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Enhancing Muffins: Elevating Physicochemical and Nutritional Qualities through Malted Barley Flour Incorporation

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Authors' contributions

This work was carried out in collaboration among all authors. Author MK did the writing-reviewing & editing, writing-original draft, methodology, investigation, formal analysis, data curation. Author GS did the writing-original draft, reviewing & editing, conceptualization, software, visualization, methodology, supervision, investigation, resources. Author KS did the supervision, visualization, conceptualization. Author PS did the visualization, conceptualization, supervision, reviewing & editing. All authors read and approved the final manuscript.

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ABSTRACT

Barley is mostly utilized for feeding and beer production, with limited use in cereal-based products. Barley is gaining popularity among agriculture and food scientists because of its high dietary fiber (such as β-glucan), vitamin, and mineral content. The current study aimed to include malted barley flour (MBF) as a partial substitute for wheat flour (WF) to enhance the sensory, physicochemical, and nutritional aspects of muffins. The recipe was formulated through Design Expert 13 software for

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mixed design as partially substituting wheat flour with malted barley flour within the range 0 to 50 parts and coded samples A, B, C, D, E, F, and G accordingly, and we performed necessary analyses (chemical, sensory assessments, antioxidant activity, and absorption capacity). From the sensory analysis, the findings showed that sample C (83.33%WF: 16.67%MBF) was superior among all the samples. Furthermore, water absorption capacity, oil absorption capacity, and foaming capacity were determined to be higher (2.24, 2.45, and 0.86 g/g) in sample C as compared to sample A. On the contrary, control sample A exhibited a higher foaming capacity (18.27%) and bulk density (0.74 g/cm^3). Overall, nutritional composition revealed that the best-formulated muffin had a significantly higher ($p<0.05$) amount of crude protein (18.1%), crude fiber (2.13%), total ash (1.95%), carbohydrate (51.02%), antioxidant activity (43.4%), calcium (70 mg/100g), and iron (9.2 mg/100g), except for moisture (27.6%) and crude fat (26.5%). Hence, the finding provides actionable recommendations for entrepreneurs to improve the nutritional and sensory attributes of regular muffins by applying MBF up to 16.67 parts.

Keywords: Malted barley flour; cereal-based product; functional food; sensory attributes; nutritional value.

1. INTRODUCTION

Muffin a cereal-based snack, due to its distinct pleasant flavor and easily digestible qualities, has been regarded as the most popular morning breakfast in recent years [1]. In several regions of the world, muffins are reasonably priced and well-liked [2]. Flour, sugar, fat, and eggs are the main constituents of muffins, all the ingredients have a significant impact on the final product`s structure, appearance, and eating quality [3,4]. For the preparation of muffins, flour is a major ingredient [1], including the proteins glutenin, gliadin, as well as carbohydrates, which together hold all ingredients and give the baked product its finished shape [5].

Barley (*Hordeum vulgare*) is mostly used to generate malt for beer production and animal feed; however, it has recently gained popularity as an ingredient in a variety of bakery goods and extruded foods, such as breads, muffins, snacks, etc. [6,7,8]. The dietary fiber, β-glucan, and non-starch polysaccharides found in barley have contributed to its significant appeal [9,10]. Global barley production in the crop year 2021/2022 was 147.05 million metric tons, down from about 160.53 million metric tons in 2020/2021. With an annual production of 52.75 million metric tons, Europe was the world's top producer of barley, followed by Asia, and America [8]. A significant portion of the world's barley is grown in areas where rice and other cereals, like maize, cannot thrive [9]. There is a correlation between consuming cereals and other dietary products based on cereal and a lower risk of certain serious illnesses [11]. It has been observed that eating a diet high in whole grains has several health benefits, one of which is lowering the risk of cardiovascular disease (CVD) [12,13]. Barley species with the highest β-glucan content are almost twice as high as the content in oats, concentrated β-glucan generated from barley lowers blood cholesterol levels in animals with hypercholesterolemia, such as hamsters. Consequently, eating a diet high in barley was discovered to be essential for studies that observed drops in blood cholesterol levels [14]. Additionally, barley grains are distinguished by the antioxidants it contain, which include aminophenolic compounds, tannins, proanthocyanidins, chalcones, flavonols, flavones, lignans, and flavanones, As a result, adding barley to a wheat-based product can increase the nutritional value of wheat flour and products derived from it [15,16]. The process of malting involves the modification of grain components to make them more easily soluble [10]. Moreover, the activity of enzymes is created during seed germination to produce fermentable sugar and free amino acids. Steeping, germination, and kilning are the typical phases involved in malting [17]. The malting of barley increases the availability of proteins, α-amylase, vitamins, and amino acids, especially tryptophan, methionine, and lysine, and lowers the glycemic index and anti-nutritional factors [18].

