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Chemical and Nutritional Evaluation of Fortified Biscuit with Yellow Corn Flour as a Functional Food

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Abstract

The research aims to study the nutritional value of yellow corn flour and biscuit samples fortified with different levels (20,30,40 and 50%) of yellow corn flour to produce biscuit characterized with higher nutritive & antioxidants value ,which can be using as a functional food. The biscuits fortified with 40 and 50% yellow corn flour were chosen, which got best sensory evaluation and experiments were conducted on them. This study results that yellow corn flour contained higher amount of fat (3.90%), ash (1.85%) and fiber content (2.87%) compared with wheat flour. Moreover, yellow corn flour possessed higher mineral content, notably zinc, iron, soduim and potassium which are vital for health compared with wheat flour and was also rich in bioactive compounds such as beta carotene (44.95 µg/g), gallic (56.68 µg/g), caffeic (40.14 µg/g) and coumaric acid (37.28 µg/g). The sensory evaluation revealed that the inclusion of 40% and 50% yellow corn flour in preparing biscuits led to improve the sensory, chemical, nutritional, bioactive compound, color and physical properties in comparison with unfortified biscuit (control).

Keyword: *Bakery products, Sensory Evaluation, β-carotene. Zea maays, antioxidants*

Introduction

Rapid population growth and evolving consumer demands call for adjustments in agricultural production and systems. The median estimate for future growth shows that the world population is projected to increase by more 1 billion in 2050 and 11.2 billion by 2100 **(Islam and Karim, 2019)**. In Egypt, the population is currently growing at a rate of 1.94%, adding about 2 million people each year **(Shalaby *et al*., 2011)**.

Wheat consumption in Egypt during last five years was 19.80, 20.10, 20.30, 20.6 and 20.5 million tons for 17/18, 18/19, 19/20, 20/21 and 21/22, respectively **(FAOSTAT, 2022)**. Egypt is the largest wheat importer in the world; however, it produces only half of the 20 million tons of wheat that it consumes annually **(Abdalla *et al*., 2022)**. Egypt's main crops in terms of cultivated area are wheat, rice, and a large diversity of vegetables and fruit trees (i.e., citrus and dates) **(FAO, 2016)**. All in all, Egypt's agricultural sector cannot meet the growing and changing demands, and the country heavily depends on the import of food, mainly wheat **(McGill *et al*., 2015)**.

Corn flour, derived from ground maize kernels, is a versatile and widely used ingredient in the world. Known for its distinctive yellow hue, corn flour offers a mild, slightly sweet flavor that complements a variety of dishes **(Kumari, 2019)**. This finely ground flour is a key ingredient in numerous traditional dishes worldwide, including tortillas, cornbread, and various baked goods **(El Khoury *et al.*, 2018)**. It is valued not only for its role in creating delicious and textured foods but also for its nutritional content, featuring essential nutrients like fiber, vitamins, and minerals. As a staple in many cuisines, corn flour continues to be a fundamental component, contributing both flavor and nutritional benefits to a diverse range of culinary creations **(Woomer and Adedeji, 2021)**.

Upon incorporating yellow corn into a product, various biologically active compounds emerge, each contributing distinct biological importance and functional properties. These compounds may include antioxidants, such as carotenoids, which play a crucial role in neutralizing free radicals, thereby contributing to cellular health **(Saini *et al.*, 2021)**. Additionally, yellow corn contains dietary fiber, promoting digestive health and assisting in weight management.

Moreover, the presence of vitamins and minerals, such as vitamin A and potassium, enhances the nutritional value of the product. These elements are vital for maintaining vision, immune function, and electrolyte balance in the body. Yellow corn also contributes to the functional properties of the product, providing texture, flavor, and color, thereby enhancing overall sensory appeal **(Acosta-Estrada *et al.*, 2019)**.

Bakery products have been a part of human diets for thousands of years, with evidence of early bread-making dating back to ancient civilizations. Today, bakeries continue to play an important role in many cultures, offering a wide range of products that satisfy both the taste buds and the soul. With the rise of specialty diets and an increased interest in sustainable food systems, bakery products are likely to remain a fixture of our diets for generations to come. Bakery products are increasingly popular because of their ready to eat convenience, cost competitiveness availability of various products with different taste and textural profile, beneficial nutritional profile and longer shelf life. Other socio-economic factors such as increased income need to save time and ready access to the shelf at any time are also responsible for the increased demand of bakery products **(Azizi *et al*., 2003)**. Also, bakery products are the most important sources of dietary fiber in the total food consumption. Dietary fiber has an important role in controlling chronic disorders like diverticulitis, bowel cancer, cardiovascular disease, diabetes, constipation etc **(Kamaljit *et al*., 2010)**. Generally, the term biscuit is used in the European countries and cookies in the USA **(Sharif *et al*., 2009)**.

