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# Physicochemical and Technological Evaluation of some Egyptian Hull-less and Hulled Barley Varieties for Biscuit Preparation

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## ABSTRACT

Recently, there is increasing interest in the utilization of barley grains in many food applications because of their prominent nutritive value and multiple health benefits. This investigation aimed to evaluate the physicochemical and functional properties for some Egyptian hull-less (Giza 130, 135, 136) and hulled (Giza 132, 133, 134, 137, 138) barley varieties, and their applications as functional and nutritive ingredients in biscuits to promote them as high-value products. The chemical and phytochemicals composition of barley flour (BF) significantly differed according to the variety of barley. BF is an excellent source of protein (9.48 – 11.38%), ash (1.53 – 1.97%), fibers (3.30 – 4.56%) and NFE (69.56 – 72.16%). It had higher contents of total phenolic (194.38 – 253.77 mg GAE/100g) and total flavonoids (19.98 – 31.61 mg QE/100g) than wheat flour (WF, 129.41 mg GAE/100g and 12.74 mg QE/100g). BF revealed optimum color characteristics and good functional properties. The addition of BF improved the most important functional properties of WF, consequently, its utilization value in food industry. The supplemented biscuits with 30% BF had excellent quality attributes and improved nutritional value in terms of protein (8.29 – 8.89%), ash (1.36 – 1.56%), fibers (1.76 – 2.39%), total phenolics (132.05 – 186.22 mg GAE/100g) and total flavonoids (13.99 – 22.13 mg QE/100g). In view of these results, BF (from hull-less and hulled barley varieties) can successfully be used (as functional and nutritive ingredients) in combination with WF (up to 30%) to obtain delicious and healthy nutritious biscuits.

***Keywords:*** Barley flour, physicochemical properties, functional properties, biscuits, nutritive ingredients.

## INTRODUCTION

Barley (*Hordeum vulgare*) is one of the most common cereal crops in the world. Also, it is one of the best-adapted crops for cultivation in diverse conditions worldwide (Chalak *et al*. 2015; Zhu, 2017). The global barley production amounted to approximately 147.72 million metric tons in 2022, with an increase from around 145.40 million metric tons in 2021 (USDA, 2022). Most of the barley grown in the world is utilized in animal feed and malt production. Only small quantities of barley grains are used for human consumption as nutritious and medicinal foods. Recently, there is increasing interest in the utilization of barley grains in many food applications because of their prominent nutritive value and multiple health benefits. This interest droves new attention towards the cultivation of barley under the light of new food purposes. Consequently, creating new and better opportunities for both farmers and food manufacturers (Yalcin *et al*. 2007; Madakemohekar *et al*., 2018; Farag *et al*., 2020; Sakellariou and Mylona, 2020; Aly *et al*., 2021).

Barley cultivars are mainly divided as hulled or hull-less based on whether the hull adheres tightly on grains or not. Hulled barley has a tough, inedible outer hull around its kernel. It is minimally processed by carefully removing the indigestible hull while leaving much of the outer bran intact. Hull-less barley is a different variety of barley in which the tough inedible outer hull is loosely attached to kernels and naturally falls off in the field during harvesting. There is no further processing required to remove the hull in this type of barley. Its bran and endosperm layers are intact. Hull-less barley has higher contents of protein and β-glucan than the hulled barley. Thus, hull-less cultivars are considered the healthiest form of barley and more suitable for the human diet. However, hull-less barley varieties have lower yield potential than hulled barley varieties under the same cultivation conditions (Yalcin *et al*. 2007; Madakemohekar *et al*., 2018; Sturite *et al*. 2019).

Barley grains are excellent sources of many valuable nutrients i.e., dietary fibres, proteins, vitamins and minerals. The highest nutritive value has been correlated with β-glucan, the main fiber components in barley grains, which are beneficial for human health. They also have high levels of tocotrienols, phenolic compounds and lignans, which are responsible to reduce the risk of coronary heart diseases, diabetes, and certain cancers. Generally, barley acts as a functional food due to its health-promoting components that have shown positive health effects. These unique properties of barley enable its exploited in the production of novel functional foods such as extruded snacks, breads, noodles, biscuits, cookies and muffins (Baik and Ullrich, 2008; Holtekjolen *et al*. 2008; Zhao *et al*., 2008; Sullivan *et al*., 2013; Idehen *et al*., 2017; Narwal *et al*., 2017; Madakemohekar *et al*., 2018; Farag *et al*., 2020; Rani *et al*., 2020; Sakellariou and Mylona, 2020; Aly *et al*., 2021; Bangar *et al*. 2022).

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In wheat grains, most of their nutrients are concentrated in the outer bran layer. Unfortunately, these nutrients are removed during milling leaving wheat flour with the starch only. Hence, the nutritional quality of wheat-based products (i.e., biscuits) is low because of the poor nutritional value of wheat flour. However, the nutritional and health benefits of these products can be extra improved by incorporating with flour from other nutritious grains (i.e., barley grains). This can provide an opportunity to upgrade the nutritional level of many people (Narwal *et al*., 2017; Farag *et al*., 2020; Ni *et al*., 2020; Bangar *et al*. 2022).

Functional properties are those physicochemical characteristics of food proteins that determine their behavior in food systems during processing, preparation, storage and consumption. These properties and the way in which proteins interfere with other food components, whether directly or indirectly, impact the processing applications, food quality and the final acceptability of food products. The kind of functional property required in a protein or a protein blend varies with the particular food system in question. Among the functional properties, protein solubility, water binding, oil absorption, emulsification, gelation and foaming are the most important functional properties that food industries require in the novel protein ingredients. The clear knowledge and deep understanding of the functional properties of individual food proteins is essential for optmizing their use in specific food systems (Abdel-Hameed, 2005; Moure *et al*., 2006; Hasmadi *et al*., 2020).

The principal aims of this investigation were to evaluate the physicochemical and functional properties for some Egyptian hull-less (Giza 130, 135, 136) and hulled (Giza 132, 133, 134, 137, 138) barley varieties, and their applications as functional and nutritive ingredients in biscuits to promote them as high-value products.

## MATERIALS AND METHODS

**Materials:**

Freshly harvested barley grains (*Hordeum valgare*) from different Egyptian hull-less (Giza 130, 135, 136) and hulled (Giza 132, 133, 134, 137, 138) barley varieties were obtained from the Field Crops Research Farm, Mallawi Agricultural Research Station, Minia, Egypt. Wheat flour (72% extraction), corn oil, sugar, vegetable bakery shortening and baking powder were obtained from the local market. The chemicals used in this investigation were of analytical grade and obtained from Sigma-Aldrich pharmaceutical chemicals.

**Methods:**

**Preparation of barley flour (BF):**

The hull-less barley grains (Giza 130, Giza 135, Giza 136) were cleaned and moistened to14% moisture for 24 hrs. The moisten grains were immediately milled using an electric laboratory hammer mill (Perten laboratory mill 3100) having a sieve passage of 0.80 mm, then sifted through 60 mesh screens to obtain fine whole barley flour. The hulled barley grains (Giza 132, 133, 134, 137, 138) were firstly subjected to dehulling (peeling) using a peeling machine (Peeling machine-ЗШН) as reported by Anisimov *et al*. (2022). The technique is based on the exposure of the grains to a high-frequency field while increasing the strength of this field during the peeling process to a certain maximum value, which leads to the separation of husks from the kernels while maintaining their quality. The hulled barley grains were separated from the husks using suitable sieves, then milled and sifted as above to obtain fine barley flour, as illustrated in Fig. 1. The obtained barley flours were packed in vacuum zip lock bags and stored in airtight containers at ~ 4°C till analysis and use.

**Fig. 1. Photographs of barley grains and their flour.**

**Preparation of biscuits:**

The control and supplemented biscuits were manufactured employing the recipe presented by Manohar and Rao (1997), as shown in Table 1 and Fig. 2. Based on the performed preliminary trials, wheat flour was substituted by 30% barley flour from each variety (Giza 130, 132, 133, 134, 135, 136, 137, 138). The corresponding codes for supplemented biscuits were B-$G_{130}$, B-$G_{132}$, B-$G_{133}$, B-$G_{134}$, B-$G_{135}$, B-$G_{136}$, B-$G_{137}$, B-$G_{138}$, respectively.

**Table 1. Formulation of control and supplemented biscuits.**

| Ingredients | Control biscuits (100% WF) | Supplemented biscuits with 30% barley flour from each variety |
|---|---|---|
| Wheat flour (WF, 72% extraction) | 100 g | 70 g |
| Barley flour (BF) | 0 | 30* |
| Powdered sugar | 30 | 30 |
| Shortening | 20 | 20 |
| Sodium chloride | 1 | 1 |
| Sodium bicarbonate | 0.50 | 0.50 |
| Ammonium bicarbonate | 1 | 1 |
| Baking powder | 0.30 | 0.30 |
| Water | 20 | 20 |

*** Based on preliminary trials.**

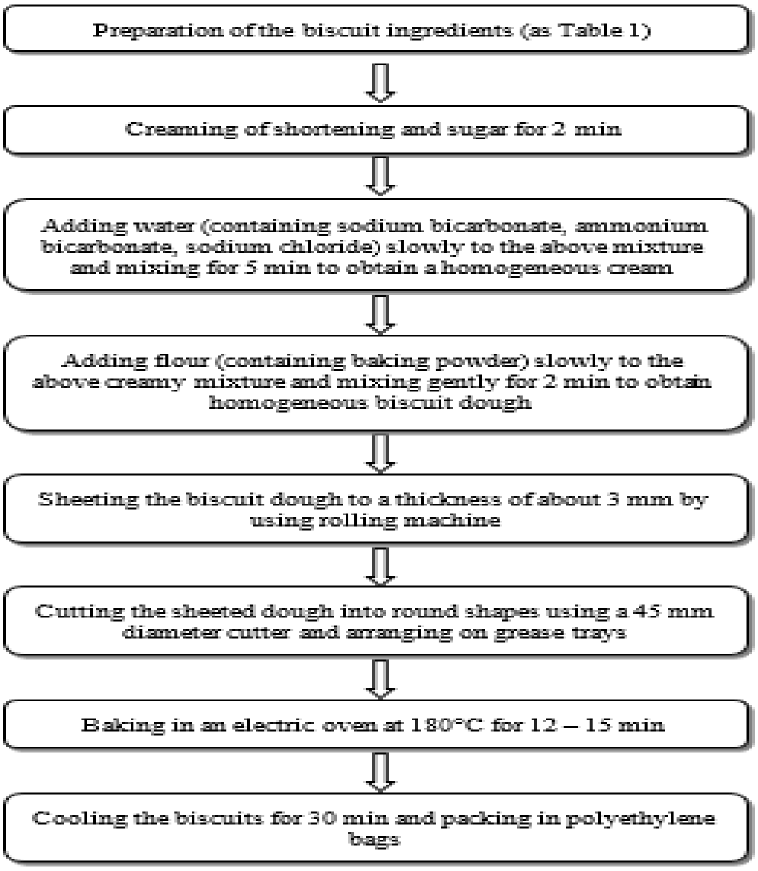


**Fig. 2. The processing steps of biscuits preparation.**

**Chemical analysis:**

The contents of moisture, protein, fat, ash and fibers were estimated using the standard AOAC (2016) techniques. Nitrogen free extract (NFE) was computed by difference [100 – (Moisture + protein + fat + ash + fibers)]. Energy value (Kcal/100g) was computed employing the factor 4 per gram proteins or NFE and 9 per gram fats (Greenfield and Southgate, 1992). All estimates were performed in 3 replicates and expressed as arithmetic averages.