Furthermore, several nutrients, including some vitamins, minerals, and dietary fiber, are lacking in the wheat flour used to make muffins [19]. Some critical amino acids, including lysine, tryptophan, and threonine, are absent in wheat flour [20]. Although malted barley is a very nutrient-dense cereal, it is rarely used to bake goods. Making muffins with malted barley would significantly increase the crop's use in applications other than brewing. The use of malted barley improves organoleptic properties and boosts bio-functional substances because it softens the texture and intensifies the flavor of the grains, giving the resultant muffin a distinct flavor [21]. Numerous studies have shown that barley may be used in a variety of processed foods, including bread, Asian noodles, biscuits, cookies, and muffins [22,23,24]. The addition of barley to wheat flour boosts β-glucan content in the finished product [15,25]. In many studies, malted barley enhances the product's texture, flavor, aroma, and nutritional content [26]. Wheat flour muffins lack several essential amino acids, particularly lysine, they are regarded as low-nutrient foods. However, by fortifying wheat flour with non-wheat proteins and fiber in varying amounts, the amino acid profile of the flour is improved, increasing the quality of the protein and fiber in muffins [27].

Farmers can widely cultivate barley all over the world, and if food producers could make malt flour in sufficient quantities, this may prove to be a much cheaper muffin component to enhance the quality of wheat muffins [28]. The main goal of scientific work is to add malted barley flour to the recipe for muffins to overcome nutritional shortcomings, and sensory quality, and also implement it in the baking industry. In a broader perspective, we highlighted the addition of malted barley flour (MBF) in muffins to enhance the overall acceptability profile and build a foundation for the baking industry to apply MBF in wheat flour muffins to enrich muffins.

2. MATERIALS AND METHODS

2.1 Raw Materials

Wheat flour (*Triticum aestivum*) and barley (*Hordeum vulgare*) were purchased from the local market of Dharan, Nepal. All the necessary apparatus and chemicals were obtained from the Central Campus of Technology Laboratory (CCT), Dharan, Nepal. All the baking ingredients butter (Amul butter), sugar, baking powder, and eggs were obtained from the local market of Dharan, Nepal.

2.2 Methods

2.2.1 Preparation of barley malt

The malting process was taken from Ojha et al. [29] with slight modifications. Cleaning is the initial process before malting, where husks, immature grains, and light particles are winnowed away in this stage, while heavier particles like specks and stones are separated by gravity as a result of the winnowing process. Following, the cleaned seed kernels were soaked for four hours in alkaline water (2% lime solution), 2% lime concentration was useful in lowering the aflatoxin levels in grains [30], then soaked for twenty-four hours in potable water (barley: water/1:3), with frequent draining and one hour of air rest every eight hours. Steeping was carried out at an average ambient temperature of 28ºC until a moisture content of 42–45% was reached. Following, the steeped grains were first gathered in a muslin towel and twirled to remove any remaining water. They were then stored for germination at an average room temperature of 28°C and 85% relative humidity. Grain drying can be prevented by misting potable water on muslin fabric and rewetting it every 12 hours. During germination, the grain bed was periodically stirred and mixed to aerate the mass and balance the moisture and temperature. The germination process lasts for about 5 days. To prevent additional germination, the barley that was germinating was dried. In a cabinet drier, multistage drying was done at 45°C for 6 hours, 50°C for 4 hours, 55°C for 8 hours, 70°C for 1 hour, and 80°C for 3 hours, or until the desired constant weight was reached. Following a period of drying, the rootlets were removed, the malt was ground using a grinder, and the resulting malted barley flour was sealed in a glass container.

2.2.2 Determination of threshold for malted barley flour

The independent variable for the experiment is the malted barley flour used to prepare muffins. The trial experiment was used to determine the threshold for malted barley flour. The trial experiment concluded that muffins with percentages higher than 50% were unacceptable. As a result, 0 to 50% is the criterion for malted barley flour. The recipe was developed using Design Expert, 13. To formulate the recipe, a simple lattice pattern known as mixed design was employed, and presented in Table 1. The muffins were prepared according to the recipe, and each recipe was assigned a code, A, B, C, D, E, F, and G, respectively.

2.2.3 Preparation of muffins

As suggested by the Design Expert, 13 different proportions of wheat and barley malt were used for the preparation of the muffins. To create a batter, the egg was beaten for two minutes, and the sugar and shortening were creamed, these components were then combined with water, composite flour, and baking powder. To produce muffins, the batter was made, panned, and cooked at 215°C for 20±3 minutes [31].

Table 1. Formulations of recipe

Ingredients	A	B	C	D	E	F	G
Wheat flour (parts)	100	87.5	83.33	75	66.66	62.5	50
Barley Malt (parts)	0	12.5	16.67	25	33.33	37.5	50
Sugar (gm)	60	60	60	60	60	60	60
Fat (gm)	65	65	65	65	65	65	65
Baking powder (gm)	1.42	1.42	1.42	1.42	1.42	1.42	1.42
Egg (gm)	57	57	57	57	57	57	57
Water (gm)	31	31	31	31	31	31	31

2.2.4 Chemical analysis for raw material and product

Moisture content, crude protein (N×6.25), crude fat, crude fiber, total ash, and reducing sugar (automated colorimetry, utilizing autoanalyzer modules to measure wavelength at 420nm) were determined by the method as described by AOAC [32] and Ranganna [33].