The increasing wheat gap puts pressure on wheat imports, which causes food insecurity, especially when international wheat prices spike and the global supply chain is disturbed under different circumstances such as COVID-19 and the Russian-Ukrainian war. The average wheat gap in the period between 2000 and 2020 is estimated at 7715 thousand tons. The gap has ranged between a maximum gap in 2019 estimated at 12,936 thousand tons and a minimum gap estimated at 3564 thousand tons in 2001 **(Abdalla *et al*., 2022)**.

So, the aim of this study was to yellow corn flour to wheat flour biscuits supplemented of as an alternative of wheat flour and evaluate of the impact of these alternative materials on chemical, physical, nutritional and organoleptic properties of the biscuits produced

Materials and methods

Materials

Wheat flour (72% extraction), yellow corn flour and materials for bakery products were obtained from local market, Kafrelsheikh, Egypt. All chemicals were in analytical grade and purchased from El-Gomhoria Company for chemicals and drugs, Tanta, Egypt. All analysis was done in triplicate.

Methods

Preparation of biscuit samples fortified with yellow corn flour

Biscuit blends were prepared by adding powder sugar and unsalted butter and mechanically beaten for 5 min until they creamed. Then the egg and baking powder and dough were added thoroughly and mixed with wheat flour for 2 min. The blended biscuits were backed in an oven at 180 °C for 20 min. After cooling at room temperature for 30 min, the biscuits were packed and used for evaluation of various physical and sensory characteristics. Yellow corn flour was substituted with wheat flour at ratios 20 (sample 2), 30 (sample 3), 40 (sample 4) and 50% (sample 5) (w/w) and sample 1 for 100% wheat flour (control) (Table A) **(Zedan, 2012).**

Table (A): The basic ingredients formula of biscuit samples

Ingredients	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Wheat flour (72%extraction)	200 g	160 g	140 g	120 g	100 g
Yellow corn flour	-	40 g	60 g	80 g	100 g
Sugar	75 g	75 g	75 g	75 g	75 g
Eggs	60 g	60 g	60 g	60 g	60 g
Butter (100% unsalted)	150 g	150 g	150 g	150 g	150 g
Baking powder	4 g	4 g	4 g	4 g	4 g

Sample 1= 100% wheat flour (Control), Samples 2, 3, 4 and 5 were formulated by 20, 30, 40 and 50% of corn flour, respectively.

Chemical Composition

Moisture, ash, crude protein, fiber and fat were determined according to **AOAC (2010).** Available carbohydrates were calculated by difference as follows: Available carbohydrates = [100 - (%fat + %proteins + %total dietary fiber + %ash)].

Minerals content

Minerals (Na, Ca, Mg, Fe, Zn and K) content was carried out using Atomic Absorption (NC. 9423-400-30042, England) by techniques described by **AOAC (2010)**.

Total Phenolic content

Total phenolic contet (TPC) was evaluated using the method of Folin-Ciocalteu, following the procedure outlined by **Attard (2013)** with some modifications. In summary, 10 µL of the sample or standard was mixed with 100 µL of diluted Folin-Ciocalteu reagent (1:10 dilution). Subsequently, 80 µL of 1M Na_2CO_3 was added, and the mixture was incubated for 20 minutes at room temperature in the dark. At the end of the incubation period, the resultant complex, displaying a blue color, was quantified at a wavelength of 630 nm. The obtained data are expressed as means ± standard deviation (SD).

β- Carotene content

About 5 mg of sample with glass beads were placed alternately in an ice bath and in a vortex with portions of 5 ml acetone. The extracts were centrifuged at 3500 rpm for 5 min and collected. The procedure was repeated three times, until both precipitate residue and supernatant became colorless. The extracts were also analyzed by reversed-phase high performance liquid chromatography (HPLC), with C18 column (250/4,6 mm) and a UV/VIS detector, with methanol: acetonitrile (75-25 v/v) as eluent. B-carotene was eluted over 30 min with a flow rate of 1 ml min. Peak was compared with retention times of standard B-carotene solution in acetone **(AOAC, 2010)**.

Color Measurement

Measurements were done using the reflection method with the use of Konica Minolta CM-3500d (Konica Minolta, Inc., Japan). Each sample was measured in six replicates.

Physical Evaluation of Biscuit

Physical properties included weight (g), thickness (cm), diameter (cm) and spread ratio (D/T) of biscuits samples were measured according to **AACC (2000)**.

Sensory Evaluation

A trained twenty-member panel consisting of students and staff member (both male and female) of the Home Economics Department was selected as their experience and familiarity with biscuit for the sensory evaluation. The tests were performed under fluorescent lighting in sensory evaluation laboratory. Tap water was provided to rinse the mouth between evaluations. The judges evaluated the samples for color, odor, taste, texture, mouth feel and overall acceptability **(Peter, 2004)**.

Statistical Analysis

Data were processed with the software of SPSS (Version 16.0, SPSS Inc., Chicago, IL) to test the variance by one-way analysis of variance (ANOVA) method. The means and the standard deviations were calculated of three repetitions **(Steel and Torrie, 1980)**.