**Phytochemicals composition:**

**Total phenolics:**

The total phenolics (for wheat flour, barley flour and biscuits) were estimated using the Folin-Ciocalteu reagent (Musa *et al*., 2011). For extraction, 20 g of each sample was homogenized with 200 mL diluted methanol (50%) for 2 min, then centrifuged at 4000 rpm for 10 min. The supernatant was obtained and filtered using Whatman No.1 filter papers. In a test tube, 1 mL extract was mixed with 4 mL distilled water, then 5 mL diluted Folin-Ciocalteu reagent (0.20 *N*) was added. After 5 min, 10 mL of 7.5% (w/v) Na2CO3 was added and mixed well using vortex. After 2 hours, the absorbance was recorded at 765 nm. Appropriate gallic acid standard curve was prepared and used for estimating the total phenolics concentration of each sample. The data was presented as mg gallic acid equivalents/100g sample (mg GAE/100g).

**Total flavonoids:**

The total flavonoids (for wheat flour, barley flour and biscuits) were estimated employing the colorimetric procedure (Abu Bakar *et al*., 2009). In a test tube, 1.00 mL sample extract was mixed with 4.50 mL distilled water then 0.30 mL of 5% (w/v) NaNO2 was added. After 6 min, 0.60 mL of 10% AlCl3.6H2O was added and allowed to stand for 5 min for reaction. Then, 2.00 mL of 4% NaOH solution (1 *M*) was added and mixed well using vortex. The absorbance was immediately taken at 510 nm. Appropriate quercetin standard curve was prepared and used for estimating the flavonoids content of each sample. The data was reported as mg quercetin equivalents/100g sample (mg QE/100g).

**Color characteristics:**

All tested flour samples as well as the produced biscuits (control and supplemented with 30% barley flour) were evaluated for their color quality attributes (L, a, b), using the Tec-PCM colorimeter (Shih *et al*., 2009). The numerical total color difference (ΔE), hue angle and chroma were computed from the measured L, a, b values, (Lo, ao, bo = L, a, b for the used reference samples), as follows:

$$\mathbf{\Delta E} = [(\mathbf{L} - \mathbf{L}o)^2 + (\mathbf{a} - \mathbf{a}o)^2 + (\mathbf{b} - \mathbf{b}o)^2]^{½}$$

$$\textbf{Hue angle} = [\mathbf{tan^{-1}}\,(\mathbf{b}/\mathbf{a})]$$

$$\textbf{Chroma} = [(\mathbf{a}^2 + \mathbf{b}^2)]^{½}$$

**Functional properties:**

**Bulk density (BD):**

Previously weighed graduated cylinders were carefully filled up to 20 mL of each flour sample and accurately reweighed. From the differences of weight, the BD was computed and presented as g/mL (Bencini, 1986).

**Water absorption capacity (WAC):**

One gram of each flour sample was weighed into a previously weighed glass centrifuge tube then 6.0 mL distilled water was added. The tube was agitated manually until the sample was dispersed. A stopper was placed on the tube and shaken for 30 min. The tubes were centrifuged at 3000 rpm for 20 min. The supernatants were removed and dried in preweighed petri dishes. The WAC was estimated by weighing the tubes after removing the supernatants and water adhering droplets. The values were corrected for soluble solids and presented as percentages of original weights (Hulse *et al*., 1977).

**Oil absorption capacity (OAC):**

One gram of each flour sample was weighed into a centrifuge tube and 5 mL of corn oil was added. The tubes were covered and shaken for 15 min. Then, they were allowed to stand for 30 min and centrifuged at 3000 rpm for 20 min. The free oil was removed and the tubes were reweighed. The OAC values were computed and presented as percentages of original weights (Hulse *et al*., 1977).

**Gelation properties:**

In test tubes (each containing 10 mL distilled water), appropriate sample suspensions (2 – 20%, w/v) were prepared and heated for one hour in a boiling water bath. After quick cooling using cold water, the tubes were further refrigerated for two hours at ~ 4°C. The gelation properties were described as the least gelation concentration (LGC), when the samples from the inverted test tubes did not fall down or slip (Sathe *et al*., 1982; Ihekoronye, 1986).

**Foaming properties:**

Three grams of each flour sample were whipped with 100 mL distilled water for 5 min using an electrical blender at high speed. They were immediately poured into 250 mL graduated cylinders and the foam volume was recorded after 30 sec. The foaming capacity (FC) was expressed as percentage volume increase as follows:

$$FC = \frac{\text{Vol. (mL) after whipping} - \text{Vol. (mL) before whipping}}{\text{Vol. (mL) before whipping}} \times 100$$

The foam stability (FS) was estimated according to McWatters *et al*. (1976); Ihekoronye (1986) by measuring the FC at 5, 10, 30, 60, 90, 120, 150 and 180 min. The FS was expressed as percentage between FC at 60 min and the real corresponding FC at 30 sec using the following formula: FS at 60 min = (FC at 60 min / FC) × 100.

**Physical characteristics of biscuits:**

Biscuits were assessed for their thickness (cm), width (cm), spread ratio (SR) and spread factor (SF). Five biscuits were employed for the evaluation and averages were noted. The SR and SF were computed employing the equations reported by Manohar and Rao (1997) as follows: SR = width / thickness; SF = (SR of sample / SR of control) × 100.

**Sensory evaluation:**

The sensory evaluation for color, texture, taste, odor and overall quality of biscuits was performed to evaluate consumers preferences, using a nine-point hedonic scale. The panelists (15 men and 15 women, 19 – 57 years old) comprising of academic staff (Department of Food Science), postgraduates who previously experienced in sensory evaluation as well as regular biscuit consumers. They were rested under white light in separate airy places during morning sessions. After random coding, biscuits were presented for the panelists to evaluate their preferences (Larmond, 1977; ISO 4121, 2003).

**Statistical analysis:**

The statistical analysis was performed employing the SPSS software program. All data was expressed as arithmetic averages ± standard deviations (SD). The averages and SD values were measured by the Duncan's multiple range test using one-way analysis of variance (ANOVA) at 5% significant level ($P < 0.05$). Principal component analysis (PCA) was performed for the color characteristics of biscuits (Snedecor and Cochran, 1980; Grane and Jach, 2014).

# RESULTS AND DISCUSSION

**Physicochemical and functional properties of barley flour:**

The physicochemical and functional properties of barley flour (from hull-less and hulled barley varieties) were evaluated for potential applications as functional and nutritive ingredients in biscuit preparation.

**Chemical composition of wheat flour and barley flour:**

The proximate chemical composition of wheat flour (WF) and barley flour (BF) are presented in Table 2. From which, it could be seen that WF (72% extraction) contained 11.41% moisture, 9.36% protein, 1.30% fat, 0.89% ash, 0.71% fibers and 76.33% nitrogen free extract (NFE). The energy value of WF was 354.46 Kcal/100g (as such basis). The results in the same table indicated that BF is considered as an excellent source of protein (9.48 – 11.38%), ash (1.53 – 1.97%), fibers (3.30 – 4.56%) and NFE (69.56 – 72.16%). The results also showed that BF contained 10.79 – 11.38% moisture and had a higher fat content (2.00 – 2.25%) as compared with WF. This could be due to the impact of milling techniques on moisture and fat contents since the separation of germ from bran during barley grain milling is not good as wheat grain milling. The chemical composition of BF significantly differed according to the variety of barley. For example, the hulled barley variety Giza 134 recorded the highest protein content (11.38%) followed by the hull-less barley variety Giza 136 which contained 10.82% protein. The lowest protein content (9.48%) was recorded for the hulled variety Giza 137. The highest fibers content (4.56%) was recorded for the hulled variety Giza 133. Whereas the hull-less barley variety Giza 130 recorded the lowest fibers content (3.30%). The energy values of BF were found to be 341.71 – 346.68 Kcal/100g (as such basis). Based on the nutritional properties of BF, it can be incorporated as a nutritive constituent for the preparation of healthy nutritious food products (i.e., biscuits).

Barley grains are characterized by their high nutritive value with respect to proteins, dietary fibers, vitamins, minerals and other bioactive compounds. According to Kaur and Das (2015), the whole BF contained 10.51% moisture, 10.21% protein, 0.87% fat, 0.99% ash, 1.82% fibers and 75.61% NFE. Regarding wheat grains, they are characterized by elevated percentage of carbohydrates (~ 70%), comparatively low contents of protein (9.0 – 13.0%), moisture, lipids, minerals, vitamins and fibers. Arshid *et al*. (2018) revealed that whole WF contained 9.08% moisture, 11.54% protein, 1.74% fat, 1.38% ash, 1.33% fibers and 76.26% NFE. The corresponding values for whole BF were 7.14, 13.63, 4.04, 3.05, 3.51 and 72.14%, respectively. Rani *et al*. (2020) analyzed three different Indian hull-less barley varieties (Dolma, BHS-352, HBL-276) for their physicochemical and functional characteristics. They reported that the hull-less barley grains contained 7.91 – 8.97% moisture, 12.80 – 14.20% protein, 2.69 – 3.24% fat, 2.26 – 2.64% ash, 2.26 – 2.81% fibers and 71.38 – 73.75% NFE.