Carbohydrate was determined by the weight difference method as described by AOAC [32].

$$\text{Carbohydrate (\%)} = 100 - (\%CP + \%CF + \%A + \%CF) \quad [\text{Eq. 1}]$$

Where %CP, %CF, %A, and %CF are crude protein, crude fat, total ash, and crude fat, respectively.

The foaming capacity of malted barley flour and wheat flour was determined using a method described by Narayan and Narasinga Rao [34]. Likewise, water and oil absorption capacities were determined according to the method described by Okezie and Bello [35]. Emulsion capacity was determined by applying the procedure of Abbey and Ibeh [36] with a slight modification.

2.2.5 Determination of minerals

According to AOAC 2012 [32], iron and calcium were determined. Iron content was then colorimetrically measured at 480 nm with 100% transmittance set as the blank. The calcium content was determined by dissolving the precipitate in hot, diluted H_2SO_4, Standard $KMnO_4$ will be used for titration.

2.2.6 Free radical scavenging activity (%RSA)

Extracts' antioxidant RSA (free radical scavenging activity) properties were assessed using the methodology outlined by Vignoli et al. [37]. Multiple extract dilutions were made with 80% methanol. Then, 1 ml of the extract was mixed with 2 ml of 0.1 mM 2, 2-diphenyl-1-1-picrylhydrazyl (DPPH) solution. The absorbance was finally measured in a spectrophotometer at 517 nm after the sample had been incubated for 30 minutes in the dark. The result was shown on the screen. The scavenging activity % of DPPH was determined by applying Equation 2.

$$\text{\% scavenging activity} = \frac{\text{Ac - As}}{\text{Ac}} \times 100\% \quad [\text{Eq. 2}]$$

Where Ac is the absorbance of the control and As is the absorbance of the test sample.

2.3 Sensory Analysis

The sensory analysis for overall quality will be conducted by semi-trained panelists, which will include teachers and students from the Central Campus of Technology. The characteristics for the sensory evaluation include texture, appearance, color, texture, taste, aroma, and overall acceptability [38].

2.4 Statistical Analysis

All measurements were made in triplicate, and the experiment was carried out in triplicate. The collected data was statistically evaluated using Genstat Discovery Edition 12.1 for Analysis of Variance (ANOVA) at a 5% threshold of significance [39]. Likewise, in the case of an independent t-test, IBM SPSS 20 (IMB Corporation, Marlborough, MA, USA) was performed by applying equality of variances and means at a 95% confidence interval [40]. Microsoft Excel LTSC MSO (version 2207), developed by Microsoft Corporation (2021) was used for data documentation, calculations, and graph plots.

3. RESULTS AND DISCUSSION

This work was done to prepare the standard quality of several muffin formulations using various ratios of malted barley to wheat flour.

Table 2. Proximate composition of wheat flour (WF), un-malted and malted barley flour (MBF)

Parameter %	Wheat flour	Un-malted barley flour	Malted barley flour
Moisture content (%wb)	11.55 ± 0.04	11.2 ± 0.23	4.9 ± 0.13
Crude protein (%db)	9.76 ± 0.07	11.9 ± 0.38	14.4 ± 0.42
Crude Fat (%db)	1.23 ± 0.07	4.6 ± 0.13	2.22 ±0.10
Crude fiber (%db)	0.64 ± 0.11	5.95 ± 0.29	8.25 ±0.13
Total ash (%db)	0.52 ± 0.12	2.93 ± 0.52	2.61 ± 0.11
Carbohydrate (%db)	87.85 ± 0.94	74.62 ± 0.97	65.72 ± 0.81
Antioxidant activity (%RSA)	5.20 ± 0.45	23.92 ± 0.88	34.76 ± 1.27
Reducing sugar (%db)	0.65 ± 0.06	1.3 ± 0.44	5.12 ± 0.15
Calcium (mg/100g)	36 ± 0.64	140 ± 1.04	165 ± 1.52
Iron (mg/100g)	3.2 ± 0.13	4.95 ± 0.34	8.40 ± 0.10

Values are the means ± standard deviations of the three determinations. wb=weight basis, db=dry basis, and RSA= Free Radical Scavenging Activity

