF + 10 % WF +20% buckwheat;* ***T_3****: 70% CF + 0 % WF +30% buckwheat*

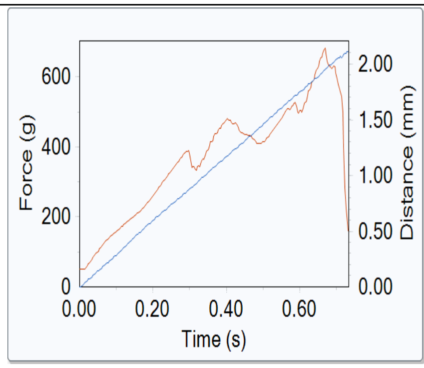
Table 6: Texture profile analysis of corn cracker with different percentages of wholegrain buckwheat flour

Samples	hardness (N)	Fracturability (N)	Adhesiveness (mJ)	Springiness (-)
C	180 ±2.55^{b}	1.9 ±0.21^{a}	34.0 ±1.88^{a}	1.20 ±0.11^{ab}
T_1	185 ±3.21^{b}	1.7 ±0.14^{a}	27.0 ±1.04^{b}	1.25 ±0.21^{a}
T_2	191 ±5.81^{b}	1.4 ±0.51^{b}	21.0 ±2.14^{c}	1.30 ±0.15^{a}
T_3	202 ±3.37^{a}	1.2 ±0.17^{b}	16.0 ±0.97^{d}	1.50 ±0.10^{ab}

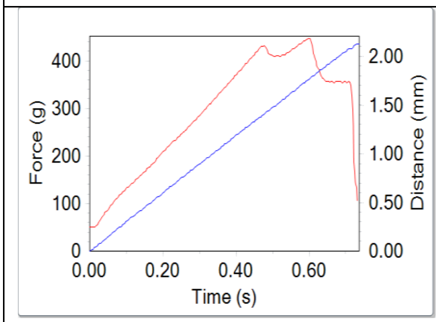
Values denoted by different letters (a–d) within the same column indicate a statistically significant difference at p ≤ 0.05. Control*: 70% CF +30 WF;* ***T_1****: 70% CF + 20 % WF +10% WBF;* ***T_2****: 70% CF + 10 % WF +20% WBF;* ***T_3****: 70% CF + 0 % WF +30% WBF*



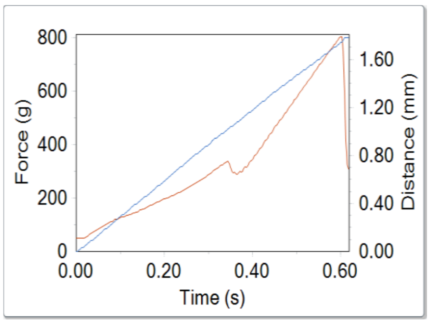
C: 70% CF +30 WF (control)



T_1: 70% CF + 20 % WF +10% buckwheat



T_2: 70% CF + 10 % WF +20% buckwheat;



T_3: 70% CF + 0 % WF +30% buckwheat

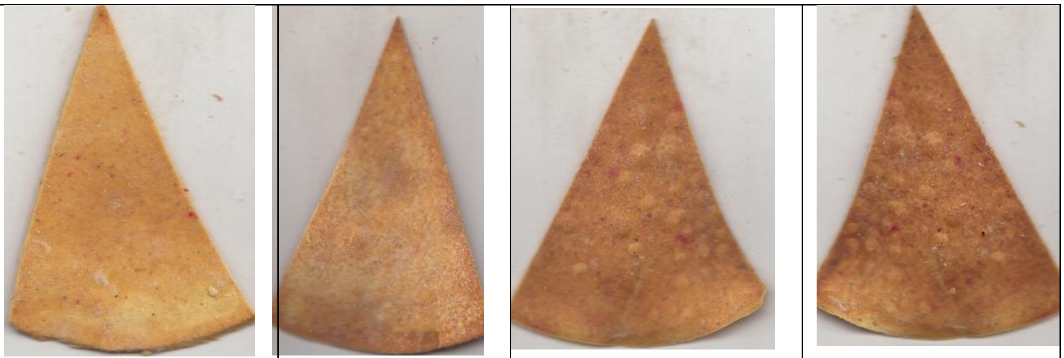
Figure *2. Texture measurement of corn crackers enriched with whole grain buckwheat flour*