**Table 2. Chemical composition of wheat flour and barley flour (as such basis).**

| Constituents (%)* | Wheat flour (72% ext.) | Hull-less (naked) barley varieties | | | Hulled barley varieties | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Giza 130 | Giza 135 | Giza 136 | Giza 132 | Giza 133 | Giza 134 | Giza 137 | Giza 138 |
| Moisture | 11.41 ± $0.03^{a}$** | $11.08^{bc}$ ± 0.07 | $10.98^{c}$ ± 0.20 | $10.90^{c}$ ± 0.10 | $10.96^{c}$ ± 0.05 | $10.86^{c}$ ± 0.03 | $10.96^{c}$ ± 0.04 | $10.79^{c}$ ± 0.13 | $11.38^{ab}$ ± 0.46 |
| Protein | 9.36 ± $0.04^{h}$ | $9.92^{e}$ ± 0.02 | $10.32^{d}$ ± 0.01 | $10.82^{b}$ ± 0.02 | $9.67^{f}$ ± 0.03 | $9.96^{e}$ ± 0.04 | $11.38^{a}$ ± 0.02 | $9.48^{g}$ ± 0.02 | $10.57^{c}$ ± 0.02 |
| Fat | 1.30 ± $0.06^{e}$ | $2.00^{d}$ ± 0.09 | $2.20^{ab}$ ± 0.04 | $2.07^{bcd}$ ± 0.09 | $2.05^{cd}$ ± 0.08 | $2.15^{abc}$ ± 0.02 | $2.25^{a}$ ± 0.08 | $2.03^{cd}$ ± 0.09 | $2.20^{ab}$ ± 0.02 |
| Ash | 0.89 ± $0.02^{g}$ | $1.53^{f}$ ± 0.03 | $1.65^{e}$ ± 0.02 | $1.64^{e}$ ± 0.01 | $1.76^{d}$ ± 0.01 | $1.83^{c}$ ± 0.02 | $1.89^{b}$ ± 0.07 | $1.84^{bc}$ ± 0.01 | $1.97^{a}$ ± 0.01 |
| Fibers | 0.71 ± $0.04^{d}$ | $3.30^{c}$ ± 0.08 | $3.44^{c}$ ± 0.07 | $3.85^{b}$ ± 0.29 | $3.87^{b}$ ± 0.07 | $4.56^{a}$ ± 0.19 | $3.94^{b}$ ± 0.16 | $4.36^{a}$ ± 0.15 | $3.57^{c}$ ± 0.13 |
| Nitrogen free extract*** | 76.33 ± $0.03^{a}$ | $72.16^{b}$ ± 0.22 | $71.40^{c}$ ± 0.17 | $70.71^{d}$ ± 0.29 | $71.68^{c}$ ± 0.03 | $70.63^{d}$ ± 0.13 | $69.56^{e}$ ± 0.18 | $71.48^{c}$ ± 0.22 | $70.29^{d}$ ± 0.49 |
| Energy value (Kcal/100g) | 354.46 ± $0.05^{a}$ | $346.32^{c}$ ± 0.11 | $346.68^{b}$ ± 0.10 | $344.75^{d}$ ± 0.13 | $343.85^{e}$ ± 0.05 | $341.71^{h}$ ± 0.06 | $344.01^{e}$ ± 0.09 | $342.11^{g}$ ± 0.11 | $343.24^{f}$ ± 0.18 |

*** Average of 3 replicates ± SD. ** The averages having diverse characters inside each row are significantly differed (*P*<0.05). *** Calculated by difference.**

**Phytochemicals composition of wheat flour and barley flour:**

The phytochemicals composition (total phenolics and total flavonoids) of WF and BF are presented in Table 3. From which it could be seen that, the total phenolics values for BF were found to be 194.38 – 253.77 mg GAE/100g. The total flavonoids values were 19.98 – 31.61 mg quercetin equivalents/100g sample (mg QE/100g). WF had a lower content of total phenolics (129.41 mg GAE/100g) and total flavonoids (12.74 mg QE/100g). The phytochemicals composition of BF significantly differed according to the variety of barley. For example, the hull-less barley variety Giza 135 recorded the highest total phenolics content (253.77 mg GAE/100g) followed by the hulled barley variety Giza 132 (224.42 mg GAE/100g). The lowest total phenolics content (194.38 mg GAE/100g) was recorded for the hull-less barley variety Giza 130. The highest total flavonoids content (31.61 mg QE/100g) was recorded for the hull-less barley variety Giza 136 followed by the hulled barley variety Giza 134 (28.59 mg QE/100g). Whereas the hull-less barley variety Giza 130 recorded the lowest total flavonoids content (19.98 mg QE/100g). These results indicated that barley grains and their products are excellent sources of natural antioxidants due to the existence of phenolic compounds. The phytochemicals present in barley grains may be largely responsible for their health benefits (Kim *et al*., 2007; Zhao *et al*., 2008; Idehen *et al*., 2017; Narwal *et al*., 2017; Bangar *et al*. 2022).

Kim *et al*. (2007) revealed that the hull-less barley groups had higher contents (268.60 μg/g) of phenolic compounds than the hulled barley groups (207.00 μg/g). According to Narwal *et al*. (2017), the hull-less barley BHS352 (an Indian barley variety) had higher (854.44 µg GAE/g) phenolic content than the whole WF HS490 (365.56 µg GAE/g). The incorporation of BF into WF (at 30% level) increased its phenolic content to 448.89 µg GAE/g. Furthermore, Bangar *et al*. (2022) evaluated the total phenolics content for BF from different India barley cultivars (cv.BH-393, cv.BH-885, cv.BH-902, cv.BH-932, cv.DWR-52, and cv.PL-172). They observed that the contents of total phenolics significantly differed among barley cultivars. Their values ranged between 2890 and 3922 µg GAE/g. A similar trend was also observed for the total flavonoids content of BF from the six barley varieties. Their values ranged between 1968 and 2198 µg catechin equivalents/g.

**Table 3. Phytochemicals composition of wheat flour and barley flour.**

| Phytochemicals* | Wheat flour (72% ext.) | Hull-less (naked) barley varieties | | | Hulled barley varieties | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Giza 130 | Giza 135 | Giza 136 | Giza 132 | Giza 133 | Giza 134 | Giza 137 | Giza 138 |
| Total phenolics*** | 129.41 ± $0.39^{f}$ | $194.38^{e}$** ± 14.20 | $253.77^{a}$ ± 1.81 | $200.23^{de}$ ± 2.36 | $224.42^{b}$ ± 2.84 | $205.12^{cd}$ ± 3.85 | $212.90^{c}$ ± 1.88 | $200.13^{de}$ ± 1.11 | $207.67^{cd}$ ± 6.59 |
| Total flavonoids**** | 12.74 ± $0.33^{g}$ | $19.98^{f}$ ± 0.15 | $26.61^{d}$ ± 0.08 | $31.61^{a}$ ± 0.69 | $26.75^{cd}$ ± 0.92 | $27.20^{cd}$ ± 0.23 | $28.59^{b}$ ± 0.21 | $21.77^{e}$ ± 0.32 | $27.59^{c}$ ± 0.79 |

*** Average of 3 replicates ± SD. ** The averages having diverse characters inside each row are significantly differed (*P*<0.05).**
***** (mg gallic acid equivalents/100g sample). **** (mg quercetin equivalents/100g sample).**

**Color characteristics of wheat flour and barley flour:**

The color characteristics of wheat flour and barley flour are shown in Table 4. From which it could be seen that the color parameters L, a, b, ΔE, hue angle and chroma for wheat flour were 89.30, 1.57, 10.97, 00.00, 81.86 and 11.08, respectively. The corresponding values for barley flour (from hull-less barley varieties) were 86.97 – 87.57, 2.13 – 2.97, 9.17 – 11.03, 2.24 – 2.99, 71.95 – 79.05 and 9.64 – 11.26, respectively. The barley flour (from hulled barley varieties) recorded the values 86.30 – 88.80, 1.77 – 2.50, 9.97 – 11.87, 1.20 – 3.28, 76.26 – 80.11 and 10.13 – 12.13, respectively. It could also be seen that the color characteristics of barley flour significantly differed (in some cases) according to the variety of barley. Consequently, significant differences in ΔE values were observed in some cases. For example, the hulled barley variety Giza 138 recorded the highest ΔE value (3.28) followed by the hull-less barley variety Giza 136 (2.99). The lowest ΔE value (1.20) was recorded for the hulled barley variety Giza 137, when compared to wheat flour. Concerning the hue angle, all barley flour samples (from hull-less and hulled barley varieties) recorded lower (71.95 – 80.11) values than wheat flour (81.86). The highest chroma value (12.13) was recorded for the hulled barley variety Giza 134 followed by the hulled barley variety Giza 138 (11.66). Whereas the hull-less barley variety Giza 136 recorded the lowest chroma value (9.64). The photographs of barley flour (from hull-less and hulled barley grains) are shown in Fig. 3.


**Fig. 3. The photographs of barley flour (from hull-less and hulled barley grains).**

**Table 4. Color characteristics of wheat flour and barley flour.**

| Color parameters* | Wheat flour (72% ext.) | Hull-less (naked) barley varieties | | | Hulled barley varieties | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Giza 130 | Giza 135 | Giza 136 | Giza 132 | Giza 133 | Giza 134 | Giza 137 | Giza 138 |
| L (Lightness) | 89.30 ± 0.44$^{a**}$ | 86.97$^{de}$ ± 0.51 | 87.53$^{cd}$ ± 0.75 | 87.57$^{cd}$ ± 0.35 | 87.50$^{cd}$ ± 0.00 | 88.03$^{bc}$ ± 0.55 | 88.37$^{bc}$ ± 0.50 | 88.80$^{ab}$ ± 0.70 | 86.30$^{e}$ ± 0.26 |
| a (redness/greenness) | 1.57 ± 0.12$^{d}$ | 2.13$^{bcd}$ ± 0.06 | 2.53$^{ab}$ ± 0.25 | 2.97$^{a}$ ± 0.15 | 2.50$^{ab}$ ± 0.10 | 1.77$^{d}$ ± 0.72 | 2.50$^{ab}$ ± 0.30 | 1.90$^{cd}$ ± 0.17 | 2.43$^{abc}$ ± 0.35 |
| b (yellowness/blueness) | 10.97 ± 0.55$^{ab}$ | 11.03$^{ab}$ ± 0.29 | 10.97$^{ab}$ ± 1.12 | 9.17$^{c}$ ± 1.17 | 10.23$^{bc}$ ± 0.55 | 9.97$^{bc}$ ± 0.76 | 11.87$^{a}$ ± 0.50 | 10.40$^{abc}$ ± 0.52 | 11.40$^{ab}$ ± 1.05 |
| ΔE*** | 0.00 ± 0.00$^{e}$ | 2.42$^{bc}$ ± 0.48 | 2.24$^{bc}$ ± 0.66 | 2.99$^{ab}$ ± 0.68 | 2.20$^{bc}$ ± 0.17 | 1.86$^{cd}$ ± 0.41 | 1.66$^{cd}$ ± 0.55 | 1.20$^{d}$ ± 0.31 | 3.28$^{a}$ ± 0.18 |
| Hue angle**** | 81.86 ± 0.68$^{a}$ | 79.05$^{abc}$ ± 0.58 | 76.91$^{bc}$ ± 1.82 | 71.95$^{d}$ ± 1.72 | 76.26$^{c}$ ± 0.63 | 80.11$^{ab}$ ± 3.20 | 78.08$^{bc}$ ± 1.68 | 79.60$^{abc}$ ± 1.39 | 77.86$^{bc}$ ± 2.21 |
| Chroma***** | 11.08 ± 0.55$^{abcd}$ | 11.24$^{abc}$ ± 0.27 | 11.26$^{abc}$ ± 1.09 | 9.64$^{d}$ ± 1.15 | 10.53$^{bcd}$ ± 0.55 | 10.13$^{cd}$ ± 0.88 | 12.13$^{a}$ ± 0.47 | 10.57$^{bcd}$ ± 0.48 | 11.66$^{ab}$ ± 1.01 |