Table 3. Proximate composition of WF and MBF

Parameter (%)	Wheat flour	Malted barley flour
Moisture content (wb)	11.55 ± 0.04^{a}	4.9 ± 0.13^{b}
Crude protein (db)	9.76 ± 0.07^{a}	14.4 ± 0.42^{b}
Crude fat (db)	1.23 ± 0.07^{a}	2.22 ±0.10^{b}
Crude fiber (db)	0.64 ± 0.11^{a}	8.25 ±0.13^{b}
Total ash (db)	0.52 ± 0.12^{a}	2.61 ± 0.11^{b}
Carbohydrate (db)	87.85 ± 0.94^{a}	75.52 ± 0.81^{b}
Antioxidant activity (% RSA)	5.20 ± 0.45^{a}	34.76 ± 1.27^{b}
Reducing sugar (db)	0.65 ± 0.06^{a}	5.12 ± 0.15^{b}
Calcium (mg/100g)	36 ± 0.64^{a}	165 ± 1.52^{b}
Iron (mg/100g)	3.2 ± 0.13^{a}	8.40 ± 0.10^{b}

Values are the means ± standard deviations of the three determinations. Mean sharing the same letter within a column is non-significant. Means followed by different letters within each column are significant and tested at a 5% level of significance. wb: wet basis, db: dry basis, RSA: Free Radical Scavenging Activity

Wheat flour (WF) and barley malt flour (MBF) were blended into 7 different ratios : A (100%WF:0%MBF), B (87.5%WF:12.5%MBF), C (83.33%WF:16.67%MBF), D (75%WF:25%MBF), E (66.67%WF:33.33%MBF), F (62.5%WF: 37.5%MBF), and G (50%WF:50%MBF), respectively.

3.1 Proximate Composition of Flour

The proximate composition of wheat, un-malted, and malted barley flour was obtained and presented in Table 2.

The chemical composition of wheat flour was analyzed and the results revealed that moisture content was 11.55 %, crude protein was 9.76 %, and crude fat was 1.23 %, respectively results corresponding with [41]. Similarly, the chemical composition of barley flour was analyzed, and similar results were reported [42].

3.2 Chemical Composition of Wheat Flour and Malted Barley Flour

The proximate composition of wheat flour (WF) and malted barley flour (MBF) was determined and a t-test was conducted among them, and presented in Table 3.

Statistical analysis showed a significant difference ($p<0.05$) in all the parameters of WF and MBF from each other. The moisture content of the wheat flour was found to be 11.55% within the range described by Sarwar [43] and the moisture content of malted barley flour was reduced to 4.9% within the range given by Arif et al. [44], which was due to the enzyme inactivation process during malting, i.e., kilning. A variety of enzymes were triggered during germination by the hydration process, and these enzymes hydrolyzed and solubilized food stores. Following, the protein content of wheat flour was within the range as revealed by [2,41]. Likewise, the sample of malted flour showed an increase in crude protein content. It was found that when barley grains were malted, their protein content rose. Furthermore, enzymes and nutrients that are made more bioavailable during the malting process may have contributed to the increase in protein content of malted barley flour, which was within the range described by Traore et al. [45].

The crude fat content of WF and MBF was found to be 1.23% and 2.22% respectively. Crude fat in the WF sample was found within the range reported by J. Lin et al. [46] and that of MBF was found to be similar to the result reported by Arif et al. [44]. Likewise, the crude fiber content in MBF was found to be higher than that in WF. This is due to the rise in bran matter and the building of dry matter during the germination process. As a result, high fiber content is crucial for digestion, hormone production, and cardiovascular health. The crude fiber in WF was observed to be similar to the value reported by Cheng and Bhat [47], whereas it was a bit higher as reported by Ikhtiar and Alam [48]. The crude fiber content of MBF was aligned with the result reported by [44,49]. Following this, the total ash content in WF was the lowest as compared to MBF. Higher mineral levels are indicated by a higher ash content. The value of total ash found in the whole WF correspondence to Shrestha [50], which was 0.52%, it was lower as revealed by J. Lin et al. [46], and 2.61% of the total ash content in MBF was within the range reported by Traore et al. [45].

WF had significantly different ($p<0.05$) carbohydrate content as compared to MBF, which was similar to the findings of different researchers [47,51,52]. According to Sramkova et al. [53], the amount of starch contained in wheat grain varied between 60 to 75%, which was within the range of our findings. The carbohydrate content in MBF was slightly higher than reported by Farooqui et al. [54]. Subsequently, it is reported that the antioxidant activity in MBF is greater than in wheat flour this is due to the presence of flavonoids, polyphenols, enzyme activity, and vitamin E, which are produced during the malting process [55]. Following this, the calcium content and iron content of WF were in close agreement with the findings of Ikhtiar and Alam [48]. The calcium content in MBF was found to be 165 mg/100g, which is slightly higher as revealed by Youssef et al. [42]. The value of iron content is similar to the result that aligns with Narsih et al. [49].

3.3 Functional Properties

The functional properties study of flour is very crucial to determining glutein formation, and enzymatic activity, which particularly influence the texture, structure, and overall quality of muffins. These values are presented in Table 4.