Results and Discussion

Gross chemical composition of wheat and yellow corn flours

Table (1) represented the chemical composition of wheat and yellow corn flours. As shown, yellow corn flour had lower moisture content (10.82%), which may contribute to its longer shelf life compared to the wheat flour. Wheat flour had higher protein content (11.41%), which was expected as wheat flour is often used for its gluten-forming properties in baking. Yellow corn flour showed higher fat content (3.90%) compared to wheat. The ash content was relatively similar across all flours. Yellow corn flour represented higher fiber content (2.87%) than wheat flour (1.12%). This makes corn flour a better source of dietary fiber than wheat flour. Yellow corn flour had lower available carbohydrate content (81.80%) than wheat flour (84.42%).

Chemical composition of wheat flour was near to the results obtained by **Zaki *et al.*, (2018)** who found that protein, fat, fiber and ash were 10.86, 1.12, 0.54 and 0.47%, respectively. Also, **Ammar *et al.*, (2021)** and **Malavi *et al.*, (2022)** reported that protein, ash and fat were 9.31 and 10.20, 1.60 and 1.80 and 1.52 and 2.3%, respectively.

Table (1): Gross chemical composition (%) of wheat and yellow corn flours (on dry weight basis).

Components	Wheat flour	Yellow corn flour
Moisture	11.52±0.85[a]	10.82±0.56[a]
Protein	11.41±0.26[a]	9.58±0.77[b]
Fat	1.75±0.42[b]	3.90±0.04[a]
Ash	1.30±0.05[b]	1.85±0.01[a]
Fiber	1.12±0.10[b]	2.87±0.03[a]
Available carbohydrates	84.42±1.11[a]	81.80±1.25[a]

Values are means ± SD. Means having the different case letter(s) within a row are significantly different at P ≤ 0.05.
Available carbohydrate% = 100 – (protein% + fat% + ash% + fiber%).

Regarding corn flour, chemical composition was in a harmony with the results reported by **Al Shehry (2016)** and **El-Hamid *et al.*, (2019)** who reported that protein, ash and fat in corn flour were 9.85, 1.12 and 2.89%. Near protein amount (8.28%) was reported also by **Gómez-Aldapa *et al.*, (1999)**, while higher amount of fat (8.15%) was mentioned. Also, **Moawad *et al.*, (2018)** reported similar chemical composition of corn flour except protein content which was lower (5.45%) than protein content in this study. **Das *et al.*, (2018)** mentioned that corn flour contained 11.26, 0.74, 9.28, 3.62 and 75.07% for moisture, ash, protein, fat and carbohydrate, respectively. These results in a harmony with **Lamiaa *et al.*, (2007)** and **Mostafa *et al.*, (2019).**

Minerals content of wheat and yellow corn flours

Regarding minerals content of raw materials used in bakery products (Table 2), yellow corn flour had higher Zn (3.85 mg/100g) and K (330 mg/100g) contents. Fe content reached about 3.18 and 4.17 mg/100g for wheat and yellow corn flour, respectively.

Near results were reported by **Sharoba *et al.*, (2009)** for minerals content of wheat flour who mentioned that wheat flour contained K, Zn and Fe which reached about 129, 0.47 and 0.73 mg/100g, respectively. Also, **El-Gammal *et al.* (2016)** reported similar results of Fe and Zn in wheat flour reached about 2.54 and 0.23 mg/100g.

Table (2): Minerals content (mg/100g) of wheat and yellow corn flours

Minerals	Wheat flour	Yellow corn flour
Na	32.5±1.12[b]	47.91±2.09[a]
Ca	35±0.63[a]	28±0.97[b]
Mg	112±1.11[b]	147±2.34[a]
Fe	3.18±0.67[b]	4.17±0.34[a]
Zn	2.70±0.22[b]	3.85±0.58[a]
K	233±2.13[b]	330±3.24[a]

Values are means ± SD. Means having the different case letter(s) within a column are significantly different at P ≤ 0.05.

Al Shehry (2016) and **Paterne *et al.*, (2019)** reported near results of minerals content of corn flour. Also, minerals content of corn flour was in a harmony with the other reported by **Nikolić *et al.*, (2019)** who mentioned that Mg, Zn, Fe, Cu, Na and K were 143, 3.01, 5.87, 0.33, 17.8 and 263mg/100g, respectively and these results agree with **Lamiaa *et al.*, (2007)** and **Mostafa *et al.*, (2019).**

Bioactive compounds of wheat and yellow corn flours and its total phenolic contents.

Regarding total phenolic, Table (3) showed that yellow corn flour contained higher total phenolic content than wheat flour reached about 177.37 and 50 mg GAE/100g, respectively. **Nikolić *et al.*, (2019)** reported near amount of total phenolic content of corn flour reached about 110 mg/100g.