*** Average of 3 replicates ± SD.** **** The averages having diverse characters inside each row are significantly differed (*P*<0.05).**
***** = $[(L - L_o)^2 + (a - a_o)^2 + (b - b_o)^2]½$ .** ****** = $[\tan^{-1} (b/a)]$.** ******* = $[(a^2 + b^2)]½$ .**

**Functional properties of wheat flour and barley flour:**

The reports on functional properties of barley flour from hull-less and hulled barley varieties are still scanty. Therefore, the functional properties i.e., bulk density (BD), water absorption capacity (WAC), oil absorption capacity (OAC), foaming capacity (FC), foam stability (FS) and least gelation concentration (LGC) of wheat flour, barley flour and their blends are evaluated and presented in Tables 5 and 6. The results showed that wheat flour had the highest value (0.52 g/mL) of bulk density as compared to barley flour (0.48 – 0.49 g/mL). The barley variety did not affect the bulk density values significantly. Blending of barley flour in wheat flour (30% level) caused a decrease in the bulk density value of wheat flour (Table 6). Bulk density is a measure of the heaviness of the flour samples. It depends on the particle size and moisture content of flour. It is important in determining how much space (volume) the material will occupy when packed (Kramer and Kwee, 1977; Hasmadi *et al*., 2020).

Concerning the WAC values, all barley flour samples (from hull-less and hulled barley varieties) recorded higher (155.05 – 173.52%) values than wheat flour (87.13%). This could be due to the variations of their protein and fiber contents (as shown in Table 2). It could also be seen that the WAC values of barley flour significantly differed according to the variety of barley. Generally, the hull-less barley varieties recorded higher WAC values (165.82 – 173.52%) than the hulled barley varieties (155.05 – 161.41%). For example, the hull-less barley variety Giza 136 recorded the highest WAC value (173.52%) followed by the hull-less barley variety Giza 130 (169.47%). Whereas the hulled barley variety Giza 137 recorded the lowest WAC value (155.05%). Data in Table 6 revealed that the addition of barley flour (from hull-less and hulled barley varieties) to wheat flour improved its ability to absorb water. In food applications the WAC is an important function of protein in viscous foods such as soups, meat rolls, comminuted meats, processed cheese, doughs, etc. It is associated with the ability to retain water against gravity, and includes bound water, hydrodynamic water, capillary water and physically entrapped water (Moure *et al*., 2006; Gharibzahedi and Smith, 2020; Hasmadi *et al*., 2020).

With respect to OAC, all barley flour samples (from hull-less and hulled barley varieties) recorded higher (109.65 – 118.12%) values than wheat flour (89.78%). In most cases, the barley variety did not affect the OAC values significantly. Excluding Giza 133, the hull-less barley varieties recorded lower OAC values (111.49 – 114.85%) than the hulled barley varieties (114.90 – 118.12%). Concerning the hull-less varieties, Giza 130 and 135 recorded nearly the same OAC values (111.49 and 111.74), whereas Giza 136 recorded a higher value (114.85%). In the case of the hulled varieties, the highest OAC value (118.12%) was observed for Giza 134 followed by Giza 138 (117.35%), whereas Giza 133 recorded the lowest value (109.65%). As shown in Table 6, the incorporation of barley flour into wheat flour up to 30% level improved its ability to absorb oil, the values had the same trend of WAC. These results clearly showed an inverse relation between bulk density and OAC. It is likely that most of oil retained by proteins is really physically trapped. Hence its quantity is principally affected by the surface area and bulk density of the protein preparations. In food applications, the WAC and OAC are associated with the texture, mouthfeel and flavor retention of food products (Shevkani *et al*., 2015; Ma *et al*., 2018; Hasmadi *et al*., 2020).

**Table 5. Functional properties of wheat flour and barley flour.**

| Functional properties* | Wheat flour (72% ext.) | Hull-less (naked) barley varieties | | | Hulled barley varieties | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Giza 130 | Giza 135 | Giza 136 | Giza 132 | Giza 133 | Giza 134 | Giza 137 | Giza 138 |
| Bulk density (g sample/mL) | 0.52 ± 0.01$^{a**}$ | 0.48$^{b}$ ± 0.01 | 0.48$^{b}$ ± 0.01 | 0.49$^{b}$ ± 0.01 | 0.48$^{b}$ ± 0.01 | 0.49$^{b}$ ± 0.01 | 0.48$^{b}$ ± 0.01 | 0.49$^{b}$ ± 0.01 | 0.48$^{b}$ ± 0.01 |
| Water absorption capacity (g water/100g)*** | 87.13 ± 0.73$^{g}$ | 169.47$^{b}$ ± 0.55 | 165.82$^{c}$ ± 0.88 | 173.52$^{a}$ ± 0.86 | 155.63$^{f}$ ± 0.97 | 158.23$^{e}$ ± 0.43 | 161.41$^{d}$ ± 0.62 | 155.05$^{f}$ ± 0.69 | 156.32$^{f}$ ± 0.40 |
| Oil absorption capacity (g oil/100g) | 89.78 ± 0.63$^{e}$ | 111.49$^{c}$ ± 1.15 | 111.74$^{c}$ ± 0.37 | 114.85$^{b}$ ± 0.97 | 114.90$^{b}$ ± 0.71 | 109.65$^{d}$ ± 1.07 | 118.12$^{a}$ ± 1.12 | 116.79$^{a}$ ± 0.49 | 117.35$^{a}$ ± 0.65 |
| Foaming capacity (%) | 53.66 ± 1.52$^{a}$ | 45.00$^{b}$ ± 3.00 | 44.33$^{b}$ ± 2.08 | 42.66$^{b}$ ± 1.15 | 44.00$^{b}$ ± 2.00 | 45.33$^{b}$ ± 1.15 | 43.33$^{b}$ ± 1.15 | 44.66$^{b}$ ± 1.15 | 44.66$^{b}$ ± 3.05 |
| Foam stability at 60 min (%)**** | 28.57 ± 0.69$^{a}$ | 25.95$^{b}$ ± 0.85 | 25.52$^{b}$ ± 1.51 | 27.34$^{ab}$ ± 1.19 | 27.31$^{ab}$ ± 1.24 | 26.45$^{ab}$ ± 1.65 | 26.15$^{ab}$ ± 1.13 | 26.84$^{ab}$ ± 1.67 | 26.51$^{ab}$ ± 1.31 |
| Least gelation concentration (% w/v) | 16.00 ± 0.02$^{a}$ | 12.00$^{b}$ ± 0.02 | 12.00$^{b}$ ± 0.02 | 12.00$^{b}$ ± 0.02 | 12.00$^{b}$ ± 0.02 | 12.00$^{b}$ ± 0.02 | 12.00$^{b}$ ± 0.02 | 12.00$^{b}$ ± 0.02 | 12.00$^{b}$ ± 0.02 |

*** Average of 3 replicates ± SD.** **** The averages having diverse characters inside each row are significantly differed ($P$<0.05).**
***** Corrected for soluble solids.** ****** $FS_{60min}$ = ($FC_{60\,min}$ / FC) × 100.**

**Table 6. Functional properties of wheat flour and wheat flour blended with 30% barley flour.**

| Functional properties* | Wheat flour (72% ext.) | Wheat flour blended with 30% barley flour | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Hull-less (naked) barley varieties | | | Hulled barley varieties | | | | |
| | | Giza 130 | Giza 135 | Giza 136 | Giza 132 | Giza 133 | Giza 134 | Giza 137 | Giza 138 |
| Bulk density (g sample/ml) | 0.52 ± 0.01$^{a**}$ | 0.49$^{b}$ ± 0.01 | 0.49$^{b}$ ± 0.01 | 0.49$^{b}$ ± 0.01 | 0.49$^{b}$ ± 0.00 | 0.49$^{b}$ ± 0.00 | 0.50$^{b}$ ± 0.01 | 0.49$^{b}$ ± 0.01 | 0.49$^{b}$ ± 0.01 |
| Water absorption capacity (g water/100g)*** | 87.13 ± 0.73$^{g}$ | 104.02$^{b}$ ± 0.82 | 103.83$^{b}$ ± 0.28 | 107.19$^{a}$ ± 0.57 | 97.97$^{f}$ ± 0.88 | 99.67$^{de}$ ± 0.56 | 100.58$^{cd}$ ± 0.47 | 98.92$^{ef}$ ± 0.26 | 101.05$^{c}$ ± 0.82 |
| Oil absorption capacity (g oil/100g) | 89.78 ± 0.63$^{e}$ | 105.79$^{b}$ ± 0.54 | 106.22$^{b}$ ± 0.34 | 106.85$^{b}$ ± 0.32 | 106.84$^{b}$ ± 0.63 | 104.68$^{c}$ ± 0.57 | 108.55$^{a}$ ± 0.57 | 108.12$^{a}$ ± 0.52 | 109.20$^{a}$ ± 1.13 |
| Foaming capacity (%) | 53.66 ± 1.52$^{a}$ | 48.66$^{b}$ ± 1.15 | 47.33$^{bc}$ ± 1.15 | 45.33$^{c}$ ± 1.15 | 46.66$^{bc}$ ± 1.15 | 47.33$^{bc}$ ± 1.15 | 46.66$^{bc}$ ± 1.15 | 46.66$^{bc}$ ± 1.15 | 48.33$^{b}$ ± 0.57 |
| Foam stability at 60 min (%)**** | 28.57 ± 0.69$^{a}$ | 27.38$^{ab}$ ± 0.53 | 26.75$^{bc}$ ± 0.57 | 26.48$^{bc}$ ± 0.68 | 25.72$^{c}$ ± 0.62 | 26.42$^{bc}$ ± 0.57 | 25.36$^{c}$ ± 0.62 | 25.72$^{c}$ ± 0.62 | 25.52$^{c}$ ± 1.37 |
| Least gelation concentration (% w/v) | 16.00 ± 0.02$^{a}$ | 14.00$^{b}$ ± 0.02 | 14.00$^{b}$ ± 0.02 | 14.00$^{b}$ ± 0.02 | 14.00$^{b}$ ± 0.02 | 14.00$^{b}$ ± 0.02 | 14.00$^{b}$ ± 0.02 | 14.00$^{b}$ ± 0.02 | 14.00$^{b}$ ± 0.02 |

*** Average of 3 replicates ± SD.** **** The averages having diverse characters inside each row are significantly differed ($P$<0.05).**
***** Corrected for soluble solids.** ****** $FS_{60min}$ = ($FC_{60\,min}$ / FC) × 100.**

Gelation properties are necessary to the structure of many foods (i.e., sausage emulsion, custard type pudding, sauces) and are related to the rheological properties of a variety of food system. They are influenced by various factors i.e., the pH values, reductants, ionic strength, temperatures, non-protein constituents, the mechanical forces applied to the system, etc. The results in Table 5 showed that the minimum concentration percentages required to obtain strong gels were 12.0% for all studied samples except for wheat flour, which formed a strong gel at a higher concentration of 16%. The barley variety did not affect the gelation properties significantly. The incorporation of barley flour into wheat flour up to 30% level enhanced the gelling properties of wheat flour (Table 6). In food systems, the gels are intermediate states between solids and liquids. The liquid is water and the gel molecular nets are formed by proteins, polysaccharides or mixtures of them (Sathe, 2002; Moure *et al*., 2006; Gharibzahedi and Smith, 2020; Hasmadi *et al*., 2020).