The water absorption capacity of 100% WF was slightly lower than that of 83.33% WF: 16.67 MBF; a similar result was reported by Esatbeyoglu et al. [56], which is due to the rise in fiber content and protein content from the MBF. Additionally, flour with an increase in water absorption ratio is a good indication of producing quality-baked products. The oil absorption capacity of 100% WF was found to be less than that of 83.33% WF: 16.67 MBF [57,58], As the oil absorption capacity of flour is very crucial, oil is a flavor enhancer and provides a good mouthfeel for foods [58]. Likewise, the emulsion capacity and foaming capacity of flour play an important role in the baking industry, It was observed that an emulsion capacity of 100% WF was less than 83.33% WF:16.67% MBF. On the contrary, the foaming capacity was found to be higher in the control muffin than that of the best-formulated muffin [57,58]. Following, the sample of 100% WF had a greater value (0.74 g/cm^3) than that of 83.33% WF:16.67% MBF (0.69 g/cm^3). Bulk density presents the idea of the relative volume and type of packaging material required for the product [59].

Table 4. Functional properties of flour

Properties	100% WF (for control sample A)	83.33% WF: 16.67 MBF (best product sample C)
Water absorption capacity (g/g)	1.92 ± 0.22	2.24 ± 0.45
Oil absorption capacity (g/g)	2.4 ± 0.14	2.45 ± 0.65
Emulsion capacity (g/g)	0.68 ± 0.33	0.86 ± 0.22
Foaming capacity (%)	18.27 ± 0.72	16.92 ± 0.36
Bulk density (gm/cm^3)	0.74 ± 0.18	0.69 ± 0.19

Values are the means ± standard deviations of the three determinations. WF= wheat flour and MBF= barley malted flour

3.4 Sensory Properties of Different Treatments

A sensory analysis was performed on the muffin prepared with various ratios of wheat flour (WF) and malted barley flour (MBF). The coded samples were given to 11 semi-trained panelists for sensory evaluation using a 9-point hedonic rating (like extremely =9, dislike extremely=1). After performing sensory tests, they were asked to give a score on experimental muffins for appearance, color, aroma, taste, texture, and overall acceptability. Statistical analysis at a 5% level of significance was used to select the best muffin among all of these samples.

3.4.1 Effect of formulation on appearance

Fig. 1 illustrates that the average appearance scores were observed to be 6.80, 6.40, 7.50, 7.30, 6.60, 6.20, and 5.80, for the muffin formulations A, B, C, D, E, F, and G, respectively. Muffin sample C, containing 83.33% WF: 16.67 MBF parts was significantly higher ($p<0.05$) than all the muffin samples except sample D. Statistical analysis showed that the incorporation of malted barley flour in the muffin had a significant effect ($p<0.05$) on the appearance of the various muffin formulations.

The sample C (83.33%WF: 16.67%MBF) got the highest score, conversely, samples F (62.5%WF: 37.5%MBF) and G (50%WF:50%MBF) ranked lowest score, which may be due to non-glutinous flour reducing loaf volume, which provides poor crumb appearance and decreases acceptability [60]. To achieve the desired quality of muffin, an appropriate balance in the amount of two major protein components (glutenin and gliadin) in wheat gluten is required. Furthermore, the substitution of gluten proteins for non-gluten-forming proteins causes a dilution effect and consequently weakens the dough. Malted barley flour interferes with gluten formation in both a direct and indirect way; the direct effect is related to an interaction between malted barley flour and gluten proteins, and the indirect effect is related to water and the availability of wheat proteins [61].

3.4.2 Effect of formulation on color

The mean sensory scores for color were observed to be 7.3, 7.2, 7.1, 6.4, 5.9, 5.9, and 5.1 for the muffin formulations A, B, C, D, E, F, and G, respectively (Fig. 2). Statistical analysis showed the incorporation of malted barley flour had a significant effect ($p<0.05$) on the color of the different muffin formulations. In general, it was observed that product A got the highest score and showed no significant difference ($p>0.05$) with samples B and C; on the other hand, it was significantly different ($p<0.05$) with samples D, E, F, and G, respectively.

During the sensory examination, researchers discovered that single wheat flour products had superior color compared to other flour products [62,63]. Furthermore, it might be that people like the naturally yellowish-white color of muffins produced just from whole wheat flour; however, when the flour contains malted barley, it takes on a deeper hue during baking, which results in muffins that are somewhat darker in color than control muffins. In sample G, a darker brown color may be the result of a higher level of malted barley flour incorporation, which may also be the reason for a lower level of color acceptability [64,65].

