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Quality Evaluation of Barely Waffle Partially Substituted with Some Broken Pulses

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Abstract: There is a general tendency toward wellness and good health. The objective of the research was to investigate the possibility of producing barley waffle samples substituted with different powdered broken pulses. Barely waffle prepared by partially substituting hulless barely flour with powdered broken pulses (0.0%, 40% chickpea, 40% lentil, and 30% white bean, individually) and wheat waffle used as commercial control. Waffle batter's properties were examined, as were the physicochemical and sensory attributes of the produced waffles. The density and viscosity of the waffle batter were reduced by substituting powdered broken pulses compared with the batter, which contained 100% barely flour. An increase in protein, ash, β-glucan, total phenolic, and carotenoids was observed in barley waffle substituted with powdered broken pulses relative to the wheat waffle, as well as *in vitro* protein digestibility and antioxidant activity. However, compared with wheat waffles, backing loss decreased in all barley waffle samples. Moreover, barely waffles substituted with broken pulse powders, particularly chickpeas, had a high overall acceptance score. This indicates the great potential of broken pulse powder utilization for producing barely waffles as a functional food.

Key words: Waffle · Hulless barley flour · Broken pulses · Batter properties · Sensory characteristics

INTRODUCTION

Pulses are the most important nutrients and economically valuable crops worldwide, especially in underdeveloped and developing countries. However, the deficiency of good harvest and post-harvest practices, incorrect management and storage services, and common milling processes are the greatest and most important causes of losses that affect the nutritional and economic value of pulses [1, 2]. Production procedures for pulses, including harvesting, storing, cleaning, shipping, and handling, invariably result in mechanical damage [3]. Broken pulses are considered seeds with some but less than one-fourth of each broken off or with one-fourth or more of the seed coat removed [4]. The quantitative losses of pulses and oilseeds are estimated to be 20% and 16% per year, globally and in the MENA Region, respectively [5]. In Egypt, the loss of pulses estimated to be 27,000 tons in 2014 reached 60,000 tons in 2018, up by 122.22% [6]. Broken pulses, or grain fragments, are frequently disregarded by producers. While broken grains are five times less expensive than whole grains and have comparable nutritional value, they provide a significant economic challenge and are important from a technology stand point [7]. Globally, there is a growing trend toward the use of some agricultural crop by-products, such as rice bran, wheat germ, broken chickpea seeds, and wheat bran, in the production of functional foods [8]. Chickpeas are a widely used source of nourishment because of their low cost and well-balanced nutrient content. Chickpeas are a major source of protein for those who cannot afford animal-based protein, vegans, and residents of semi-arid areas. As a result of the process of extracting chickpea seeds from their dried horns, broken chickpea seeds are one of the residues and have the same composition as chickpeas, in addition to the low price of broken chickpeas [9, 10]. A high-quality lentil by-product can be utilized as a beneficial source of protein due to its inexpensive price [11]. Thus, Hassan *et al.* [12] assessed the possibility of using lentil screenings by-product as an alternative protein source and their influence on nutrients digestibility. Beans represent habits of excellent nutritional, economic and functional importance in manufacturing. Broken beans are fragmented components

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that are occasionally disregarded during production, even though they are five times less expensive and have similar nutritional value to whole beans. Broken grains typically point to a significant economic issue, but their utilization in production is a sign of advancements in technology [13]. Barley (*Hordeum vulgare,* L.) is the best crop to cultivate in Egypt's challenging conditions, and it can be grown in newly reclaimed areas with low water quality and few soils [14]. Barley (*Hordeum vulgare* L.) is unjustly neglected as a food crop. Recently, there has been a rise in interest in barley's application in the food business. Barley and its derivatives are mostly composed of, sugar, proteins, fat, ash and β-glucan bakery products can be produced very easily using barley, and the products have better nutritional qualities and acceptable sensory characteristics [15]. In Egypt, the total area under cultivation for barley from 2004/2005 to 2018/2019 was around 84.9 thousand feddans, with an average production of 91.35 thousand tons [16]. The planting of barley in the growing season of 2020-2021 was 53.3 thousand feddans, yielding 87.6 thousand tons with productivity of 1.6 tons/fed [17]. Barely is obtaining more interest due to its nutritional importance, especially because of the content of dietary fiber and non-starch polysaccharides, barely is a rich source of fiber supplying useful [18,19]. Although barley is frequently utilized in animal feed, its emphasis on bioactive components is reviving interest in it as a component in the manufacturing of functional foods [20, 21]. Many by-products rich in valuable compounds are produced by the food industry and can be useful for future uses, particularly as ingredients in functional foods. Because of the favorable effects on human health, the environment, and the profitability of process production, this is a trend that is becoming more and more popular. Because consumers have good attitudes about these foods, there is a steady increase in the production of functional foods enhanced with by-products [22, 23]. Waffles are a tasty convenience food with a smooth texture similar to cakes. Waffle ingredients typically include eggs, milk, sugar, flour, fat and flavours. Also, waffle is a frequently used product that is made up of three main ingredients: sugar, fat, and wheat flour [24, 25]. In recent years, waffles have gradually become a regular meal among people, as white wheat flour is a main ingredient in waffle making and is considered poor in nutrients, replacing it with enriched grain flour may improve some important nutrients [26].

