Preparation of Malted Barley (*Hordeum vulgare*) Flour Incorporated Muffin: Improvement of Sensory, Physiochemical and Nutritional Attributes

ABSTRACT

Barley (*Hordeum vulgare*) is an ancient cereal grain,barley cuisine is becoming more and more popular due to its high nutritious content. The current research work was carried out for the incorporation of malted barley flour (MBF) as a partial substitute for wheat flour (WF) to enhance the sensory, physiochemical, and nutritional attributes of muffins. After the malting of barley, it was observed that there was an increase in crude protein, crude fiber, reducing sugar, calcium, antioxidant activity, and iron. On the other hand, a decrease in moisture content, crude fat, and total ash was observed. The recipe was formulated through Design Expert 13 software for 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 respectively. The superior product obtained through sensory evaluation of 9-point hedonic rating.These findings highlighted that malted barley flour be safely added to refined wheat flour up to a concentration of(83.33%WF: 16.67%MBF)sample C without compromising the flour's sensory attributes, which was then put through additional physiochemical study. Moreover, the crude protein, crude fat, crude fiber, total ash, carbohydrate, antioxidant activity, iron, calcium of best-formulation sample (sample C) were found to be.18.1%, 26.8%, 2.13%, 1.95%, 51.02%, 43.4 %, 9.2(mg/100g), and 70(mg/100g), respectively whereas the control sample (A) wheat flour muffin was found to be 16.29%, 26.5%, 1.2%, 1.39%, 53.99%, 37.67%, 7.2(mg/100g), and 39(mg/100). Overall, the statistical study ($p<0.05$) revealed that, when compared to wheat flour muffins, substituting malted barley flour considerably enhanced all the physicochemical parameters (crude protein, crude fiber, total ash, carbohydrate, antioxidant, calcium, and iron), exceptmoisture and crude fat.

Keywords: Malted barley flour; Cereal-based product; Functional components; 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. The main component of flour used to make muffins is gluten, a key protein found in wheat flour [1]. In some regions, muffins are both relatively affordable and well-liked. Some institutions have benefited from this and established great reputations for themselves [2,3]There is a correlation between consuming cereals and other dietary products based on cereal and a lower risk of certain serious illnesses [4].

Barley (*Hordeum vulgare*) may have originated as human food but, owing in part to the rise in popularity of wheat and rice predominantly evolved into a feed, malting, and brewing grain. Because of its nutritious richness, barley food is experiencing popularity across the globe. β-glucans, derived from barley, oats, and other cereals, are also considered to be crucial functional components of the cereal food sector[5,6].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, the European was the world's top producer of barley followed by ASIA, and America [7].A significant portion of the world's barley is grown in areas where rice and other cereals like maize cannot thrive [8]. The process of malting involves the modification of grain components more easily soluble [9]. Additionally,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. Furthermore, three primary types of modifications occur in the cereal grain during the malting process: (a) hydrolytic enzymes' mobilization; (b) several chemical alterations that take place in the grain and; (c) physical alteration that manifests as the grains being softer and weaker [10]. The malting of barley increases the availability of proteins, sugar, vitamins, and amino acids, especially tryptophan, methionine, and lysine, and lowers of glycemic index and anti-nutritional factors[11].

Furthermore, several nutrients, including some vitamins, minerals, and dietary fiber, are lacking in the wheat flour used to make muffins [12]. Some critical amino acids, including lysine, tryptophan, and threonine, are absent in wheat flour [13] Because school children typically consume muffins as a snack and require more protein per unit of body weight than adults, the low nutritional content of muffins is cause for serious worry of nowadays.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[14].

In many research, malted barley enhances the product's texture, flavor, aroma, and nutritional content [15]. Numerous studies on the nutritional content of regular wheat flour muffins have been conducted. Wheat 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 [16]. The main goal of scientific work is to add malted barley flour to the recipe for muffinsto overcomenutritional shortcomings, and sensory improvement, and also implement it in the baking industry.