Foaming properties are desired and utilized in many food systems for aeration and whipping. They are largely depend on various processes including molecular movements, penetrations and rearranging at the air-water interfaces. Foaming capacity (FC) measures the amount of interfacial area created by proteins during foaming. Foam stability (FS) indicates the ability to stabilize against gravitational and mechanical stresses. It is a necessary quality index for many food products (i.e., whipping creams and ice creams). The results of foaming properties (Table 5) showed that all barley flour samples (from hull-less and hulled barley varieties) recorded lower (42.66 – 45.33%) FC than wheat flour (53.66%). The FS of wheat flour (28.57%) was nearly the same as barley flour (26.15 – 27.34%), except for Giza 130 (25.95%) and Giza 135 (25.52%). The barley variety did not affect the foaming properties significantly, all of them had nearly the same values of FC and FS. Data in Table 6 revealed that the addition of barley flour (from hull-less and hulled barley varieties) to wheat flour significantly decreased its foaming properties. In food systems, proteins are the principal surface active agents needed for stabilizing the dispersed gaseous phase (Moure *et al*., 2006; Ma *et al*., 2018; Gharibzahedi and Smith, 2020; Hasmadi *et al*., 2020).

As mentioned before, the reports on functional properties of barley flour from hull-less and hulled barley varieties are still scanty. In this respect, Rani *et al.* (2020) analyzed three different Indian hull-less barley varieties (Dolma, BHS-352, HBL-276) for their physicochemical and functional characteristics. Their results showed that the bulk density of barley grains was found to be 0.71 – 0.75 g/mL. The WAC for barley flour was found in the range of 2.20 to 2.70 mL/g. The Dolma variety showed the highest WAC due to its greater content of small granules starch. A positive correlation was detected between β-glucan content and WAC.

The highest OAC value (1.60 mL/g) was observed for the BHS-352 barley variety, whereas Dolma variety recorded the lowest value (1.40 mL/g). The variations in the values of WAC and OAC could be due to the various contents of proteins and their interaction with water and conformational properties.

Regarding the functional properties of WF, nearly similar findings were reported by Abdel-Hameed (2005); Abdel-Hameed and Abdel-Aleem (2017). Their results revealed that WF (72% ext.) recorded the values of 0.48 – 0.54 g/mL for BD, 74.90 – 85.24% for WAC, 85.35 – 89.66% for OAC, 54.00 – 60.00% for FC, 25.00 – 27.78% for $FS_{60min}$, 16% for the LGC. The partial replacement of WF with dried mushroom powder (up to 15% level) or defatted papaya kernel flour (up to 10% level) enhanced the functional properties of WF and the obtained blends.

In conclusion, barley flour (from hull-less and hulled barley varieties) revealed good functional properties. The addition of barley flour successfully improved the most important functional properties of wheat flour, consequently its utilization value in food industry.

**Nutritional, physical and sensory characteristics of biscuits:**

Barley flour from hull-less and hulled varieties, based on their physicochemical and functional properties, were used as functional and nutritive ingredients in biscuits to promote them as high-value products. The produced biscuits (control and supplemented with 30% barley flour) were assessed for their nutritional, physical and sensory characteristics.

**Chemical composition of control and supplemented biscuits:**

The proximate chemical composition of control and supplemented biscuits (referring to their nutritive values) are shown in Table 7. From which, it could be seen that control biscuits (100% wheat flour) contained 3.36% moisture, 7.82% protein, 13.32% fat, 1.13% ash, 0.51% fibers and 73.84% nitrogen free extract (NFE). The energy value of control biscuits was 446.52 Kcal/100g (as such basis). The results in the same table indicated that the supplemented biscuits with 30% barley flour (from hull-less and hulled barley varieties) had higher contents of moisture (3.50 – 4.51%), protein (8.29 – 8.89%), fat (14.26 – 15.55%), ash (1.36 – 1.56%) and fibers (1.76 – 2.39%) than control biscuits. This could be due to the fact that barley flour had higher contents of protein, fat, ash and fibers than wheat flour, as mentioned in Table 2. Conversely, the supplemented biscuits had a lower content (68.30 – 70.51%) of NFE than control biscuits (73.84%). In most cases, the chemical composition of supplemented biscuits significantly differed according to the variety of barley. Concerning the hull-less barley varieties, the supplemented biscuits with Giza 130 (B-$G_{130}$) and Giza 136 (B-$G_{136}$) recorded nearly the same protein content (8.38 – 8.43%), whereas the supplemented biscuits with Giza 135 (B-$G_{135}$) recorded a higher value (8.49%). In the case of the hulled barley varieties, the highest protein content (8.89%) was observed for the supplemented biscuits with Giza 137 (B-$G_{137}$) followed by the supplemented biscuits with Giza 134 (B-$G_{134}$) (8.67%), whereas the supplemented biscuits with Giza 132 (B-$G_{132}$) recorded the lowest value (8.29%). The highest fat content (15.55%) was recorded for biscuits with the hulled barley variety Giza 134 (B-$G_{134}$). Whereas biscuits with the hull-less barley variety Giza 130 (B-$G_{130}$) recorded the lowest fat content (14.26%). Generally, the supplemented biscuits with hull-less barley flour (B-$G_{130}$, B-$G_{135}$, B-$G_{136}$) had lower contents of ash (1.36 – 1.39%) and fibers (1.76 – 2.03%) than the supplemented biscuits with hulled barley flour (B-$G_{132}$, B-$G_{133}$, B-$G_{134}$, B-$G_{137}$, B-$G_{138}$) (1.44 – 1.56% and 2.04 – 2.39%, respectively). The energy values of the supplemented biscuits were found to be 439.32 – 449.63 Kcal/100g (as such basis). Based on the nutritional properties of the supplemented biscuits, it could be concluded that the incorporation of barley flour (from hull-less and hulled barley varieties) into wheat flour up to 30% level enhanced their nutritive values in terms of protein, ash and fibers.

**Table 7. Chemical composition of control and supplemented biscuits (as such basis).**

| Constituents (%)* | Control biscuit (100% WF) | Biscuit supplemented with 30% barley flour | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Hull-less barley biscuits | | | Hulled barley biscuits | | | | |
| | | B-$G_{130}$ | B-$G_{135}$ | B-$G_{136}$ | B-$G_{132}$ | B-$G_{133}$ | B-$G_{134}$ | B-$G_{137}$ | B-$G_{138}$ |
| Moisture | 3.36 ± 0.02$^{e}$** | 3.71$^{cd}$ ± 0.12 | 3.79$^{c}$ ± 0.16 | 4.18$^{b}$ ± 0.01 | 3.78$^{c}$ ± 0.12 | 3.93$^{c}$ ± 0.06 | 3.50$^{de}$ ± 0.20 | 4.51$^{a}$ ± 0.07 | 3.78$^{c}$ ± 0.10 |
| Protein | 7.82 ± 0.02$^{g}$ | 8.38$^{e}$ ± 0.04 | 8.49$^{d}$ ± 0.01 | 8.43$^{e}$ ± ± 0.02 | 8.29$^{f}$ 0.01 | 8.56$^{c}$ ± 0.04 | 8.67$^{b}$ ± 0.03 | 8.89$^{a}$ ± 0.01 | 8.58$^{c}$ ± 0.02 |
| Fat | 13.32 ± 0.19$^{f}$ | 14.26$^{e}$ ± 0.14 | 15.25$^{ab}$ ± 0.11 | 14.68$^{cd}$ ± 0.19 | 15.02$^{bc}$ ± 0.05 | 14.69$^{cd}$ ± 0.14 | 15.55$^{a}$ ± 0.08 | 14.51$^{de}$ ± 0.16 | 15.32$^{ab}$ ± 0.11 |
| Ash | 1.13 ± 0.01$^{d}$ | 1.38$^{c}$ ± 0.03 | 1.39$^{c}$ ± 0.02 | 1.36$^{c}$ ± 0.01 | 1.52$^{a}$ ± 0.02 | 1.44$^{b}$ ± 0.02 | 1.45$^{b}$ ± 0.01 | 1.44$^{b}$ ± 0.03 | 1.56$^{a}$ ± 0.03 |
| Fibers | 0.51 ± 0.04$^{e}$ | 1.76$^{d}$ ± 0.05 | 1.94$^{cd}$ ± 0.02 | 2.03$^{c}$ ± 0.14 | 2.15$^{bc}$ ± 0.14 | 2.39$^{a}$ ± 0.18 | 2.08$^{c}$ ± 0.12 | 2.35$^{ab}$ ± 0.16 | 2.04$^{c}$ ± 0.13 |
| Nitrogen free extract*** | 73.84 ± 0.07$^{a}$ | 70.51$^{b}$ ± 0.08 | 69.14$^{cd}$ ± 0.08 | 69.32$^{cd}$ ± 0.07 | 69.24$^{cd}$ ± 0.07 | 68.99$^{d}$ ± 0.09 | 68.75$^{d}$ ± 0.09 | 68.30$^{e}$ ± 0.09 | 68.72$^{d}$ ± 0.08 |
| Energy value (Kcal/100g) | 446.52 ± 0.12$^{c}$ | 443.90$^{e}$ ± 0.09 | 447.77$^{ab}$ ± 0.07 | 443.12$^{e}$ ± 0.09 | 445.30$^{d}$ ± 0.05 | 442.41$^{f}$ ± 0.09 | 449.63$^{a}$ ± 0.09 | 439.35$^{g}$ ± 0.09 | 447.08$^{bc}$ ± 0.08 |