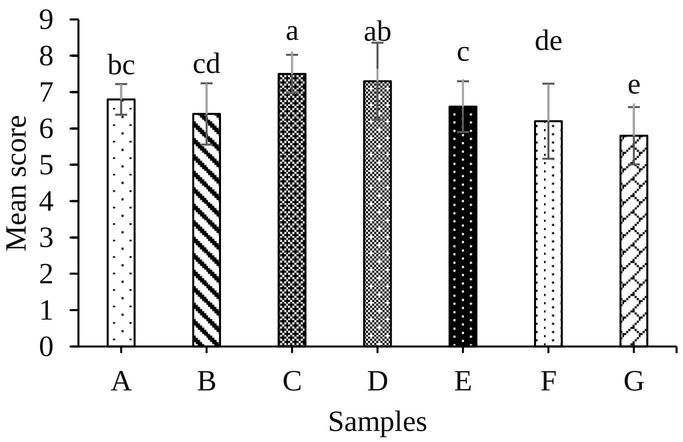

Fig. 1. Mean sensory scores for the appearance of muffins of different formulations

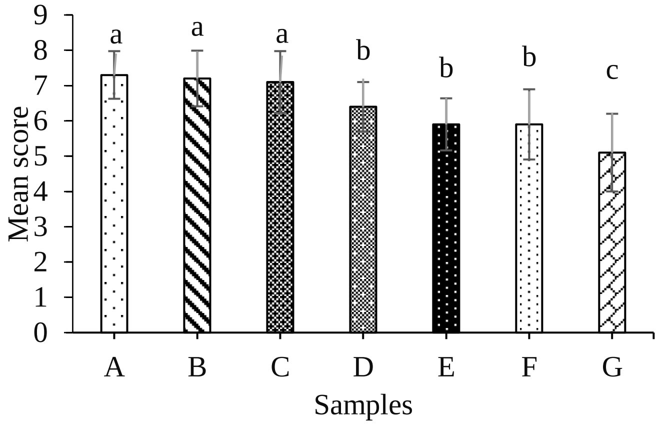

Fig. 2. Mean sensory scores for the color of muffins of different formulations

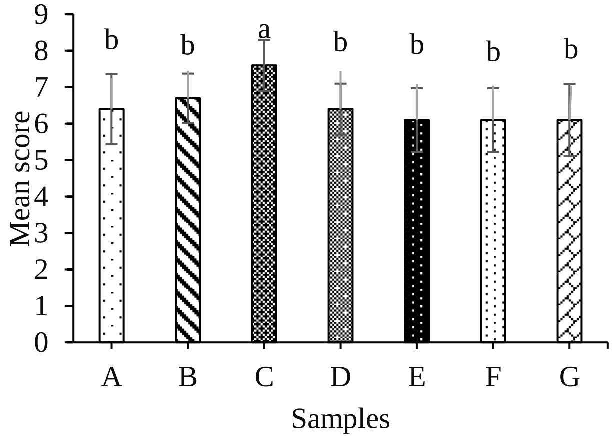

Fig. 3. Mean sensory scores for the aroma of muffins of different formulations

3.4.3 Effect of formulation on aroma

The average mean aroma for the muffin formulations A, B, C, D, E, F, and G was found to be 6.40, 6.70, 7.60, 6.40, 6.10, 6.10, and 6.10, respectively (Fig. 3). Malted barley flour was shown to have a substantial ($p<0.05$) impact on the aroma of the various muffin formulations using statistical analysis. From the observation, sample C (83.33%WF: 16.67%MBF) was found to be the highest. Furthermore, malted barley flour has higher water as well as oil observation capacity, which leads to good flavor development and a better mouthfeel [66].

Samples E, F, and G, which included the muffins with the largest percentage of malted barley, scored lowest, which may have been caused by the muffin`s higher total phenolic and flavonoid content, which gave the panelists an unsatisfactory aroma or flavor aligning with Udeh et al. [67]. It was discovered that sample C's flavor was well-balanced and blended overall, making it superior to other product formulations.

3.4.4 Effect of formulation on taste

Statistical investigation revealed a substantial ($p<0.05$) impact on the taste when malted barley flour was partially substituted for wheat flour. The mean sensory scores for the taste of muffin samples with varying formulations are displayed in Fig. 4. Moreover, when compared to the other samples, Sample C seemed to have the best flavor. Sample C was discovered to differ considerably from all the other samples. On the other hand, samples E, F, and G had the lowest scores out of all the formulations, suggesting that a higher percentage of malted barley flour in the formulations may decrease the product's acceptance in terms of taste [56]. Overall, sample C's composition shows that it is balanced for a decent muffin taste since the muffins have a characteristic, pleasing malty flavor.