2. MATERIAL 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 (Weikfied Food Pvt. Ltd.,), and egg 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. [17]with slight modification. Cleaning is the initial process before malting where husk, 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[18], 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 of malted barley flour

The independent variable for the experiment is 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 employedwhich was presentedin 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.

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

2.2.3Preparation of muffin

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, then these components were 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 [19].

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 [20] and Ranganna [21].

Carbohydrate was determined by weight difference method as described by AOAC [20].

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

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 byNarayan and Narasinga Rao [22]. Likewise, Water and oil absorption capacities were determined according to the method described by Okezie and Bello[23]. Emulsion capacity was determined by applying the procedure of Abbey and Ibeh[24] with slight modification.

2.2.5 Determination of minerals

According to AOAC 2012 [20] iron and calcium were determined. Iron content was then colorimetrically measured at 480 nm with 100% transmittance set as the blank. Following, 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. [25]. 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.

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

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 [26].

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 [27]. 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 [28].

3. RESULTS AND DISCUSSION

This work was done toprepare the standard quality of several muffin formulations using various ratios of malted barley to wheat flour. Wheat flour (WF) and barley malt flour (MBF) was blended into 7 different ratios as 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

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

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

The chemical composition of wheat flour was analyzed and the result revealed that moisture content was 11.55 %, crude protein 9.76 %, and crude fat 1.23 %, respectively results corresponding with [29]. Similarly, the chemical composition of barley flour was analyzed and similar results were reported [30].

3.2Chemical composition of wheat flour and malted barley flour

The independent t-test was conducted between wheat flour (WF) and malted barley flour (MBF) is presented in Table 3.

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 were the means ± standard deviations of the three determinations. Mean sharing same the 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

Statistical analysis showed aSignificant difference ($p<0.05$) in all the parameters of WF and MBF from each other.The moisture content of the wheat flour found to be 11.55 within the range described by Sarwar [31] and the moisture content of malted barley flour was reduced to 4.9 is found within the range given by Arif et al. [32], which was due to 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 [3,29]. 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 was within the range described by Traore et al. [33].

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. [34]and that of MBF was found similar to the result reported by Arif et al. [32]. Likewise,the crude fiber content in MBF was found to be higher than 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 found similar to the value reported by Cheng and Bhat [35], Conversely, abit higher as reported by Ikhtiar and Alam [36].The crude fiber content of MBF was aligned with the result reported by[32,37]. Following this, the total ash content in WF was lowest and higher in MBF.Higher mineral levels are indicated by higher ash content. The value of total ash found in the whole WFcorrespondenceto Shrestha [38], which was 0.52%it was lower as revealedby J. Lin et al. [34] and 1.1% of total ash content in MBF was within the range as reported by Traore et al. [33].

WF had significantly different ($p<0.05$) in carbohydrate content as compared to MBF, which was similar to the findings of different researchers [35,39,40].According to Sramkova et al.[41] stated that the amount of starch contained in wheat grain varied between 60 to 75% which was in the range of our findings. The carbohydrate content in MBF was slightly higher than reported by Farooqui et al. [42].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 is produced during the malting process [43]Following, the calcium content and iron content for WF were in close agreement with the findings of Ikhtiar and Alam [44]. The calcium content in MBF was found to be 165mg/100g, which is slightly higher as revealed by Youssef et al. [30]. The value of iron content is similar to the result that aligns withNarsih et al. [37].

3.3 Functional properties

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

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 were the means ± standard deviations of the three determinations. WF= Wheat Flour and MBF= Barley Malted Flour

The water absorption capacity of WF was slightly lower than that of 83.33% WF: 16.67 MBF, a similar result was reported by Esatbeyoglu et al. [45], 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 to produce quality-baked products. The Oil absorption capacity of 100% WF was found to be less than that of 83.33% WF: 16.67 MBF [46,47], as the oil absorption capacity of flour is very crucial, oil is a flavor enhancer and provides a good mouth feel of foods[47]. 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, foaming capacity was found to be higher in control muffin than that best formulated-product [46,47]. Consequently,the sample 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 [48].