The aim of this work was the development of a novel functional food product: barely waffles substituted with different amounts of powdered broken pulses, and to assess their impact on the final product's chemical composition, antioxidant activity, total phenolic content, color changes, and sensory appeal

MATERIALS AND METHODS

Materials:

Raw Materials: Hulless barley grain (*Hordeum vulgare*) cultivar Giza 130 was obtained from the Barley Research Section, Field Crops Research Institute, Agricultural Research Center, Giza, Egypt. Broken pulses of chickpea (*Cicer arietinum* L.), lentil (*Lens culinaris* L.), and white bean (*Phaseolus vulgaris* L.) were obtained from Al-Sayyad Agricultural Crops Company, Damanhour, Egypt. Wheat flour 72% extraction rate was obtained from South Cairo Mills Company, Egypt. Gallic acid, DPPH (2, 2-diphenyl-1-picrylhydrazyl), pancreatin and Pepsin were purchased from Sigma-Aldrich Chemical Company (St. Louis, USA). The Folin Ciocalteu reagent was purchased from LOBA Chemie, India. All chemicals were of the analytical grade. The following ingredients were purchased from the local market in Giza, Egypt: sugar, egg, skimmed milk powder, corn oil, salt, baking powder and vanilla.

Methods:

Sample Preparation: The broken pulses (chickpea, lentil, and white bean) and hullless barley (whole grain) were carefully cleaned, then ground into a fine powder in a Laboratory Mill Junior, passed through a 500 µm sieve, packed in polyethylene bags, and stored at -18°C before being used for preparing waffles and undergoing further analysis.

Preparation of Different Types of Waffle: A preliminary experiment was conducted with various substitution ratios of barley flour as a whole meal with (10, 20, 30, 40, and 50%) of broken pulse powder (chickpea, lentil, and white bean). So as to obtain the appropriate substitution ratio to produce barley waffles with good sensory properties. The best results were achieved by substituting flour barley at 40, 40, and 30% for each broken powder of chickpea, lentil, and white bean, respectively. The formula of Choi *et al.* [27] with some modifications was used to prepare waffles. Table 1 displays the formulas for waffle samples. The waffle was prepared by creaming the sugar, egg and vanilla together in a kitchen-aid mixer for three minutes on speed 5, then adding the oil and blending for

Table 1: Ingredients and formulas for preparing different waffle samples.

	Waffle formulas				
Ingredients (%)	Wheat	Barley	Chickpea	Lentil	White bean
Wheat flour	60	---	---	---	---
Barley flour	---	60	36	36	42
Chickpea powder	---	---	24	---	---
Lentil powder	---	---	---	24	---
White bean powder	---	---	---	---	18
Fresh whole egg	20	20	20	20	20
Skimmed milk powder	7	7	7	7	7
Sun flower oil	8	8	8	8	8
Sugar	3	3	3	3	3
Baking powder	1.5	1.5	1.5	1.5	1.5
Vanillin	0.5	0.5	0.5	0.5	0.5

Ratio between barley flour to chickpea 60:40; Ratio between barley flour to lentil 60:40; Ratio between barley flour to white bean70:30: The water was added as required.

two minutes at the same speed. Following the addition of the flour, skimmed milk powder and baking powder, the batter was blended for four minutes at speed 2. Carefully measured dough portions were placed in the center of a Kempen, Germany-made Clatronic HA 3494 waffle maker, and they were baked for approximately 1.5 minutes at 180°C. Following their cooling, the waffles were packed and used for more analysis.

Sensory Evaluation of Waffle Samples: The sensory evaluation of waffles was done by ten panelists comprised of members of Food Technology Research Institute staff, Agriculture Research Center, Giza, Egypt. Using a nine-point hedonic scale (1 = strongly dislike to 9 = strongly like), panelists were asked to evaluate the waffles' acceptability based on their appearance, color, flavor, taste, texture, and overall acceptability [28].

Proximate Chemical Composition: The AOAC [29] was used to assess the raw materials and waffle samples (moisture, protein, ash, crude fiber, and fat) content on dry weight basis. Carbohydrate content was calculated by the difference: [Carbohydrates=100 - (protein + ash + crude fibers +fat)]. Value of energy (kcal/100 g) = protein ×4.0+ fat ×9.0+ carbohydrate ×4.0. Using Agilent Technologies Microwave Plasma Atomic Emission Spectrometers (Model 4210 MPAES, USA), the contents of calcium, iron, potassium, and zinc were determined in samples in accordance with the procedure described in the AOAC [29]. The colorimetric method of Trough and Mayer [30] was used to determine phosphorus.

Total Phenolic Determination: Following Singleton and Rossi [31], the Folin-Ciocalteu method was used to estimate the total phenolic content of the raw materials and waffle samples. The standard curve was prepared using gallic acid as standard.

Total Carotenoids Determination: The method outlined by Santra *et al*. [32] was used to determine the total carotenoids content of the raw materials and waffle samples. A mixture of 3 g of samples and 15 ml of water-saturated n-butanol (8:2 ratio of n-butanol to distilled water) was maintained in the dark for 16-18 hours. The supernatant absorbance was determined at 440 nm in respect to the blank using a Jenway Spectrophotometer. The unit of measurement used was mg/kg, and the standard used was β-carotene.

DPPH Radical Scavenging (%): According to Brand-Williams *et al*. [33], the antioxidant activity (%) of the waffle samples' methanolic extract was determined based on its capacity to scavenge radicals when they reacted with a stable DPPH free radical. In brief, 0.10 ml of sample extract was mixed with 3.90 ml of DPPH solution (2.40 mg of DPPH in 100 ml of methanol). The mixture was measured at 515 nm after being violently shaken for just a few seconds using a tube shaker. It was then left to stand at room temperature for 30 minutes in the dark. Using the following calculation, the radical scavenging percentage (DPPH) was determined:

$$\text{DPPH radical scavenging (\%)} = [(A0 - A1/A0)] \times 100$$

A0 = Absorbance of the control reaction (all reagents except test compounds included)

After 30 minutes, A1 = Absorbance with the tested extracts present.