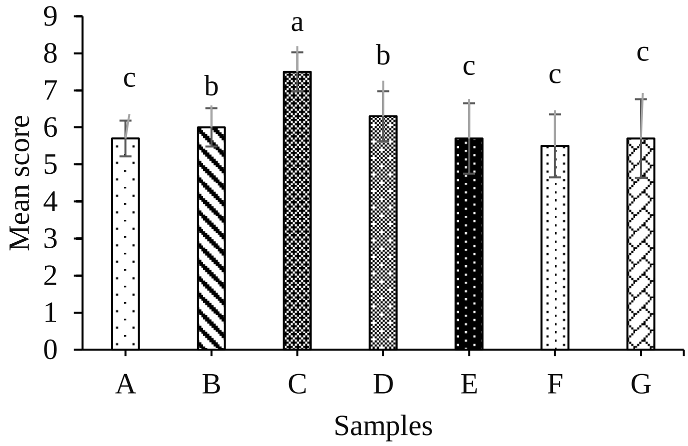

Fig. 4. Mean sensory scores for taste of the muffins of different formulations

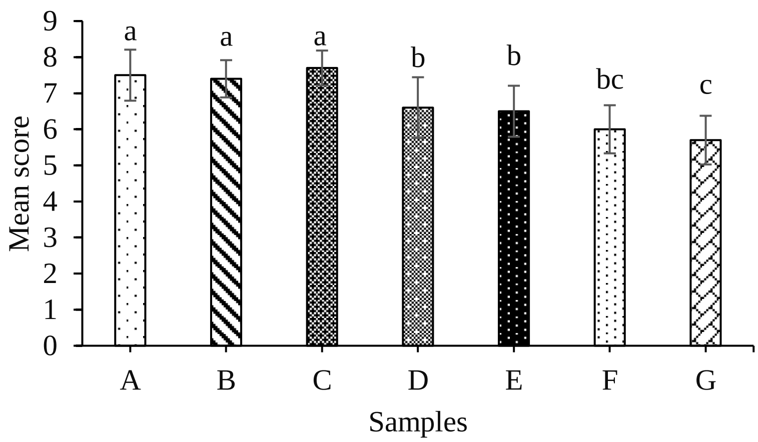

Fig. 5. Mean sensory scores for texture of muffins of different formulations

3.4.5 Effect of formulation on texture

The mean scores of the muffin formulations A, B, C, D, E, F, and G were found to be 7.50, 7.40, 7.70, 6.60, 6.50, 6.0, and 5.70, respectively (Fig. 5). An examination of the data using statistical methods revealed that the texture was significantly affected ($p<0.05$) when wheat flour was partially substituted with malted barley flour.

Sample C got the highest score, which was not significantly different ($p>0.05$) from samples A and B, however, there was a significant difference ($p<0.05$) with samples D, E, F, and G. The texture score drops with increasing amounts of malted barley flour, possibly as a result of the muffin being firmer. The outcome is consistent with research by Chiou et al. [68], who discovered that substituting a larger quantity of other flour for wheat flour increases the fiber content, resulting in muffins with a firmer texture. The texture score declined as the amount of malted barley flour increased, possibly as a result of the crust's fissures and harder texture. Sample C had a solid texture and no cracks, which might indicate that there was enough gluten development. Given its significant impact on customer acceptability of the product, texture is a crucial consideration when evaluating muffins [69].

3.4.6 Effect of formulation on overall acceptability

The mean sensory scores for overall acceptability for muffin formulations A, B, C, D, E, F, and G were found to be 6.60, 6.90, 7.50, 6.80, 6.10, 5.90, and 5.40, respectively (Fig. 6).

A statistical examination of the experimental data revealed that there was a significant difference (p<0.05) in the overall acceptability of samples that had a partial substitution of malted barley flour.

Sample C had the highest overall panelist acceptance score, which may have been attributed to its excellent flavor, appearance, taste, and texture. Sample G largest percentage of malted barley flour may have contributed to its lowest overall acceptance score [56]. In sample C, the right amount of malted barley flour composition produced a pleasing texture and mouthfeel. Based on statistical sensory analysis, sample C, which was formulated as malted barley flour: wheat flour 16.67:83.33, was determined to be the best product.

3.5 Proximate Composition of Control and Best-formulated Muffin

Applying statistical sensory analysis, the best product was found to be sample C, which was prepared as malted barley flour: wheat flour 16.67:83.33. Table 5 illustrates the chemical composition of the control muffin and the optimum formulation muffin.

The optimal formulation's moisture content and crude fat were determined to be not appreciably different from the control muffins (p>0.05). The moisture content of the control muffin and the best-formulated muffin were found to be 27.6% and 28.3%, respectively. The overall moisture content as well as crumb and crust moisture were found to be slightly higher after the incorporation of malted barley flour in product C. The possible reason could be due to the higher amount of soluble dietary fiber (SDF) in malt flour [55]. Moreover, the higher moisture content makes it very prone to microbial attack, which could decrease the shelf life of the product. However, it gives characteristic firmness to the bread. Likewise, the slightly higher fat content in the best-formulated muffin (C) is due to the malted barley flour contributing to the rise in fat.