Carotenoids are lipid soluble bioactive components responsible for the yellow, orange and red colors in various fruits, flowers and vegetables **(Rao and Rao, 2007)**. Carotenoids are generally minor components of cereal grains **(Irakli *et al.*, 2011)**, although the amount of consumption of cereals as the staple food in most human cultures might make the cereals an important carotenoid source for humans **(Graham and Rosser, 2000)**. Among the carotenoids, β-carotene is the most important provitamin A carotenoid. It is found in fruits, leafy green vegetables, orange, yellow vegetables and some cereals **(Burri, 2011** and **Van Jaarsveld *et al*., 2005)**. Yellow corn flour recorded higher beta-carotene content (44.95 µg/g) than wheat flour showed beta-carotene content 2.24 µg/g. So, from the data reported, yellow corn flour was chosen in preparing bakery products. Near result was obtained by **Zaki *et al.* (2018)** who mentioned beta-carotene amount in wheat flour (0.11 mg/100g).

Table (3) presented the concentrations of various phenolic compounds in yellow corn flour and wheat flour. Phenolic compounds are a group of bioactive substances known for their potential health benefits due to their antioxidant properties.

Table (3): Bioactive compounds of wheat and yellow corn flours and its total phenolic contents

Bioactive compounds	**Wheat flour**	**Yellow corn flour**
Total phenolic (mg GAE/100 g)	50±1.03[b]	177.37±1.43[a]
Beta carotene (µg/g)	2.24±0.14[b]	44.95±0.78[a]
Gallic acid (µg/g)	25.46±1.11[b]	56.68±1.21[a]
Protocatechuic acid (µg/g)	35.82±0.99[b]	40.39±1.08[a]
Chlorogenic acid (µg/g)	33.49±0.54[b]	40.52±1.25[a]
Caffeic acid (µg/g)	1.31±0.37[b]	40.14±2.52[a]
Syringic acid (µg/g)	ND	7.77±0.21
Coumaric acid (µg/g)	ND	37.28±0.98

Values are means ± SD. Means having the different case letter within a row are significantly different at $P \leq 0.05$. ND= not detected.

Among the compounds analyzed, gallic acid is found in higher amount in yellow corn flour (56.68 µg/g) than wheat flour (25.46 µg/g). The same findings were observed for protocatechuic acid and chlorogenic acid, with yellow corn flour having higher levels of both compounds. Notably, caffeic acid was significantly higher in yellow corn flour (40.14 µg/g) compared to wheat flour (1.31 µg/g). Syringic acid was found in small amounts in yellow corn flour (7.77 µg/g) while in wheat flour it was not detected. Interestingly, coumaric acid was presented in notable quantities in yellow corn flour (37.28 µg/g) but was not detected in wheat flour. These results indicate that yellow corn flour contained higher overall levels of phenolic compounds than wheat flour. The variations in phenolic compound levels among the flours may be attributed to differences in their respective chemical compositions and processing methods. Phenolic compounds are of interest due to their potential health benefits, and these findings could have implications for food and nutritional research, as well as the development of functional foods with enhanced antioxidant properties.

Color measurement of wheat and yellow corn flours blends some raw materials used in prepared biscuit samples

From the results in Table (4) about the color parameters L*, a* and b* of the different flours used in the study, it could be concluded that:

L* value: This parameter measures the lightness or darkness of the sample. In this study, the 100% wheat flour had the highest L* value, indicating that it was lighter in color compared to the other flours. On the other hand, the 100% yellow corn flour had the lowest L* value, indicating that it was darker in color compared to the other flours.

a* value: This parameter measures the redness or greenness of the sample. The 100% yellow corn flour had the highest a value, indicating that it was redder in color compared to the other flours. While, all other samples reported no significant differences between them in a* value.

b* value: This parameter measures the yellowness or blueness of the sample. The 100% yellow corn flour had the highest b* value, indicating that it was more yellow in color compared to the other flours.

Table (4): Color measurement of wheat, yellow corn flours and blends

Samples	L*	a*	b*
100% wheat flour	97.86 ± 1.90^{a}	2.33 ± 1.68^{b}	10.89 ± 0.27^{d}
100% yellow corn flour	92.81 ± 0.45^{b}	5.04 ± 0.58^{a}	27.49 ± 0.79^{a}
20% yellow corn flour	97.32 ± 2.33^{ab}	2.75 ± 1.50^{b}	13.67 ± 0.62^{c}
30% yellow corn flour	97.06 ± 2.22^{ab}	2.21 ± 0.90^{b}	13.38 ± 0.49^{c}
40% yellow corn flour	96.41 ± 1.08^{ab}	2.35 ± 0.63^{b}	16.68 ± 0.29^{b}
50% yellow corn flour	94.98 ± 1.62^{ab}	2.53 ± 0.86^{b}	17.32 ± 0.62^{b}

Values are means ± SD. Means having the different case letter within a column are significantly different at $P \leq 0.05$.

The 100% wheat flour had the lowest b* value, indicating that it was less yellow in color compared to the other flours. Regarding blends between wheat and corn flour, it could be noticed that by increasing the amount of corn flour (40 and 50%) b* value increased followed by blends with 20 and 30%.