β-glucan Content: The method outlined by Carr *et al*. [34] was used to determine the β-glucan content.

Water Holding Capacity (WHC): Using the Beuchat [35] method, the flours' capacity to absorb water was ascertained. After one gram of material was mixed with ten milliliters of distilled water and allowed to remain at room temperature (30°C±2) for thirty minutes, it was centrifuged for thirty minutes at 2000 xg. (Model Z 206 A, HERMLE Labrotechnik GmbH, Wehingen, Germany). Water absorption was examined using the percentage of water bound in each gram of flour.

Characterization of Waffle Batters: The pH value and batter density are determined in accordance with Huber and Schönlechner [25]. A pH meter (Testo GmbH, Vienna, Austria) was used to measure each batter's pH. The density: A 100 ml cup was filled with batter, and the weight (g/100 ml) was recorded to determine the density. The viscosity of various waffle batters was determined in accordance with the Brookfield Manual [36]. Using the Brookfield Engineering Labs DV-III Ultra Rheometer, the sample was placed in a small adaptor, and the appropriate temperature was kept constant using a water bath. The viscometer's rpm range was 10 to 60. At room temperature (25°C ± 1), the viscosity was measured directly from the instrument, the measurement was conducted using the SC4-21 spindle. Three replicates were used to average the measurement for each sample.

The microstructure of the batters was observed with a DM750 light microscope attached with a Leica camera (ICC50 HD Leica Microsystems IR GmbH, Switzerland) with Magnifications 40xs.

Color Parameters, Hardness and Baking Loss:

Color Parameters: In accordance with McGurie's [37] methodology using a handheld chromameter (model CR-400, Konica Minolta, Japan), the surface of each waffle sample was measured. The parameters of color were expressed by the following values: lightness (L*), redness (a*), and yellowness (b*). Three replicates were used to average the measurement for each sample.

Hardness: In accordance with the method described by Jambrec *et al*. [38], hardness was measured using Brookfield Engineering Lab. Inc., Middleboro, MA 02346-1031, USA. Each waffle was divided into quarters and placed on the texture analyzer platform. The waffle pieces were compressed with a cylindrical probe using 50% strain. The maximum force required to break the waffle was reported in Newton (N).

Baking Loss: The following formula was used to calculate the baking loss of waffles, giving information on the moisture loss during baking as described by Huber and Schönlechner [25].

$$\text{Baking loss (\%)} = 1 - \left[\frac{\text{Weight waffel (g)}}{\text{Weight batter (g)}}\right] \times 100$$

***In vitro* Protein Digestibility:** The *In vitro* protein digestibility was determined according to Akeson and Stahmann [39] method. Briefly one g sample was added to 15 ml of HCl (0.1 M) containing 1.5 mg pepsin, then incubated for three hours at 37°C. NaOH (0.2 M) was used to neutralize the suspension that was obtained following the addition of 7.50 ml of pancreatin (4 mg in 0.2 M phosphate buffer, pH 8.0) After that, the mixture was softly shaken and kept at 37°C for 24 hours. Following a 10% trichloroacetic acid treatment, the samples were centrifuged at 5000 xg for 20 minutes at room temperature. The Kjeldahl method AOAC [29] was used to estimate the amount of protein in the supernatant. Using the following equation, the percentage of protein digestibility was calculated:

$$\text{IVPD (\%)} = \frac{\text{(N in supernanant - N in Blank)}}{\text{N in sample}} \text{X100}$$

IVPD = *In vitro* protein digestibility; N = Nitrogen.

Statistical Analysis: The data from this study were statistically analyzed using the Costat statistical software for means and standard deviations as Steel *et al.* [40]. The data were subjected to one-way analysis of variance (ANOVA) using one way, followed by Duncan's multiple range tests (at $p<0.05$) to assess differences between sample means.

RESULTS AND DISCUSSION

The chemical composition of wheat flour (72% ext.), barley flour and broken pulse powder (chickpea, lentil, and white bean) is presented in Table 2. Results showed that the lentil had the highest protein level (25.25%), followed by chickpea (22.03%) and white bean (21.56%). The protein content was lowest in barley and wheat flour (11.85 and 12.18 %, respectively). Results indicated that, in comparison to the other raw materials under study, the broken white bean powder had the highest values of ash and crude fiber, at 3.17 and 3.97%, respectively. However, wheat flour had the lowest amounts of ash and crude fiber, at 0.55 and 0.61%, respectively. Furthermore, broken chickpea powder had the highest amount of fat (3.03%) relative to other raw materials. As shown in Table 2 wheat flour had higher carbohydrate content, followed by barley flour (85.44 and 81.34% respectively) compared to broken pulse powder. These results are in line with those reported by El-Taib *et al*. [41], Twfik *et al*. [42], Sharma *et al*. [43], Ali and Abdelsalam [44], and Xu *et al* [45].

Table 2: Chemical composition, total phenolic, carotenoids and water holding capacity of raw materials.