*** Average of 3 replicates ± SD. ** The averages having diverse characters inside each row are significantly differed (*P*<0.05). *** Calculated by difference.**

These results were in line with some previously reported results. For example, Skrbic and Cvejanov (2011) evaluated the impact of enrichment of wheat cookies with hull-less barley flour (30 and 50% levels) on their nutritional, physical and sensory properties. Their results revealed that the supplemented cookies had higher contents of protein (8.73 – 9.15%), fat (17.80 – 18.00%), ash (0.90 – 1.13%), cellulose (0.50 – 0.71%) and β-glucan (1.31 – 2.06%) than control cookies (7.45, 0.59, 17.70, 0.18 and 0.18%, respectively). Conversely, they had lower contents of moisture (3.04 – 3.36%) and NFE (62.60 – 64.00%) than control biscuits (3.57 and 65.10%, respectively). Related observations were found by Aly *et al*. (2021) for biscuits supplemented with whole barley flour (from hull-less barley grains) as a partial substitute (20 and 40% levels) of wheat flour. The supplemented biscuits had higher contents of moisture (3.29 – 3.86%), protein (8.70 – 9.20%), fat (17.98 – 18.25%), ash (1.52 – 2.03%) and fibers (0.80 – 1.67%) than control biscuits

(2.92, 8.30, 17.67, 0.51 and 0.46%, respectively). Conversely, they had a lower content (64.95 – 67.70%) of NFE than control biscuits (70.10%). Furthermore, Nakov *et al.* (2022) investigated the possibility of partial replacement of wheat flour with hull-less barley flour (at 25 – 100% levels) to improve the functional properties and nutritional value of short-dough cookies. They reported that the barley-enriched cookies had significantly higher contents of moisture (4.63 – 5.99%), protein (6.33 – 7.02%), fat (15.53 – 15.58%), ash (0.95 – 1.47%), total dietary fibers (4.37 – 9.84%) and β-glucan (0.77 – 2.80%) than control cookies (4.61, 6.03, 15.30, 0.78, 3.50 and 0.12%, respectively). Conversely, they had lower contents of NFE (65.03 – 69.92%) and energy values (428.18 – 444.78 Kcal/100g) than control cookies (71.25 % and 446.78 Kcal/100g).

**Phytochemicals composition of control and supplemented biscuits:**

The phytochemicals composition (total phenolics and total flavonoids) of control and supplemented biscuits are shown in Table 8. From which, it could be seen that control biscuits (100% WF) had the values of 104.57 mg GAE/100g for total phenolics and 9.76 mg QE/100g for total flavonoids. The results in the same table indicated that the supplemented biscuits with 30% barley flour (from hull-less and hulled barley varieties) had higher contents of total phenolics (132.05 – 186.22 mg GAE/100g) and total flavonoids (13.99 – 22.13 mg QE/100g) than control biscuits. This could be due to the fact that barley flour had higher contents of total phenolics (194.38 – 253.77 mg GAE/100g) and total flavonoids (19.98 – 31.61 mg QE/100g) than wheat flour (129.41 mg GAE/100g and 12.74 mg QE/100g, respectively), as mentioned in Table 3. In most cases, the phytochemicals composition of supplemented biscuits significantly differed according to the variety of barley. Concerning the hull-less barley varieties, the highest total phenolics content (168.27 mg GAE/100g) was observed for the supplemented biscuits with Giza 130 (B-$G_{130}$) followed by the supplemented biscuits with Giza 136 (B-$G_{136}$) (159.46 mg GAE/100g), whereas the supplemented biscuits with Giza 135 (B-$G_{135}$) recorded the lowest value (138.65 mg GAE/100g). In the case of the hulled barley varieties, the highest total phenolics content (186.22 mg GAE/100g) was observed for the supplemented biscuits with Giza 132 (B-$G_{132}$) followed by the supplemented biscuits with Giza 138 (B-$G_{138}$) (170.58 mg GAE/100g), whereas the supplemented biscuits with Giza 137 (B-$G_{137}$) recorded the lowest value (132.05 mg GAE/100g). The highest total flavonoids content (22.13 mg QE/100g) was observed for the supplemented biscuits with the hull-less barley variety Giza 136 (B-$G_{136}$) followed by the supplemented biscuits with the hulled barley variety Giza 134 (B-$G_{134}$) (20.02 mg QE/100g). Whereas the supplemented biscuits with the hull-less barley variety Giza 130 (B-$G_{130}$) recorded the lowest value (13.99 mg QE/100g). In view of these results, the incorporation of barley flour (from hull-less and hulled barley varieties) into wheat flour (up to 30% level) significantly improved the phytochemicals composition of biscuits in terms of total phenolics and total flavonoids. This indicated that barley grains and their food products are good sources of natural antioxidants that offer health benefits if incorporated into regular diets from early life to be effective. The antioxidant properties of barley grains and their potential health benefits largely depend on the barley variety and its flour extraction rate. These findings agree with some previous studies (Kim *et al*., 2007; Holtekjolen *et al*. 2008; Zhao *et al*., 2008; Gupta *et al*., 2011; Sharma and Gujral, 2014; Idehen *et al*., 2017; Narwal *et al*., 2017; Bangar *et al*. 2022).

According to Narwal *et al.* (2017), wheat flour was blended with barley flour (at 5 – 30% levels) to enhance the nutritive value and health benefits of wheat-based food products (chapattis and biscuits). The results revealed that the addition of barley flour (at 30% level) significantly increased their phenolic contents from 63 to 135 µg GAE/g for biscuits and from 237 to 287 µg GAE/g for chapattis. Related observations were found by Nakov *et al.* (2022) for cookies supplemented with hull-less barley flour (at 25 – 100% levels) as a partial substitute of wheat flour. They observed that the barley-enriched cookies had significantly higher total phenolics content (270.51 – 621.42 µg GAE/g) and antioxidant capacity (2.15 – 2.34 mmol Trolox equivalent (TE)/100g) than 100% WF cookies (160.53 µg GAE/g and 2.09 mmol TE/100g, respectively). The nutritional and physicochemical properties of barley-enriched cookies significantly improved as a result of the partial replacement of wheat flour with hull-less barley flour up to 50% level.

**Table 8. Phytochemicals composition of control and supplemented biscuits.**

| Phytochemicals* | Control biscuit (100% WF) | Biscuit supplemented with 30% barley flour | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Hull-less barley biscuits | | | Hulled barley biscuits | | | | |
| | | B-$G_{130}$ | B-$G_{135}$ | B-$G_{136}$ | B-$G_{132}$ | B-$G_{133}$ | B-$G_{134}$ | B-$G_{137}$ | B-$G_{138}$ |
| Total phenolics*** | 104.57 ± 5.68$^{f}$** | 168.27$^{b}$ ± 0.05 | 138.65$^{d}$ ± 2.79 | 159.46$^{c}$ ± 3.53 | 186.22$^{a}$ ± 2.99 | 138.29$^{d}$ ± 3.50 | 161.81$^{c}$ ± 1.15 | 132.05$^{e}$ ± 0.50 | 170.58$^{b}$ ± 0.45 |
| Total flavonoids**** | 9.76 ± 0.47$^{f}$ | 13.99$^{e}$ ± 0.08 | 18.63$^{c}$ ± 0.04 | 22.13$^{a}$ ± 0.34 | 18.73$^{c}$ ± 0.46 | 19.04$^{c}$ ± 0.12 | 20.02$^{b}$ ± 0.11 | 15.24$^{d}$ ± 0.16 | 19.32$^{bc}$ ± 0.39 |

*** Average of 3 replicates ± SD. ** The averages having diverse characters inside each row are significantly differed (*P*<0.05). *** (mg gallic acid equivalents/100g sample). **** (mg quercetin equivalents/100g sample).**

**Color characteristics of control and supplemented biscuits:**

The color characteristics of control and supplemented biscuits are shown in Table 9 and Fig. 4. From which it could be seen that the color parameters L, a, b, ΔE, hue angle and chroma for control biscuits (100% wheat flour) were 78.47, 4.90, 35.10, 00.00, 82.05 and 35.44, respectively. The corresponding values for the supplemented biscuits with 30% barley flour (from hull-less barley varieties) (B-$G_{130}$, B-$G_{135}$, B-$G_{136}$) were 75.97 – 77.60, 3.60 – 4.70, 25.97 – 28.50, 7.07 – 9.27, 80.64 – 82.11 and 26.22 – 28.89, respectively. The supplemented biscuits with 30% barley flour (from hulled barley varieties) (B-$G_{132}$, B-$G_{133}$, B-$G_{134}$, B-$G_{137}$, B-$G_{138}$) recorded the values 74.13 – 78.30, 3.47 – 5.43, 25.87 – 28.83, 7.13 – 9.36, 79.33 – 82.48 and 26.10 – 29.34, respectively. It could also be seen that the color characteristics of the supplemented biscuits significantly differed (in some cases) according to the variety of barley. Consequently, significant differences in ΔE values were observed in some cases. For example, the supplemented biscuits with 30% Giza 133 barley flour (B-$G_{133}$) recorded the highest ΔE value (9.36) followed by the supplemented biscuits with 30% Giza 136 barley flour (B-$G_{136}$) (9.27). The lowest ΔE value (7.07) was recorded for the supplemented biscuits with 30% Giza 135 barley flour (B-$G_{135}$), when compared to control biscuits. Despite these changes, all supplemented biscuits had acceptable color characteristics.

Concerning the hue angle, all supplemented biscuits with 30% barley flour (from hull-less and hulled barley varieties) recorded nearly the same values (79.33 – 82.48) as compared to control biscuits (82.05). Chroma values (the indicator of color saturation and intensity) were significantly decreased from 35.44 for control biscuits and reached 26.10 and 29.34 for supplemented biscuits with 30% Giza 133 (B-$G_{133}$) and Giza 132 barley flour (B-$G_{132}$), respectively. This could be due to the change in the values of both redness (a-value) and yellowness (b-value) as a result of the supplementation process.

In view of these results, there were not many changes in the color characteristics as a result of the partial replacement of wheat flour with barley flour (from hull-less and hulled barley varieties) up to 30% level and all supplemented biscuits revealed optimum color values. Related observations were found by Nakov *et al*. (2022) for cookies supplemented with hull-less barley flour (at 25 – 100% levels) as a partial substitute of wheat flour. They observed that the supplementation with barley flour did not affect the color characteristics of barley-enriched cookies significantly, especially at low and moderate incorporation levels.