Table 7: Sensory evaluation of corn crackers enriched with whole grain buckwheat flour

Samples	Sensory evaluation (scores 1-9)				
	Color	**Taste**	**Odor**	**Crispness**	**Overall acceptance**
C	8.27±0.21^{a}	8.00±0.31^{a}	8.00±0.70^{a}	7.00±0.11^{b}	8.47±0.19^{a}
T1	8.10±0.30^{a}	8.30±0.11^{a}	8.00±0.31^{a}	7.74±0.50^{a}	8.50±0.20^{a}
T2	7.72±0.11^{b}	8.28±0.14^{a}	8.00±0.80^{a}	7.80±0.27^{a}	8.16±0.31^{a}
T3	7.01± 0.40^{c}	7.08±0.00^{b}	8.00±0.11^{a}	6.55±0.33^{c}	6.95±0.11^{b}

Values denoted by different letters (a–d) within the same column indicate a statistically significant difference at p ≤ 0.05.

***Control**: 70% CF +30 WF; **T_1**: 70% CF + 20 % WF +10% WBF; **T_2**: 70% CF +10 % WF +20% WBF; **T_3**: 70% CF + 0 % WF +30% WBF*



C: 70% CF +30 WF (control)	**T_1**: 70% CF + 20 % WF +10% buckwheat	**T_2**: 70% CF + 10 % WF +20% buckwheat;	**T_3**: 70% CF + 0 % WF +30% buckwheat

***Figure 3:** Photos of corn crackers enriched with whole grain buckwheat*

الخصائص الريولوجية والتغذوية والحسية لمقرمشات الذرة المدعمة بدقيق الحنطة السوداء

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الملخص العربي:

تصنع العديد من مقرمشات الذرة أساسًا من دقيق الذرة، مع إضافة دقيق القمح لأغراض التصنيع وتحسين الخصائص الوظيفية. وقد أُجريت هذه الدراسة باستخدام دقيق الحنطة السوداء الكامل (WBF) بثلاث نسب مختلفة (10%، 20%، و30%) كبديل جزئي لدقيق القمح في تركيبة مقرمشات الذرة، وذلك بهدف دراسة التركيب الكيميائي، والخصائص الريولوجية، والخصائص الفيزيائية (مثل اللون والملمس)، إضافة إلى الخصائص الحسية لهذه المقرمشات. بلغت نسب الرطوبة، البروتين، الدهون، الرماد، الألياف، والكربوهيدرات في دقيق الحنطة السوداء الكامل 9.72%، 13.53%، 2.97%، 1.91%، 11.37%، و70.60% على التوالي. وأظهرت العينات المدعّمة بدقيق الحنطة السوداء مستويات أعلى من البروتين، الدهون، الألياف، والرماد مقارنة بالعينة الضابطة (الكنترول). فيما يتعلق بالخصائص الريولوجية، أدّت إضافة دقيق الحنطة السوداء إلى العجينة إلى زيادة ملحوظة في معايير جهاز الميكسولاب، بما في ذلك امتصاص الماء، ووقت تطوير العجينة، واستقرار العجينة، حيث تراوحت الزيادة من 0.36 إلى 5.05%، ومن 6.06 إلى 36.36%، ومن 10.81 إلى 48.64% على التوالي. ومع زيادة نسبة الحنطة السوداء، لوحظ انخفاض معنوي ($p \le 0.05$) في قيم الشفافية (L^*) والاحمرار (a^*) ، في حين لوحظت زيادة معنوية ($p \le 0.05$) في قيمة الاصفرار (b^*) ، والتي تراوحت بين 24.86 و27.32 في المقرمشات. ووفقًا لنتائج الدراسة، فقد أثبتت النسبة 20% من دقيق الحنطة السوداء الكامل فعاليتها في إنتاج مقرمشات ذات قيمة غذائية عالية وصفات فيزيائية ممتازة.

الكلمات المفتاحية: *دقيق القمح، التركيب الكيميائي، الميكسولاب ، تحليل القوام ، الخصائص الحسية.*