Parameters	Wheat flour	Barley flour	Chickpea	Lentil	White bean
Moisture (%)	9.11±0.04[a]	7.40±0.01[c]	6.55±0.03[e]	8.03±0.03[b]	6.96±0.02[d]
Protein (%)	12.18±0.09[d]	11.85±0.02[e]	22.03±0.02[b]	25.25±0.03[a]	21.56±0.02[c]
Ash (%)	0.55±0.01[d]	2.10±0.01[c]	3.06±0.04[b]	2.16±0.03[c]	3.17±0.03[a]
Crude fiber (%)	0.61±0.01[d]	2.66±0.01[c]	3.47±0.02[b]	2.64±0.02[c]	3.97±0.02[a]
Fat (%)	1.22±0.01[d]	2.05±0.04[c]	3.03±0.02[a]	2.47±0.03[b]	2.03±0.05[c]
Carbohydrates (%)	85.44±0.06[a]	81.34±0.07[b]	68.41±0.06[d]	67.48±0.02[e]	69.27±0.05[c]
Minerals content (mg/100g sample)					
Calcium	11.45	118.35	87.15	49.77	291.70
Iron	2.17	9.25	4.39	6.06	4.93
Potassium	111.15	456.90	948.16	947.25	1298.78
Zinc	2.38	3.15	3.75	3.42	4.21
Phosphorus	116.71	470.5	452.28	435.25	202.50
Total phenolic (mgGAE/100g)	50.49±0.16[c]	110 ±2.83[b]	115±1.41[b]	123±4.24[a]	122±2.83[a]
Carotenoids (mg/kg)	3.88±0.07[d]	4.86±0.07[c]	7.36±0.13[b]	9.04±0.02[a]	3.29±0.15[e]
WHC (%)	92.45±0.63[d]	130.02±0.56[a]	121.65±0.50[b]	111.00±1.41[c]	128.10±0.71[a]

Values followed by the same letter in a row are not significantly different at p ($\leq$ 0.05). WHC: water holding capacity. Chemical composition, minereals, total phenolic and carotenoids were calculated based on the dry weight basis.

Table 3: Waffle batters characterization: pH, temperature, density and viscosity of different waffle batter samples.

Waffle batters	pH	Temperature [°C]	Density [g/100ml]	Viscosity (Pa*s)
Wheat	6.65±0.07[a]	26.25±0.07[a]	0.87±0.01[c]	10.6±0.28[e]
Barley	6.50±0.10[ab]	26.15±0.10[a]	0.93±0.00[a]	24.2±0.30[a]
Chickpea	6.35±0.00[c]	26.25±0.07[a]	0.90±0.00[b]	14.2±0.28[c]
Lentil	6.45±0.07[bc]	26.20±0.14[a]	0.91±0.01[b]	12.6±0.20[d]
White bean	6.20±0.00[d]	26.15±0.10[a]	0.90±0.00[b]	19.6±0.50[b]

Values followed by the same letter in a column are not significantly different at p($\leq$0.05).

The minerals content of the various samples (cereals and broken pulses) was shown in the same Table 2. In general, it is clear from the results that the minerals content of hulless barley and different broken pulse samples is higher than that found in wheat flour. Iron and phosphorus appeared at highest level (9.25 and 470.5 mg/100g sample, respectively) in hulless barley compared with other samples. The similar results were found by Mananga *et al*. [46] and Galal, *et al*. [47]. On the other hand, it is clear that broken white bean powder had the highest content of calcium, potassium and zinc, which were (291.70, 1298.78 and 4.21 mg/100g, respectively), compared to the rest of the samples. Also the data confirms that the minerals content of ground hulless barley were superior in its amount of various minerals to wheat flour. This result is agreement with Yan *et al*. [48].

Comparing wheat flour (WF) to other broken pulse powders and barely flour, the table data indicates that WF had a lower amount of total phenolics (50.49 mg GAE/100g). The total phenolic in barely flour was 110 mg GAE/100g. Simic *et al*. [49] reported that the total phenolic content of barely ranged from 91 to 200 mg GAE/100g According to the same table, broken lentil powder had the highest content of total phenolics and carotenoids (123 mg GAE/100g and 9.04 mg/kg, respectively). According to El-Taib *et al*. [41], barley flour has a higher percentage of total phenolic compounds than wheat flour. As reported by Kan *et al*. [50], White bean had a very low amount of carotenoids, while lentils had the highest concentration (4.53-21.34 mg/kg DW).

Regarding water holding capacity, it was clear that barley flour had highest water holding capacity (130.02%), followed by broken white bean powder (128.1%), while wheat flour had the lowest water holding capacity (WHC) (92.45%). White bean flour exhibited the highest water-holding capacity, while red lentil flour had the lowest [51]. The component of barley flour tends to help in water absorption and therefore improving physical characteristics like water holding capacity [52].

Characterization of Waffle Batters: The waffle batter's characteristics (pH, temperature, density, and viscosity) are displayed in Table 3. The batters had pH values ranging from 6.20 to 6.65. Among the batters, white bean batter had the least pH reduction. The optimum pH value for waffle batter lies in the range of pH 5.5 to pH 7.0 and it is well known that batter with high pH values can cause waffles to stick more than usual [25].

There was no noticeable temperature difference between the waffle batter samples. The temperature range of the batter was 26.15 to 26.25°C, which was within the suggested range for making waffles [25]. An excessively high batter temperature causes the batter to clump, which might result in an excessive amount of sticky waffles and no consistent batter deposit amounts. The fluidity properties of batters and eventually, the quality of waffles are significantly influenced by two parameters: density and viscosity. The waffle batter's density varied from