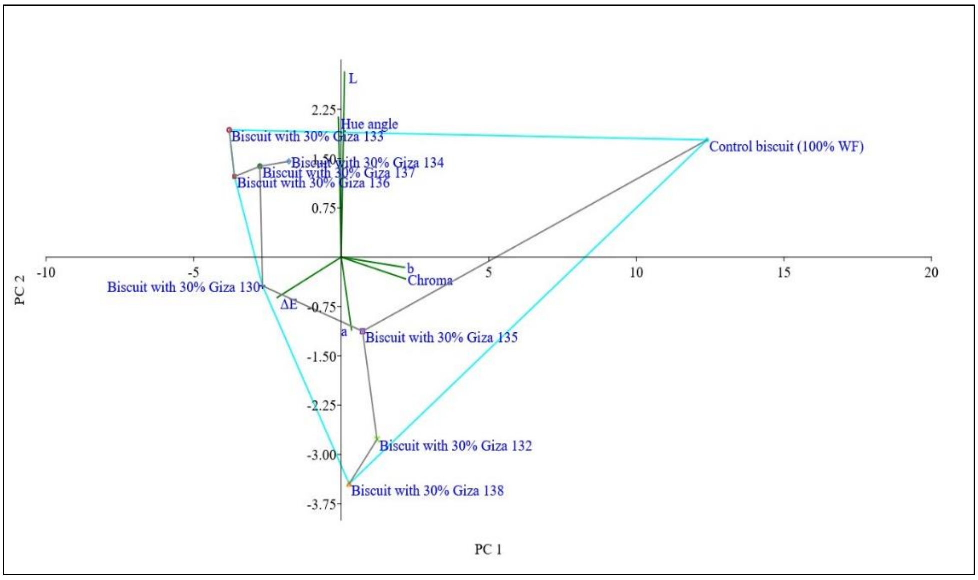


**Fig. 4. The principal component analysis (PCA) for color characteristics of control and supplemented biscuits with 30% barley flour.**

**Table 9. Color characteristics of control and supplemented biscuits.**

| Color parameters* | Control biscuit (100% WF) | Biscuit supplemented with 30% barley flour | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Hull-less barley biscuits | | | Hulled barley biscuits | | | | |
| | | B-$G_{130}$ | B-$G_{135}$ | B-$G_{136}$ | B-$G_{132}$ | B-$G_{133}$ | B-$G_{134}$ | B-$G_{137}$ | B-$G_{138}$ |
| L (Lightness) | 78.47 ± 0.06$^{a**}$ | 76.13$^{c}$ ± 0.21 | 75.97$^{c}$ ± 0.46 | 77.60$^{b}$ ± 0.10 | 75.13$^{d}$ ± 0.40 | 78.30$^{a}$ ± 0.70 | 78.30$^{a}$ ± 0.26 | 77.47$^{b}$ ± 0.15 | 74.13$^{e}$ ± 0.25 |
| a (redness/greenness) | 4.90 ± 0.26$^{bc}$ | 4.03$^{d}$ ± 0.06 | 4.70$^{c}$ ± 0.17 | 3.60$^{de}$ ± 0.40 | 5.43$^{a}$ ± 0.32 | 3.47$^{e}$ ± 0.15 | 3.93$^{de}$ ± 0.35 | 3.50$^{e}$ ± 0.26 | 5.27$^{ab}$ ± 0.25 |
| b (yellowness/blueness) | 35.10 ± 0.10$^{a}$ | 26.57$^{cd}$ ± 0.32 | 28.50$^{b}$ ± 0.35 | 25.97$^{d}$ ± 0.15 | 28.83$^{b}$ ± 0.21 | 25.87$^{d}$ ± 0.61 | 26.97$^{c}$ ± 0.55 | 26.50$^{cd}$ ± 1.04 | 28.47$^{b}$ ± 0.50 |
| ΔE*** | 0.00 ± 0.00$^{e}$ | 8.89$^{ab}$ ± 0.26 | 7.07$^{d}$ ± 0.43 | 9.27$^{a}$ ± 0.22 | 7.13$^{d}$ ± 0.23 | 9.36$^{a}$ ± 0.62 | 8.20$^{bc}$ ± 0.50 | 8.77$^{abc}$ ± 1.04 | 7.94$^{cd}$ ± 0.53 |
| Hue angle**** | 82.05 ± 0.40$^{a}$ | 81.37$^{a}$ ± 0.22 | 80.64$^{a}$ ± 0.23 | 82.11$^{a}$ ± 0.82 | 79.33$^{a}$ ± 0.69 | 82.37$^{a}$ ± 0.22 | 81.69$^{a}$ ± 0.86 | 82.48$^{a}$ ± 0.41 | 79.52$^{a}$ ± 0.58 |
| Chroma***** | 35.44 ± 0.13$^{a}$ | 26.87$^{cd}$ ± 0.31 | 28.89$^{b}$ ± 0.37 | 26.22$^{d}$ ± 0.21 | 29.34$^{b}$ ± 0.15 | 26.10$^{d}$ ± 0.62 | 27.25$^{c}$ ± 0.51 | 26.73$^{cd}$ ± 1.06 | 28.95$^{b}$ ± 0.48 |

*** Average of 3 replicates ± SD. ** The averages having diverse characters inside each row are significantly differed ($P$<0.05).**
***** = $[(L - L_o)^2 + (a - a_o)^2 + (b - b_o)^2]^{½}$ . **** = $[\tan^{-1} (b/a)]$. ***** = $[(a^2 + b^2)]^{½}$ .**

**Physical characteristics of control and supplemented biscuits:**

The physical characteristics of biscuits are one of the key factors when consumers decide whether to buy them or not. Various physical quality characteristics (i.e., width, thickness, spread ratio, spread factor) of biscuits as influenced by the partial replacement of wheat flour with 30% barley flour (from hull-less and hulled barley varieties) are given in Table 10. The data showed a decrease in spread ratio of biscuits upon incorporation of barley flour. Considering the spread factor of control as 100, it was decreased to 94.13 – 96.08 when barley flour was incorporated at 30%. The decrease in spread ratio and spread factors for all types of supplemented biscuits could be due to the decrease in width and the increase in thickness of these biscuits. As shown in Table 10, the width decreased from 26.53 cm for the control biscuit to 26.20 – 26.33 cm for the supplemented biscuits with 30% barley flour. Conversely, the thickness increased from 2.06 to 2.13 – 2.16 cm for the same samples, respectively. In most cases, these changes are not statistically significant. The barley variety did not affect the physical characteristics of biscuits significantly, all of them had nearly the same values. The partial substitution of wheat flour with barley flour (up to 30%) resulted in the production of high quality biscuits. Nearly similar findings were reported by Abdel-Hameed (2005) for biscuits fortified with dried mushroom powder (up to 15% level); Gupta *et al*. (2011); Sharma and Gujral (2014) for cookies prepared using wheat-barley flour blends; Abdel-Hameed and Abdel-Aleem (2017) for biscuits fortified with defatted papaya kernel flour (up to 10% level).

Skrbic and Cvejanov (2011) made cookies supplemented with 30% barley flour (from hull-less barley grains) as a partial substitute of wheat flour. They found that the supplemented cookies recorded higher spread ratio (3.92 – 4.52) than control cookies (3.39). Nakov *et al*. (2022) prepared cookies supplemented with hull-less barley flour (at 25 – 100% levels) as a partial substitute of wheat flour. Their results showed a significant decrease in both width and thickness of cookies upon incorporation of barley flour. This reduction in cookies width and thickness was proportional to the increase of the incorporated levels of barley flour. The spread factor had the same trend of width and thickness. The barley-enriched cookies had lower spread factor (50.14 – 52.98) than the control cookies (52.80). The cookies with the higher spread factor are more acceptable.

**Table 10. Physical characteristics of control and supplemented biscuits.**

| Physical c haracteristics* | Control biscuit (100% WF) | Biscuit supplemented with 30% barley flour | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Hull-less barley biscuits | | | Hulled barley biscuits | | | | |
| | | B-G$_{130}$ | B-G$_{135}$ | B-G$_{136}$ | B-G$_{132}$ | B-G$_{133}$ | B-G$_{134}$ | B-G$_{137}$ | B-G$_{138}$ |
| Width (cm)*** | 26.53 ± 0.05$^{a}$** | 26.30$^{b}$ ± 0.10 | 26.33$^{b}$ ± 0.05 | 26.26$^{b}$ ± 0.05 | 26.26$^{b}$ ± 0.05 | 26.30$^{b}$ ± 0.10 | 26.30$^{b}$ ± 0.10 | 26.20$^{b}$ ± 0.10 | 26.20$^{b}$ ± 0.10 |
| Thickness (cm)**** | 2.06 ± 0.05$^{a}$ | 2.13$^{a}$ ± 0.05 | 2.13$^{a}$ ± 0.05 | 2.13$^{a}$ ± 0.06 | 2.13$^{a}$ ± 0.05 | 2.16$^{a}$ ± 0.05 | 2.16$^{a}$ ± 0.05 | 2.13$^{a}$ ± 0.05 | 2.16$^{a}$ ± 0.05 |
| Spread ratio (SR)***** | 12.84 ± 0.35$^{a}$ | 12.33$^{ab}$ ± 0.33 | 12.34$^{ab}$ ± 0.34 | 12.31$^{ab}$ ± 0.35 | 12.31$^{ab}$ ± 0.31 | 12.14$^{b}$ ± 0.32 | 12.14$^{b}$ ± 0.32 | 12.28$^{ab}$ ± 0.29 | 12.09$^{b}$ ± 0.28 |
| Spread factor****** | 100.00 ± 0.00$^{a}$ | 95.98$^{ab}$ ± 2.60 | 96.08$^{ab}$ ± 2.67 | 95.84$^{ab}$ ± 2.74 | 95.85$^{ab}$ ± 2.47 | 94.50$^{b}$ ± 2.56 | 94.50$^{b}$ ± 2.56 | 95.61$^{ab}$ ± 2.27 | 94.13$^{b}$ ± 2.25 |

*** Average of 3 replicates ± SD. ** The averages having diverse characters inside each row are significantly differed (*P*<0.05).**
***** For five sequenced biscuits. **** For five stacked biscuits. ***** Width/Thickness. ****** (SR of sample / SR of control) × 100. B-G$_{130}$ =**

**Sensory characteristics of control and supplemented biscuits:**

The sensory evaluation for color, texture, taste, odor and overall quality of control and supplemented biscuits as influenced by the incorporation of barley flour was performed to evaluate consumers preferences. The results are shown in Fig. 5. From which, it could be seen that the control (100% wheat flour) and supplemented biscuits with 30% barley flour (B-G$_{130}$, B-G$_{132}$, B-G$_{133}$, B-G$_{134}$, B-G$_{135}$, B-G$_{136}$, B-G$_{137}$, B-G$_{138}$) recorded nearly the same sensory quality in terms of color (8.80 – 9.00), texture (9.00), taste (8.80 – 9.00), odor (9.00) and overall quality (8.80 – 9.00). There were no significant changes in the sensory assessment values for supplemented biscuits (up to 30% level). They had excellent sensory quality as compared to control. This data indicated that barley flour (from hull-less and hulled barley varieties) could be successfully incorporated with wheat flour up to 30% level to obtain healthy nutritious biscuits with excellent quality attributes. The photographs of control and supplemented biscuits are shown in Fig. 6.