Also, **Gebreil *et al*., (2020)** mentioned that corn flour color was near to the previous results which reached about 92.88, 1.10 and 31.12 for L*, a* and b*, respectively. **Ammar *et al*., (2021)** mentioned similar results of corn flour color which reported to be 71.4 for L*, 6.75 for a* and 36.85 for b* and these results agree with those obtained by **Lamiaa *et al*., (2007)** and **Mostafa *et al*., (2019)**

Sensory evaluation of prepared biscuit as a functional food fortified with different levels of yellow corn flour

Figure (1) and Table (5) represented the prepared biscuit and the sensory evaluation for biscuit samples fortified with different levels of yellow corn flour, respectively. The scores were evaluated based on sample taste, color, odor, texture, mouth feel and overall acceptability.

The result showed that sample 1 (100% wheat flour) had good overall acceptability and scores consistently across all parameters evaluated. When 20% yellow corn flour (sample 2) was added to the product, the texture and mouth feel scores decrease slightly, whereas, the other parameters remained significantly the same. However, the addition of 30% yellow corn flour (sample 3) has improved the mouthfeel and overall acceptability of the product significantly.

Furthermore, the addition of 40 (sample 4) and 50% (sample 5) yellow corn flour showed even higher scores than samples 2 and 3, with scores consistently high in all parameters evaluated. Particularly, samples 4 and 5 appeared to have resulted in the highest scores in samples compared to samples 2 and 3.

Table (5): Sensory evaluation of prepared biscuit samples fortified with different levels of yellow corn flour.

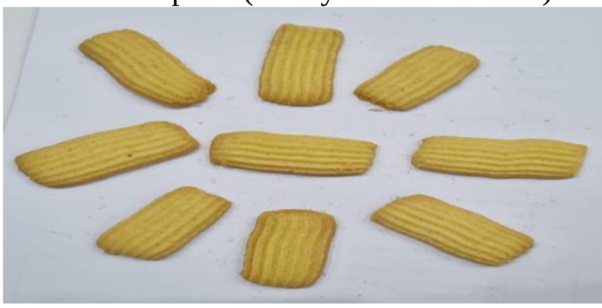
Biscuit samples	Taste	Color	Odor	Texture	Mouth feel	Overall acceptability
Sample 1	8.35 ± 1.60^{b}	8.95 ± 1.36^{a}	8.45 ± 1.79^{a}	8.75 ± 1.59^{ab}	8.40 ± 1.85^{bc}	8.40 ± 1.27^{b}
Sample 2	8.15 ± 1.35^{b}	9.00 ± 1.30^{a}	8.45 ± 1.47^{a}	7.85 ± 1.46^{b}	8.00 ± 1.45^{b}	8.20 ± 1.20^{b}
Sample 3	8.45 ± 1.39^{b}	9.30 ± 1.38^{a}	9.05 ± 1.28^{a}	8.60 ± 0.94^{ab}	8.90 ± 1.12^{abc}	8.70 ± 1.13^{ab}
Sample 4	9.60 ± 0.50^{a}	9.65 ± 0.67^{a}	9.55 ± 0.80^{a}	9.10 ± 1.07^{a}	9.55 ± 0.76^{a}	9.55 ± 0.69^{a}
Sample 5	8.98 ± 1.03^{ab}	9.75 ± 0.44^{a}	9.45 ± 0.89^{a}	9.15 ± 1.18^{a}	9.40 ± 0.94^{ab}	9.35 ± 0.75^{a}

Values are means ± SD. Means having the different case letter(s) within a column are significantly different at $P \leq 0.05$. Sample 1= 100% wheat flour (Control), Samples 2, 3, 4 and 5 were formulated by 20, 30, 40 and 50% of corn flour, respectively.

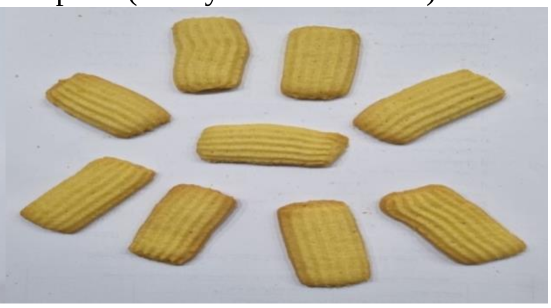
Sample 1 (Control 100% wheat flour)

Sample 2 (20% yellow corn flour)

Sample 3 (30% yellow corn flour)



Sample 4 (40% yellow corn flour)



Sample 5 (50% yellow corn flour)

Figure (1): Prepared biscuit as a functional food fortified with different levels of yellow corn flour

Finally, the results of overall acceptability showed that the biscuit samples 4 and 5 were the best sample as compared to biscuit samples and the other prepared one.