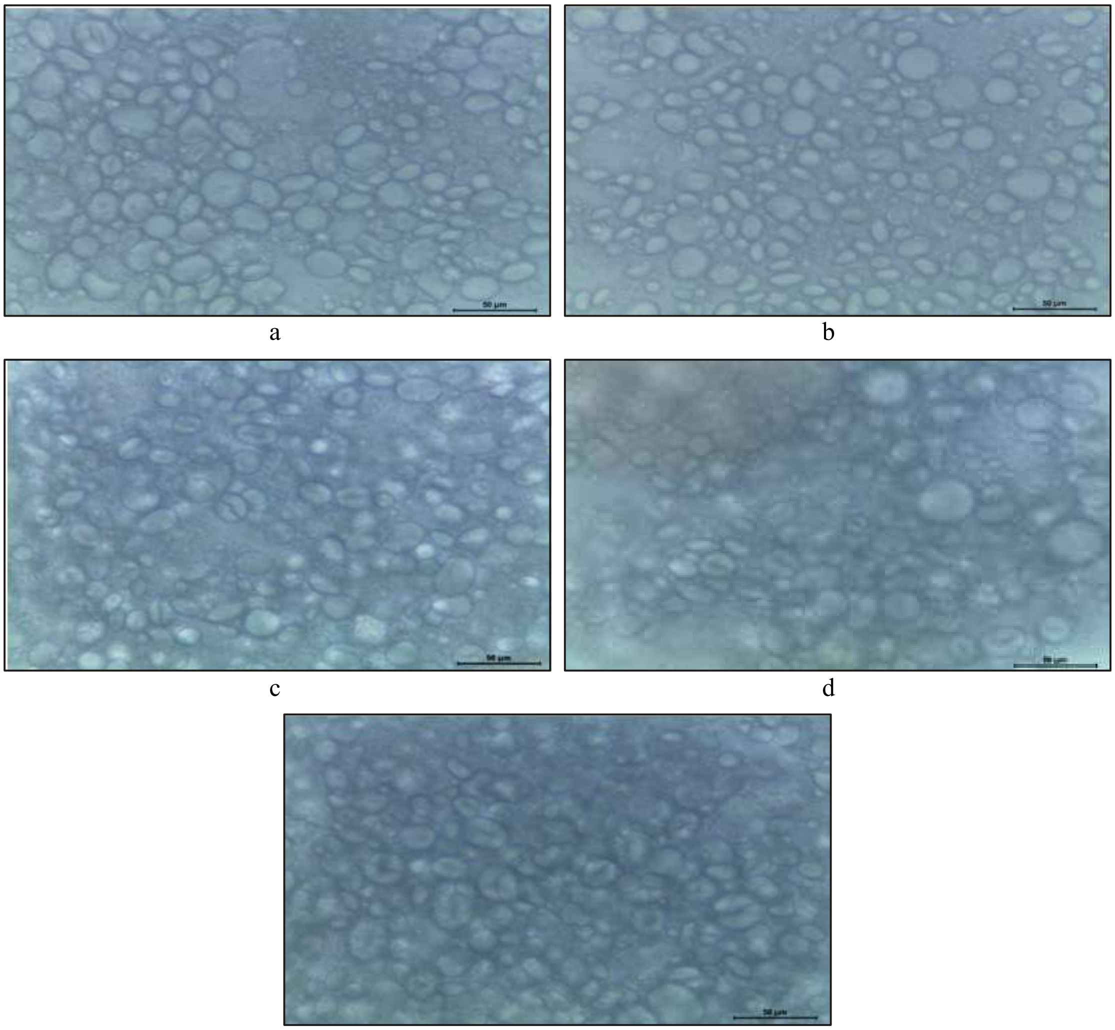

Fig. 1: Image microscopy of waffle batters: a: Wheat; b: Barley; c: Chickpea; d: Lentil; e: White bean.

0.87 to 0.93 g/100 ml. Waffle batter density should be between 0.80 and 0.95 g/100 ml to exhibit appropriate fluidity behavior and fill the entire baking plate after application. There is more dough waste when the dough is extremely liquid [25]. With the incorporation of the pulses, the batter density significantly decreased ($p<0.05$), indicating that more air had been incorporated into the structure. There were variations in the batter samples incorporation of air bubbles. The microstructure of the batters (Fig. 1) supports that observation. Furthermore, pulse batters displayed an uneven structure with more gas cells. However, the microstructure of the wheat batter was uniformly characterized (Fig. 1). The viscosity of the barely batter (100% barely flour) was higher than other batter samples (24.2 Pa*s). Moreover, the viscosity was decreased by substituting with broken pulses, which may have been caused by a decrease in β-glucan contents. According to Malunga *et al*. [53] the waffles' viscosity increased as their β-glucan concentration increased.

Density and viscosity measurements for each batter sample were in an acceptable range for waffle batters. These findings are consistent with those of Maghaydah *et al*. [54].

Sensory Evaluation of Different Waffle Samples: The results of the sensory evaluation (appearance, color, flavor, taste, texture and overall acceptability) of waffle samples are displayed in Table 4. The results indicated that, with the exception of flavor and texture, there are significant variations in each sensory attribute between the wheat waffle and the barely waffle sample, which contained 100% hulless barely flour. However, the

Table 4: Sensory evaluation of different waffle samples.

Waffle samples	Appearance	Color	Flavor	Taste	Texture	Overall acceptability
Wheat	8.65±0.41[a]	8.50±0.47[a]	8.45±0.44[a]	8.50±0.42[a]	8.40±0.32[ab]	8.50±0.00[a]
Barley	7.90±0.32[c]	7.30±0.26[c]	8.25±0.26[ab]	7.80±0.37[c]	8.25±0.26[ab]	8.25±0.35[b]
Chickpea	8.45±0.37[ab]	8.20±0.26[ab]	8.30±0.35[ab]	8.20±0.26[ab]	8.50±0.33[a]	8.65±0.24[a]
Lentil	8.20±0.26[bc]	7.95±0.37[b]	8.35±0.34[ab]	8.10±0.32[bc]	8.30±0.42[ab]	8.45±0.16[ab]
White bean	8.15±0.24[bc]	8.35±0.41[a]	8.05±0.28[b]	7.90±0.39[bc]	8.15±0.24[b]	8.45±0.28[ab]

Values followed by the same letter in a column are not significantly different at ($p \leq 0.05$).