Related observations were found by Gupta *et al.* (2011) for cookies supplemented with 10 – 40% barley flour; Skrbic and Cvejanov (2011) for cookies supplemented with 30% barley flour; Aly *et al*. (2021) for biscuits supplemented with 20% barley flour; Nakov *et al*. (2022) for cookies supplemented with 50% barley flour (from hull-less barley grains) as a partial substitute of wheat flour. They reported that the barley-enriched cookies/biscuits revealed acceptable sensory quality, especially at low and moderate incorporation levels.

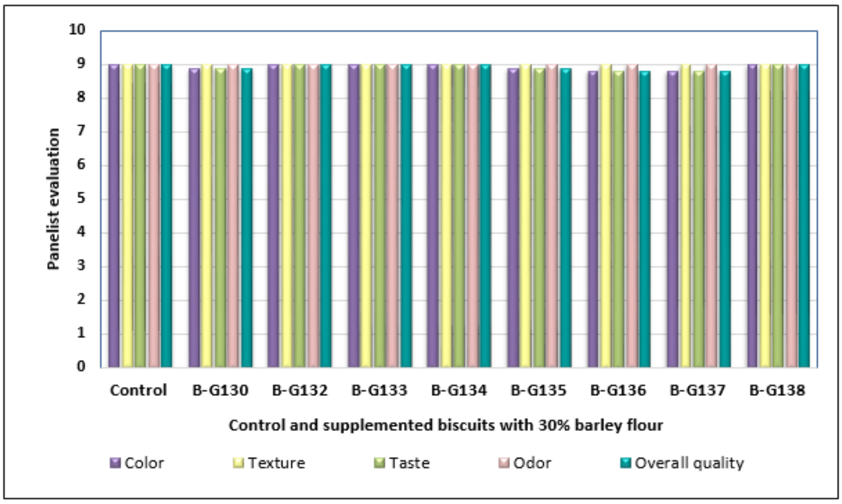


**Fig. 5. Sensory characteristics of control and supplemented biscuits with 30% barley flour.**

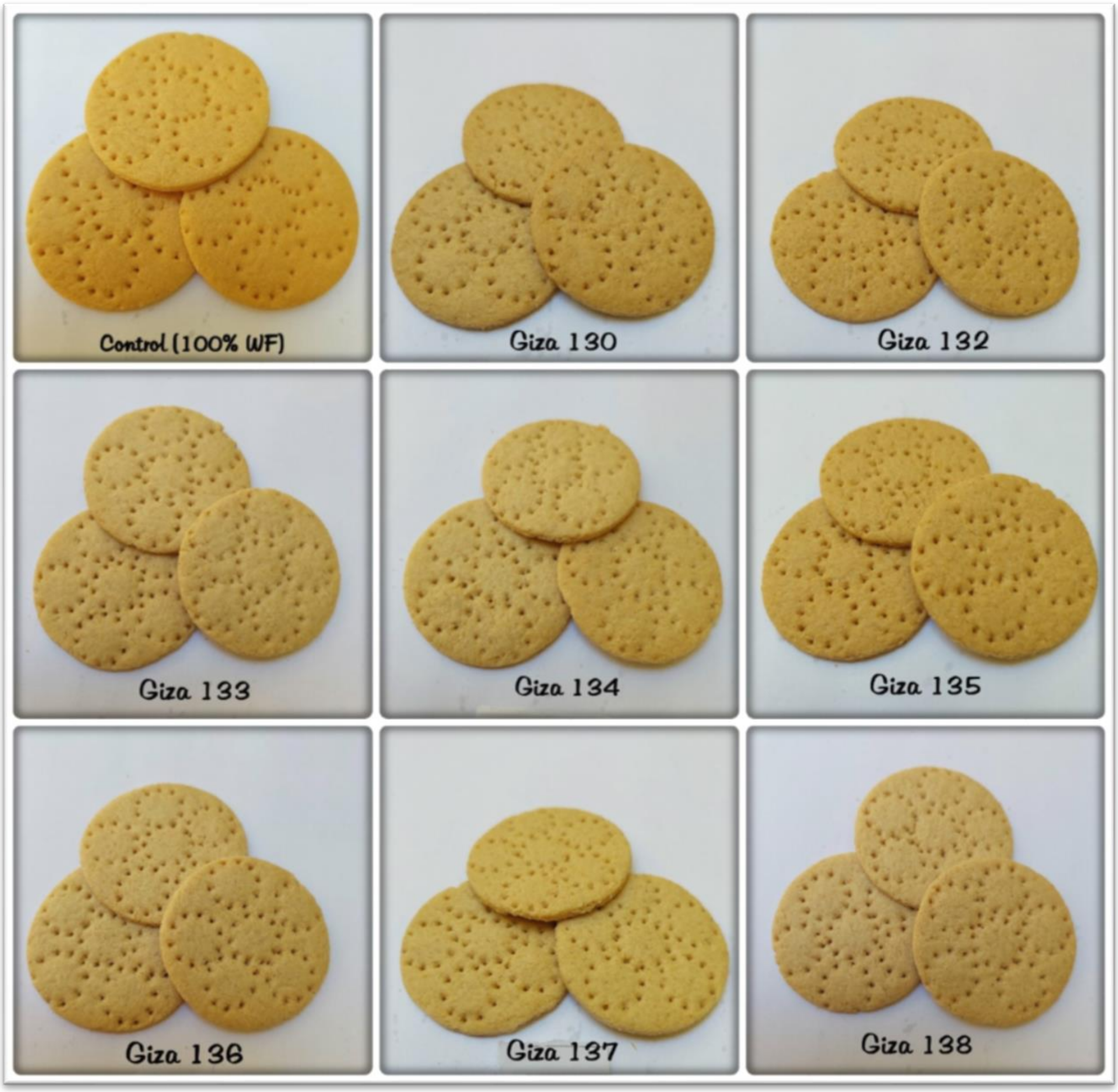


**Fig. 6. The photographs of control and supplemented biscuits with 30% barley flour.**

## CONCLUSION

The physicochemical and functional properties of barley flour (from hull-less and hulled barley varieties) were evaluated for their potential applications as functional and nutritive ingredients in biscuits to promote them as high-value products. The chemical and phytochemicals composition of barley flour (BF) significantly differed according to the variety of barley. BF is an excellent source of protein, ash, fibers, NFE, total phenolics and total flavonoids. When compared to wheat flour (WF), BF revealed optimum color characteristics and good functional properties. The addition of BF improved the most important functional properties of WF, consequently its utilization value in food industry. The supplemented biscuits with 30% BF had excellent quality characteristics and improved nutritional value. Barley grains and their food products are good sources of natural antioxidants that offer health benefits if incorporated into regular diets from early life to be effective. In view of these results, BF (from the tested hull-less and hulled barley varieties) can successfully be used (as functional and nutritive ingredients) in combination with WF (up to 30% level) to obtain delicious and healthy nutritious food products (i.e., biscuits).

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# التقييم الفيزيوكيميائي والتكنولوجي لبعض أصناف الشعير المصري العاري والمغطى لإعداد البسكويت

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## الملخص

في الآونة الأخيرة ، هناك اهتمام متزايد باستخدام حبوب الشعير في العديد من التطبيقات الغذائية نظراً لقيمتها الغذائية البارزة وفوائدها الصحية المتعددة. يهدف هذا البحث إلى تقييم الخصائص الفيزيوكيميائية والوظيفية لبعض أصناف الشعير المصري العاري (جيزة 130 ، جيزة 135 ، جيزة 136) والمغطى (جيزة 132 ، جيزة 133 ، جيزة 134 ، جيزة 137 ، جيزة 138) ، وتطبيقاتها كمكونات وظيفية وغذائية في البسكويت للترويج لها كمنتجات عالية القيمة. أوضحت النتائج اختلاف التركيب الكيميائي والمركبات النباتية النشطة حيوياً لدقيق الشعير اختلافاً كبيراً وفقاً لصنف الشعير. يعتبر دقيق الشعير مصدراً ممتازاً للبروتين (9،48 – 11،38%) ، الرماد (1،53 –1،97%) ، الألياف (3،30 – 4،56%). محتوى دقيق الشعير من الفينولات الكلية (194،38 – 253،77 ملليجم مكافئات حامض الجاليك/100جم عينة) والفلافونويدات الكلية (31،61 – 19،98 ملليجم مكافئات الكوارستين/100جم عينة) أعلى من دقيق القمح (129،41ملليجم مكافئات حامض الجاليك/100جم ، 12،74 ملليجم مكافئات الكوارستين/100جم). أظهر دقيق الشعير خصائص لون مثلى وكذلك خصائص وظيفية جيدة مقارنة بدقيق القمح. أدى إضافة دقيق الشعير لتحسين أهم الخصائص الوظيفية لدقيق القمح وبالتالي تحسين قيمة استخدامه في صناعة الأغذية. أظهر البسكويت المدعم بـ 30% دقيق شعير خواص جودة ممتازة وقيمة غذائية محسنة من حيث البروتين (8،29 – 8،89%) ، الرماد (1،36 – 1،56%) ، الألياف (1،76 – 2،39%) ، الفينولات الكلية (132،05 – 186،22 ملليجم مكافئات حامض الجاليك/100جم عينة) والفلافونويدات الكلية (13،99 – 22،13 ملليجم مكافئات الكوارستين/100جم عينة). في ضوء هذه النتائج ، يمكن استخدام دقيق الشعير (من أصناف الشعير العاري والمغطى) بنجاح كمكونات وظيفية وغذائية بالاشتراك مع دقيق القمح (حتى مستوى 30%) للحصول على بسكويت لذيذ صحي ومغذي.

***الكلمات المفتاحية:*** دقيق الشعير – الخصائص الفيزيوكيميائية – الخصائص الوظيفية – البسكويت – المكونات الغذائية.