Gross chemical composition of prepared biscuit fortified with different levels of yellow corn flour

Regarding the chemical composition of biscuit samples fortified with different levels of yellow corn flour, the results showed that using yellow corn flour in biscuit production could increase the fiber, fat and ash contents of the product which reached about 0.80, 0.91, 16.30% for sample 4 (40% yellow corn flour) and 0.91, 0.96 and 16.48% for sample 5 (50% yellow corn flour), respectively (Table 6). On the other hand, protein content was reduced from 13.10% for sample 1 (100% wheat biscuits) to 11.30 and 10.95% for sample 4 and 5 (40 and 50% yellow corn flour), respectively. These results in harmony with **Lamiaa *et al*., (2007)** and **Mostafa *et al*., (2019)**

Table (6): Chemical composition of prepared biscuit samples fortified with different level of yellow corn flour (on dry weight basis).

Biscuit samples	Moisture	Protein	Fat	Ash	Fiber	Available carbohydrates
Sample 1	4.35±0.3[a]	13.10±0.1[a]	15.60±0.05[c]	0.70+0.01[b]	0.53±0.02[c]	70. 07±0.12[b]
Sample 4	4.82±0.4[a]	11.30±0.32[b]	16.30±0.12[a]	0.91±0.01[a]	0.80±0.03[b]	70.69±0.16[a]
Sample 5	5.10±0.2[a]	10.95±0.64[c]	16.48 ±0.52[a]	0.96±0.02[a]	0.91 ±0.02[a]	70.70±0.19[a]

Values are means ± SD. Means having the different case letter within a column are significantly different at $P \leq 0.05$.
Available carbohydrate% = 100 – (protein% + fat% + ash% + fiber%)
Sample 1= 100% wheat flour (Control), Samples 4 and 5 were formulated by 40 and 50% of corn flour, respectively.

When comparing the two types of biscuits made from corn flour, it could be seen that, the biscuit made with 50% yellow corn flour had lower protein content (10.95%) and higher fiber content (0.91%) than the biscuits made with 40% yellow corn flour (11.30 and 0.80%, respectively). However, the fat, ash and available carbohydrate contents are not significantly different between the two types of biscuits.

Approximately results were obtained by **El-Hamid *et al*., (2019)** for the chemical composition of biscuits made from 100% wheat flour which reached about 3.95, 0.35, 8.92, 17.31, 0.89 and 72.35% for moisture, ash, protein, fat, fiber and carbohydrate, respectively. Also, **Makinde and Taibat (2018)** reported that biscuits made from 100% wheat flour contained 1.70% ash, 9.73% protein, 11.52% fat, 1.09% fiber and 74.86% carbohydrate.

Also, **Van Toan and Tran (2012)** reported that substitution of wheat flour by corn flour in preparation of biscuits resulted in improvement of its nutritional values as chemical composition.

Das *et al*., (2018) studied the effect of supplementation of wheat flour with corn flour on the chemical composition of biscuits and found that, 100% wheat flour, 10, 15 and 20% corn flour contained 4.91, 4.75, 4.66 and 4.59% for moisture, 0.77, 0.79, 0.84 and 0.91% for ash, 7.86, 7.78, 7.71 and 7.65% for protein, 17.60, 17.72, 17.78, and 17.83% for fat, 68.86, 68.96, 69.01 and 69.05% for carbohydrate, respectively. These results were near to our results which indicated that by increasing corn flour amount in biscuits, ash, fat and available carbohydrate increased, while protein amount decreased.

Minerals content of prepared biscuit fortified with different levels of yellow corn flour

Table (7) provided the nutritional composition of three different types of biscuits made with different types of flours: wheat flour, corn flour with 40 and 50%

yellow corn flour. Data showed the amount of macronutrients (Na, Ca, Mg, K) and micronutrients (Fe, Zn) in each type of biscuit mg/100 g.

In terms of sodium (Na) content, sample 1 had lower amount at 99 mg/100g. The yellow corn flour biscuit had higher amounts, with the 40% corn flour biscuit (sample 4) containing 181.4 mg/100g and the 50% corn flour biscuit (sample 5) containing 217.2mg / 100g.

Table (7): Minerals content (mg/100g) of prepared biscuit samples fortified with different levels of yellow corn flour.

Minerals	Sample 1	Sample 4	Sample 5
Na	99.00±1.23^{c}	181.40±2.31^{b}	217.20±1.98^{a}
Ca	59.70±2.63^{c}	181.40±2.31^{a}	73.60±1.52^{b}
Mg	58.80±3.45^{a}	51.30±1.21^{b}	45.10±0.99^{c}
Fe	1.16±0.07^{a}	1.05±0.04^{a}	0.90±0.11^{b}
Zn	0.75±0.02^{c}	0.84±0.02^{b}	0.95±0.01^{a}
K	145.70±1.24^{c}	152.80±2.51^{b}	169.40±1.64^{a}

Values are means ± SD. Means having the different case letter within a column are significantly different at $P \leq 0.05$.
Sample 1= 100% wheat flour (Control), Samples 4 and 5 were formulated by 40 and 50% of corn flour, respectively.