Table 5: Chemical composition (%), energy value (Kcal/100g) and β-glucan content (%) of different waffle samples.

Waffle samples	Moisture	Protein	Ash	Crude fiber	Fat	Carbohydrates	Energy value (Kcal/100g)	β-Glucan
Wheat	6.54±0.01[a]	12.45±0.05[d]	1.87±0.04[c]	0.38±0.03[d]	11.02±0.03[d]	74.28±0.07[a]	446.10±0.25[a]	0.19±0.01[d]
Barley	6.59±0.03[a]	12.24±0.04[e]	2.80±0.03[b]	1.59±0.02[c]	11.49±0.03[c]	71.88±0.01[b]	439.89±0.17[bc]	4.59±0.02[a]
Chickpea	6.58±0.03[a]	14.68±0.03[b]	3.03±0.02[a]	1.80±0.02[b]	11.77±0.01[a]	68.72±0.01[d]	439.53±0.35[c]	2.55±0.04[c]
Lentil	6.54±0.02[a]	15.46±0.04[a]	2.83±0.02[b]	1.58±0.01[c]	11.62±0.03[b]	68.51±0.03[e]	440.46±0.24[b]	2.54±0.02[c]
White bean	6.55±0.03[a]	13.98±0.03[c]	3.07±0.02[a]	1.86±0.02[a]	11.47±0.03[c]	69.62±0.05[c]	437.63±0.18[d]	2.97±0.03[b]

Values followed by the same letter in a column are not significantly different at $p \leq 0.05$. Chemical composition was calculated based on the dry weight basis.

substitution with broken pulse powders enhanced sensory characters in barely waffles, particularly the chickpea waffle, as there were no significant differences between it and the wheat waffle in all sensory attributes. Nonetheless, barely waffle substituted with broken pulse powders got an acceptable score (above 7) in all sensory characteristics. Regarding overall acceptability, all barely waffle samples substituted with different broken pulse powder had a good acceptability for sensory evaluation and there is no significant difference in the overall acceptability of waffle prepared from wheat flour, particularly waffle substituted with chickpea. These results were similar with Kaewmak *et al*. [24].

Chemical Composition, Energy Value and β-glucan Content of Different Waffle Samples: The chemical composition of the control waffle (wheat and barley waffle) and waffle substituted with broken pulse (40% chickpea, 40% lentil and 30% white bean) powder is shown in Table 5. From the results in Table 5 it could be noticed that, the barley waffle subsisted with broken pulse leads to a significantly increase of protein content in lentil, chickpea, and white bean waffle samples (15.46, 14.68 and 13.98%, respectively) compared with control wheat and barley waffle samples (12.45 and 12.24%, respectively). As well as observed, the protein content increased as the substitution of pulses percentage increased. This confirmed that pulses are characterized by a higher content of proteins as compared to cereals [55]. Combinations of cereal and legumes are essential for the creation of products that offer a comprehensive protein source [56]. It is a nutritional characteristic that provides more protein needs. Pulses are excellent sources of proteins that can be used to fortify starch-based bakery products [42].

Ash content increased in white bean waffle followed by chickpea waffle (3.07 and 3.03%, respectively) relative to barley waffle (2.80%). White bean and chickpea waffle samples had the highest crude fibres content. The fat content in the waffle samples ranged from 11.02% to 11.77%. These values are comparable to the value of 10.60% as reported by Giau *et al*. [26]. Results also, indicated that significantly reduction in carbohydrates of waffle samples prepared broken pulses compared to wheat and barley waffle control due to the high content in protein and ash of pulses, in addition, This is probably because pulses contained lower carbohydrate content than wheat and barley flour as mentioned in Table 2. As gradually, decreasing in total carbohydrates caused by the gradually increased in protein content, ash and total lipid content [42]. Finally, it can be concluded that the incorporation of broken pulses (chickpea, lentil, and white bean powder) in the preparation of the barley waffle samples significantly increased the protein and ash content. This was due to the substitution with pulses which contain higher protein, ash and fat content than wheat and barley flour [57]. Regarding energy values provided from the nutrients in waffle samples, there are significant differences between samples whereas, the total energy of chickpea and white bean waffle samples is (439.53 and 437.63 kcal/100 g) lower than the total energy of barley control sample (439.89 kcal/100 g). The β-glucan content of waffle samples is presented in Table 5. As mentioned in the results, it could be observed that the proportions of barley flour with broken pulses powder increased the β-glucan content of waffle samples, as