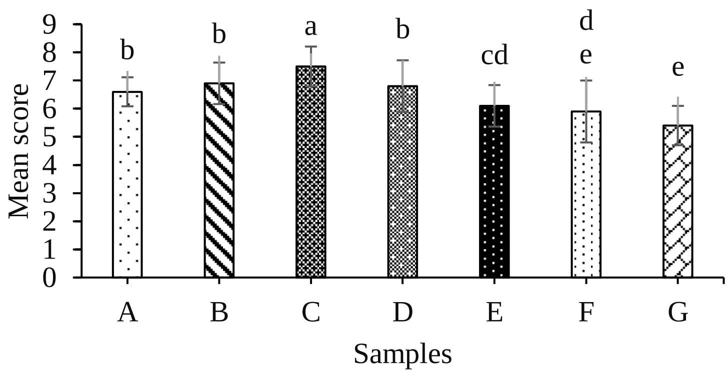

Fig. 6. Mean sensory scores for the overall acceptability of muffins of different formulations

Table 5. Composition of control muffin (A) and best-formulated muffin (C)

Parameters	Control muffin (A)	Best formulation (C)
Moisture (% wb)	27.6 ± 0.26[a]	28.3 ± 0.65[a]
Crude protein (% db)	16.92 ± 0.15[a]	18.1 ± 0.1[b]
Crude fat (% db)	26.5 ± 0.36[a]	26.8 ± 0.26[a]
Crude fiber (% db)	1.2 ± 0.2[a]	2.13 ± 0.14[b]
Total ash (% db)	1.39 ± 0.25[a]	1.95 ± 0.13[b]
Carbohydrate (% db)	53.99 ± 0.52[a]	51.02 ± 0.15[b]
Antioxidant (RSA %)	37.67 ± 0.5[a]	43.4 ± 0.2[b]
Crumb Moisture (% wb)	31.2 ± 0.4[a]	33.6 ± 0.45[b]
Crust Moisture (% wb)	14.81 ± 0.17[a]	15.7± 0.34[b]
Calcium (mg/100g)	39 ± 0.2[a]	70 ± 0.16[b]
Iron (mg/100g)	7.2 ± 0.34[a]	9.2 ± 0.30[b]

Values are the means ± standard deviations of the three determinations. Mean sharing the same letter within a column is non-significant. Means followed by different letters within each column are significant and tested at a 5% level of significance. wb: wet basis, db: dry basis, RSA: Free Radical Scavenging Activity

Comparing the best formulation to the control muffin, it was discovered that the crude protein, crude fiber, total ash, carbohydrate, antioxidant activity, calcium, and iron were considerably greater ($p<0.05$). The protein content increased with the partial addition of malted barley flour to the control muffin from 16.92 to 18.1%, which is due to the increase in albumin and globulin content during the malting process [70]. Likewise, increasing crude fiber in the best-formulated product (C) is due to the rise in bran matter and the building of dry matter during the germination process, which aligns with Aly et al. [14]. The higher fiber content in the best-formulated sample facilitates digestion and maintains a healthy balance of gut microbes. Similarly, the ash content of muffins rose after malted barley flour substitution, this rise may be due to the high mineral content in barley flour, such as phosphorous, calcium, iron, zinc, sodium, magnesium, etc. correspondence with Youssef et al. [42].

The total antioxidant activity of malted barley flour formulated muffin (C) was found to be higher than the control muffin sample (A). Barley malted flour is responsible for raising the % antioxidant activity because MBF contains numerous polyphenols, which can have anti-inflammatory, anti-oxidative, and anti-carcinogenic properties aligning with Aly et al. [14]. Eating foods high in antioxidant activity is linked to better health outcomes. Similarly, the muffin with malted barley flour muffin observed an increase in iron and calcium content compared to the wheat muffin, similar to the report revealed by [71]. An increase in calcium and iron can facilitate a person with deficient micronutrients, iron improves blood volume, avoids anemia and tiredness, supports renal function, and promotes cell formation [72]. Calcium strengthens bones and teeth, heart functioning, and blood clotting [73].

4. CONCLUSION

The study focused on enhancing the nutritional and sensory profiles of barley-based products. While its direct application in processed food is so limited, however, it may be combined with other flour to prepare healthy and nutritious products. Malted barley flour (MBF) was observed to raise crude protein, crude fiber, total ash, reducing sugar, antioxidant activity, iron, and calcium, which enhanced the nutritional attributes of MBF-incorporated muffins. The findings of the sensory evaluation highlighted that muffins prepared from (83.33% WF:16.67% MBF) were observed to be superior in terms of appearance, texture, aroma, taste, and overall acceptability except color. Likewise, the functional properties of flour (83.33% WF: 16.67% MBF) such as water absorption capacity, oil absorption capacity, and emulsion capacity, were found to be a bit higher compared to wheat flour muffins (100% WF). The inclusion of low malted barley flour up to 16.67 parts resulted in muffins with superior nutritional value as well as acceptable sensory attributes. According to statistical analysis, comparing the wheat flour muffin sample A to the malted barley flour substitute muffin sample C (83.33% WF: 16.67% MBF) showed that, there was an enhancement in nutritional attributes including protein, fiber, ash, antioxidant activity, and mineral content. It can be concluded that applying malted barley flour to the production of muffins results in acceptable quality muffins with improved functional nutritional value. Since, barley malt has a variety of nutritional and health-promoting properties (high fiber, mineral content, β-glucan content, antioxidant activity, and improved protein digestibility). Consequently, we can maximize the potential explosion of malted barley flour as a functional food.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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