Calcium (Ca), magnesium (Mg) and potassium (K) were essential minerals for healthy bones, muscles and heart function. Sample 1 (100%wheat flour) had higher amount of magnesium (58.8 mg per 100g) compared to the yellow corn flour biscuits. Sample 4 (40% yellow corn flour) and 5 (50% yellow corn flour) had a higher amount of calcium (60.10 and 73.60 mg/100g) than sample 1(100% wheat flour) (59.70 mg/100g). All three types of biscuits were good sources of potassium, with sample 1(100% wheat flour) having the lowest amount (145.7 mg/100g) and sample 5(50% yellow corn flour) having the highest amount (169.40 mg/100g).

Iron (Fe) and zinc (Zn) were essential micronutrients involved in various physiological processes, such as immune function, growth, and development. Sample 1 (100% wheat flour) contained 1.16 mg of iron and 0.75 mg of zinc/100g, while the yellow corn flour biscuits contain higher amount of Zn for sample 4 and sample 5 (0.84 and 0.95 mg/100g, respectively) and lower amount of Fe.

In conclusion, the nutritional composition of biscuits can vary depending on the type of flour used. The wheat flour biscuit (sample 1) had higher magnesium and iron, while the yellow corn flour biscuits (samples 4 and 5) have higher sodium, calcium, zinc and potassium content. All three types of biscuits are good sources of essential minerals.

El-Hamid *et al*., (2019) found near minerals content of biscuits made from 100% wheat flour which was determined to be 71.96, 1.74 and 2.08 mg/100g for Ca, Fe and Zn, respectively. While, **Makinde and Taibat (2018)** reported lower results for biscuits made from 100% wheat flour.

β-carotene and total phenolic content of prepared biscuit fortified with different levels of yellow corn flour

Among the various cereal dietary sources of carotenoids, maize (Zea mays L.), especially the yellow seeded type, is notable as the cereal that accumulates the highest level of carotenoids **(Pixley *et al.*, 2013)**.

The results of β-carotene and total phenolic contents were demonstrated in Table (8). When wheat and corn flours were used to prepare biscuits samples, the resulting β- carotene and total phenolic content varied depending on the different levels of flours used. Sample 1 had the lowest beta carotene and total phenolic content (10.94 µg/100g and 55.08 mg/100g, respectively), while sample 5 had the highest β-carotene and total phenolic content (27.82 µg/100g and 109.75 mg/100g, respectively). Sample 4 contained 19.36 µg/100g and 89.70 mg/100 for β-carotene and total phenolic content, respectively.

Table (8): β-carotene and total phenolic content of prepared biscuits samples fortified with different levels of yellow corn flour.

Biscuit samples	β- carotene (µg/100g)	Total phenolic(mg/100g)
Sample 1	10.94 ± 0.02^{c}	55.08 ± 0.02^{c}
Sample 4	19.36 ± 0.01^{b}	89.70 ± 0.03^{b}
Sample 5	27.82 ± 0.01^{a}	109.75 ± 0.02^{a}

Values are means ± SD. Means having the different case letter within a column are significantly different at $P \leq 0.05$.
Sample 1= 100% wheat flour (Control), Samples 4 and 5 were formulated by 40 and 50% of corn flour, respectively.

Similar results were reported by **Van Toan and Tran (2012)** who found that total phenolic content in biscuits made from 100% wheat flour was 23.4 mg/100g. These results revealed that incorporating yellow corn flour into biscuit formulations can increase their beta carotene and total phenolic content.

Color measurement of prepared biscuit fortified with different levels of yellow corn flour:

Table (9) showed the color results of biscuits samples made with different flour compositions: 100% wheat flour (sample 1), 40% corn flour and 50% yellow corn flour (samples 4 and 5, respectively).

The L* parameter measures the lightness of the color, where higher values indicate lighter colors, and lower values indicate darker colors.

The L* parameter indicated that sample 1 (66.92) had a higher lightness value compared to both sample 4 (66.50) and sample 5 (66.31), which had lower L* values, but without any significant differences.The same observation was reported regarding the a* parameter, between the three batches of biscuits.

Table (9): Color measurement of prepared biscuit samples fortified with different levels of yellow corn flour

Biscuit samples	L*	a*	b*
Sample 1	66.92±1.48^{a}	8.00±1.48^{a}	35.80±3.04^{b}
Sample 4	66.50±1.09^{a}	6.47±0.70^{a}	41.23±1.01^{ab}
Sample 5	66.31±1.85^{a}	7.94±0.54^{a}	41.57±2.24^{a}

Values are means ± SD. Means having the different case letter within a column are significantly different at P ≤ 0.05.
Sample 1= 100% wheat flour (Control), sample 4= 40% yellow corn flour, sample 5= 50% yellow corn flour.

For the b* parameter, which measures the yellowness-blueness of the color, samples 4 and 5 (41.23 and 41.57, respectively) had significantly higher values than sample 1 (35.80) which was due to the results of b* in yellow corn flour.

In summary, the results showed that the biscuits made with 40 (sample 4) and 50% (sample 5) yellow corn flour had a significantly higher yellowness (b*). Near results for the color of biscuits made from 100% wheat flour was reported by **El-Hamid *et al*., (2019)**. Also, **Guohua and Na (2018)** reported that corn flour enhanced the specific volume, springiness and color of sponge cake significantly.