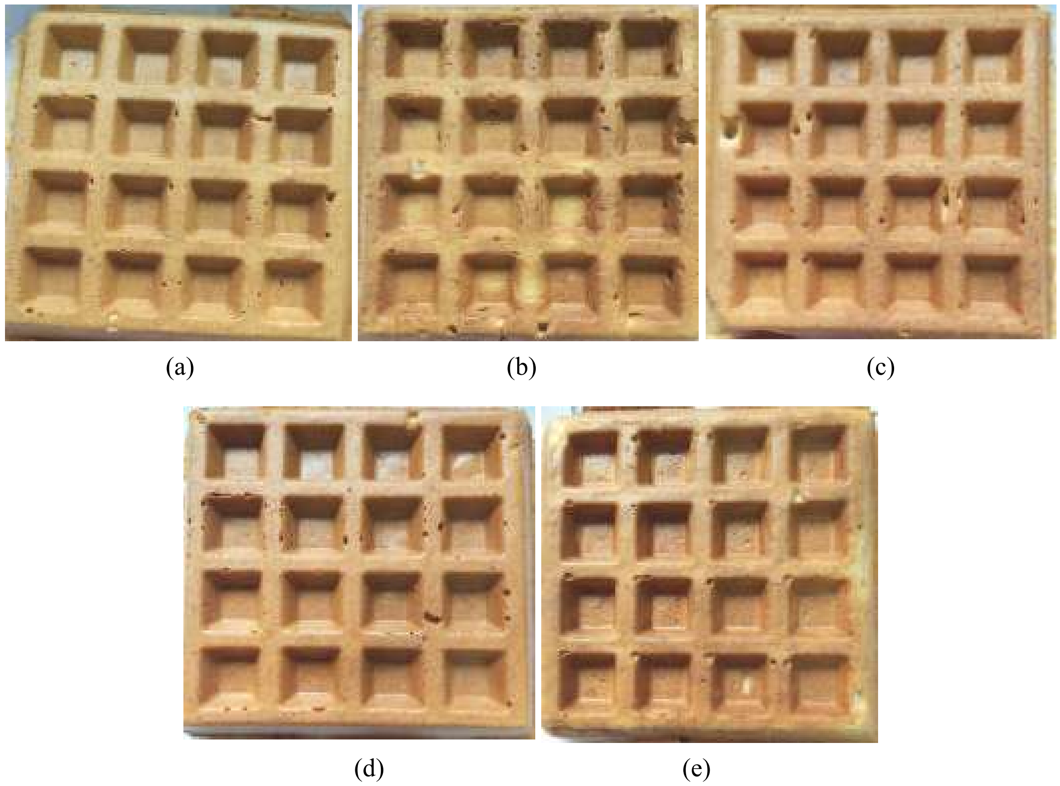

Fig. 2: Photos of waffle samples; a): Wheat; b): Barley; c): Chickpea; d): Lentil; e): White bean.

compared with the control wheat waffle, While, the barley waffle sample recorded the highest significantly β-glucan content (4.59%) followed by the white bean waffle sample (2.97%) but, the wheat waffle sample recorded the lowest β-glucan content (0.19%). The increase of β-glucan for waffle samples is due to the barley grains containing β-glucan, which ranged from 5 to 11% according to Lante, *et al*. [58] and nearly matched with Khaleghdoust *et al*. [59] who evaluated the β-glucan content and ranged from 3.53 to 5.85%. Increasing the β-glucan content in waffle samples is very important due to importance of β-glucan from barley in lowering blood glucose levels after eating [53]. This has been supported by the evidence that high molecular weight β-glucan tends to be more effective in impairing intestinal carbohydrate assimilation than its low molecular weight counterparts [60]. EFSA [61] suggest that 4g or more of β-glucan for every 30g of available carbohydrates is required to notice a significant decrease in post-prandial blood glucose approved. Blewett *et al*. [62] conducted a feeding experiment on waffle samples that contained amounts of β-glucan equivalent to 2.4, 4, and 6 g for every 30 g of available carbohydrates, all the three concentrations of β-glucan resulted in significant reductions in postprandial glucose concentrations.

Total Phenolic, Carotenoids, Antioxidants Activity and *in Vitro* Protein Digestibility: Figure 3 display, Total phenolic, carotenoids, antioxidants and *in vitro* protein digestibility. It could be observed that the proportions of barley flour with broken pulse powder increased the total total phenolic, caroteinoids content and antioxidant activity of waffle samples, as compared with wheat waffle, these results indicated that barley grains and their products are excellent sources of natural antioxidants due to the existence of total phenolic. The health advantages of barley grains may be mostly attributed to their phytochemical content [63] and [64]. The highest total phenolic content observed in waffle incroporated with lentil followed by white bean. Waffle with lentil had a higher carotenoids content followed by chickpea. A similar study was carried out by Tok and Ertas [65] in which the obtained results for TPC in cookies with lentil powder were higher than in the control and other pulses. The reason for such a high increase is possibly due to higher TPC of their lentil powder.

Broken pulse powders were incorporated to produce a protein-enriched waffle with significantly ($p<0.05$) higher accessibility protein and high *in vitro* digestibility. The pH rapidly decreased in the chickpea waffle, subsequently in the lentil and white bean waffle, showing an increase in

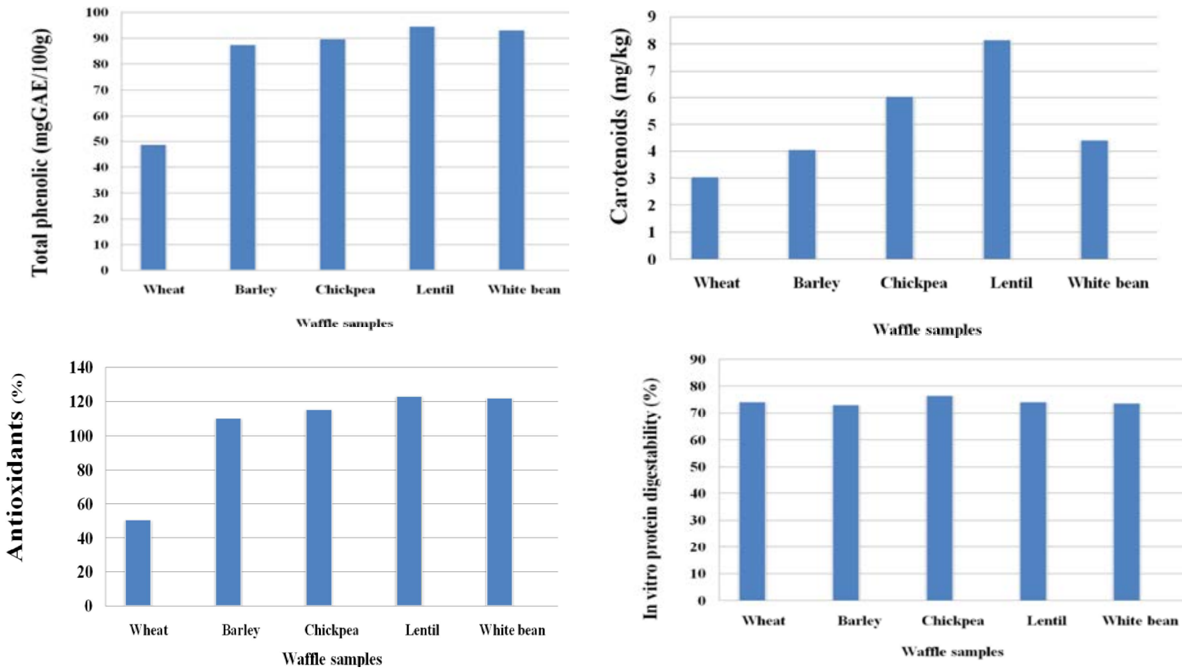

Fig. 3: Total phenolic (mgGAE/100g), caroteinoids (mg/kg), antioxidants activity (%) and *in vitro* protein digestability (%) of waffle samples.

Table 6: Color parameters, hardness and baking loss of waffle samples

	Color parameters				
Waffle samples	*L**	*a**	*b**	Hardness (N)	Baking loss (%)
Wheat	68.42±0.44^{a}	7.27±0.08^{e}	24.17±0.08^{e}	6.28±0.07^{d}	20.06±0.08^{a}
Barley	65.39±0.29^{c}	10.56±0.07^{b}	25.68±0.04^{d}	6.97±0.04^{a}	10.30±0.18^{c}
Chick pea	66.16±0.17$_{b}$	9.93 ±0.04^{d}	26.98±0.09^{b}	6.52±0.13^{c}	15.17±0.35^{b}
Lentil	64.85±0.12^{d}	10.68±0.05^{a}	27.79±0.11^{a}	6.42±0.02^{cd}	15.82±0.13^{b}
White bean	65.65±0.09^{c}	10.36±0.05^{c}	25.89±0.07^{c}	6.78±0.04^{b}	10.52±0.43^{c}

Values followed by the same letter in a column are not significantly different at ($p \leq 0.05$). L*= Lightness, a*= redness and b*= yellowness.

the *in vitro* protein digestibility (Fig. 3), which is induced by the release of carboxyl groups during enzymatic protein digestion [66]. For the reason of assessing a protein's nutritional quality, its digestibility serves as an indicator of the availability of its amino acids [66].

Color Parameters, Hardness and Baking Loss of Waffle Samples: Color is considered to be one of the most important variables assessing the acceptance of food products by consumers, as well as one of the most significant sensory factors that influence a consumer's decision and preference for any food product. The color parameters which including (lightness, redness and yellowness) of crust waffle samples were measured in Table 6. It was obvious that the highest value of lightness was found in wheat flour waffle. On the contrary, to lentil waffle which possessed the lowest lightness, whereas, the other formulas lied in between.

The studied formulas could be arranged according to redness value in the following descending order: lentil, barley, white bean, chickpea and wheat. Lentil sample showed the highest value in yellowness. On the contrary wheat had record the lowest yellowness. According to Koubaier *et al*. [67] adding lentil flour reduced *L** and increased *a** values, indicating a more reddish and less white color. Gómez *et al*. [23] explained that the differences in color are due to the replacement of barley flour with different amounts of pulses powder caused change from wheat flour. This could be explained by the effect of original color of legume powder. It was also indicated in literature that addition of pulses to bakery products resulted in color change [68]. The similar results were found by Sakiyan [69] and Ozkahraman *et al*. [70] they reported that lightness decreased with increased levels of pulses to cake. This may be due to a negative relationship between protein content and lightness. Color characteristic differences can be caused by the amount and kind of proteins [71]. Regarding to hardness, all barely waffles had significantly higher values of hardness than wheat waffle (6.28N). Moreover, substituted with broken pulses decreased hardness of waffles compared to 100% barely waffle.

Baking loss provides details about the moisture loss during baking. Baking loss was significantly influenced by substitution by powdered broken pulse. Baking loss was decreased in barley waffle sample relative to wheat waffle Ashokkumar and Adler-Nissen [72] and Ashokkumar *et al*. [73] found that sticking of pancakes was influenced by moisture loss of the products. Huber and Schönlechner [25] reported it was shown that an increase in pH of the batter and addition of ingredients with increased water holding capacity to limit baking loss can play a positive role. These values of baking loss (%) of waffles are comparable to the value of as reported by Giau *et al*. [26].

CONCLUSION

To conclude, the study aimed to evaluating the potential benefits of producing barley waffle samples that were substituted with different powdered broken pulses (chickpea, lentil, and white bean) by replacing the 100% barely flour-containing batter with powdered broken pulses, the waffle batter's density and viscosity were decreased. When barley waffle was substituted with powdered broken pulses as opposed to wheat waffle, there was an increase in protein, ash, β-glucan, total phenolic and carotenoids, as well as in nevertheless backing loss for each barley waffle sample as compared to wheat waffle samples. Furthermore, the waffle that was enhanced with powdered broken pulse especially the chickpea had a high acceptance score all over. Compared to wheat waffles, there was an apparent decrease in barley waffle production, according to the production cost evaluation. This suggests that broken pulses would be recommended for enriching barely waffle.

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