Physical properties of prepared biscuit

Table (10) presented the physical properties of three types of biscuits. The average diameter of the biscuits samples increases from 6.00 cm for sample 1 (100% wheat flour) to 6.30 cm for sample 4 (40% yellow corn flour) and 6.50 cm for sample 5 (50% yellow corn flour). The average thickness/height remained relatively consistent, sample 1 at 0.42 cm, sample 4 at 0.40 cm and sample 5 at 0.41 cm. As for the spread ratio, the biscuit made with 50% yellow corn flour (sample 5) showed the highest expansion (15.85), followed by sample 4 (15.75) and sample 1 (14.63).

Table (10): Physical properties of prepared biscuit samples fortified with different levels of yellow corn flour.

Biscuit samples	Diameter(cm)	Thickness/Height	Spread ratio	Weight (g)
Sample 1	6.00±0.01^{c}	0.42±0.02^{a}	14.63±0.12^{b}	15.22±0.10^{c}
Sample 4	6.30±0.02^{b}	0.40±0.01^{a}	15.75±0.15^{a}	16.17±0.13^{b}
Sample 5	6.50±0.02^{a}	0.41±0.03^{a}	15.85±0.09^{a}	17.53±0.09^{a}

Values are means ± SD. Means having the different case letter within a column are significantly different at P ≤ 0.05.
Sample 1= 100% wheat flour (Control), sample 4= 40% yellow corn flour, sample 5= 50% yellow corn flour.

Additionally, the weight of the biscuits increased with corn content, with sample 1 weighing 15.22 g, sample 4 weighing 16.17 g and sample 5 weighing 17.53 g. These results suggested that the inclusion of yellow corn in the biscuit formulation leads to larger and heavier biscuits with increased spread during baking, which may be attributed to differences in ingredient properties and these results agree with **Lamiaa *et al*., (2007)** and **Mostafa *et al*., (2019).**

Conclusion

It could be concluded from the results of the study the addition of Yellow corn flour at levels 40and 50% in the formulation of biscuits had significant effects on color value, sensory quality, bioactive compounds and physical characteristics of the biscuits, like size, thickness, and spread, are positively impacted by the inclusion of yellow corn flour with increased of beta-carotene , total phenolics ,essential minerals and decreased carbohydrates. As a result of the sensory and chemical evaluation, the overall acceptance of biscuits was found best in biscuits supplemented with 40 and 50% Yellow corn flour. It can be concluded that Yellow corn flour addition improved the nutritional quality and functional of biscuits

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التقييم الكيميائي والغذائي للبسكويت المدعم بدقيق الذرة الأصفر كغذاء وظيفي

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الملخص العربي

يهدف البحث إلى دراسة القيمة الغذائية لدقيق الذرة الصفراء وعينات البسكويت المدعمة كغذاء وظيفي باستبدالات مختلفة (20 – 30 – 40 – 50%) من دقيق الذرة الصفراء وتم اختيار البسكويت المضاف إليه دقيق الذرة الصفراء بنسبة 40 و 50% وحصل على أفضل تقييم حسي وأجريت التجارب عليه.

أظهرت نتائج الدراسة أن دقيق الذرة الصفراء يحتوي على نسبة عالية من الدهون (3.90%) والرماد (1.85%) والألياف (2.87%) مقارنة بدقيق القمح. علاوة على ذلك، يحتوي دقيق الذرة الصفراء على نسبة عالية من الأملاح المعدنية ، لا سيما الزنك (3.85 ملجم/100 جم) والحديد (4.17 ملجم/100 جم) والصوديوم (47.91 ملجم/100 جم) والبوتاسيوم (330 ملجم/100 جم) التي تعتبر حيوية للصحة بالقارنة بدقيق القمح، كما يحتوي على نسبة عالية من المركبات النشطة بيولوجيًا مثل البيتا كاروتين (44.95 ميكروجرام/جم)، وحمض الجاليك (56.68 ميكروجرام/جم)، والكافيين (40.14 ميكروجرام/جم) وحمض الكوماريك (37.28 ميكروجرام/جم). وقد أظهر التقييم الحسي أن التدعيم بدقيق الذرة الصفراء بنسبة 40% و50% في تحضير البسكويت أدى إلى تحسن التقييم الحسي والكيميائي والغذائي والحيوي واللون والخصائص الفيزيائية مقارنة بالبسكويت غير المدعم (الكنترول).

وتوصي الدراسة بضرورة تسليط الضوء على إضافة دقيق الذرة الصفراء بمستوى 40 و50% للبسكويت لزيادة الخصائص الحسية والكيميائية والغذائية والحيوية واللونية، حيث يمكن استخدام البسكويت كغذاء وظيفي في الوجبات اليومية.

الكلمات المفتاحية: منتجات المخابز، التقييم الحسي، بيتا كاروتين، الذرة، مضادات الأكسدة