3.4 Sensory properties of different treatments

A sensory analysis was performed on the muffin made with various ratios of wheat flour (WF) and malted barley flour (MBF). The coded samples were given to 11 semi-trained panelists for sensory using a 9-point hedonic rating (like extremely =9, dislike extremely).After performing sensory, 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

Fig1, illustrates 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. Except for muffin sample C, formulation A containing 100 parts of wheat flour was significantly higher ($p<0.05$) than all the muffinsamples. 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.

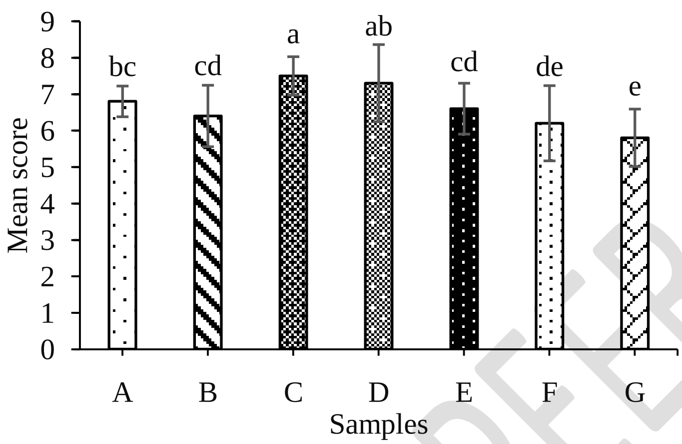

Fig 1 Mean sensory scores for the appearance of muffins of different formulations

The sample C (83.33%WF: 16.67%MBF) got the highest score, conversely, sample F (62.5%WF: 37.5%MBF) and G (50%WF:50%MBF) ranked lowest score which may be due to non-glutinous flour reduces loaf volume, which provides poor crumb appearance and decreases acceptability [49].To achieve the desired quality of muffin, an appropriate balance in the amount of two major protein components (glutenin and gliadin) of wheat gluten is required. Furthermore, the substitution of gluten proteins by 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 availability of wheat proteins [50].

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 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 thehighest score and showed no significant difference ($p<0.05$) with samples B and C on the other hand, significantly different with samples D, E, F, and G respectively.

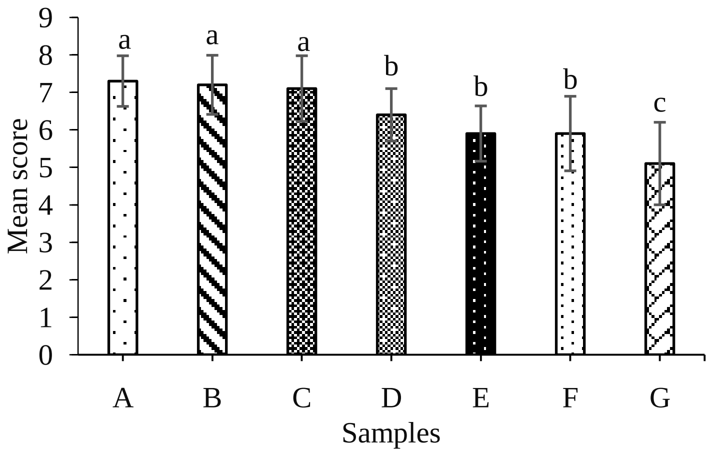

Fig 2 Mean sensory scores for the color of muffins of different

During the sensory examination, researchers discovered that single wheat flour products had superior color compared to other flour products [51,52]. 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 correspondence with [53,54].

3.4.3 Effect of formulation on aroma

The average mean aroma for the muffin formulation 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 color of the various muffin formulations using statistical analysis. From the observation, it was found 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 better mouth feel [55].

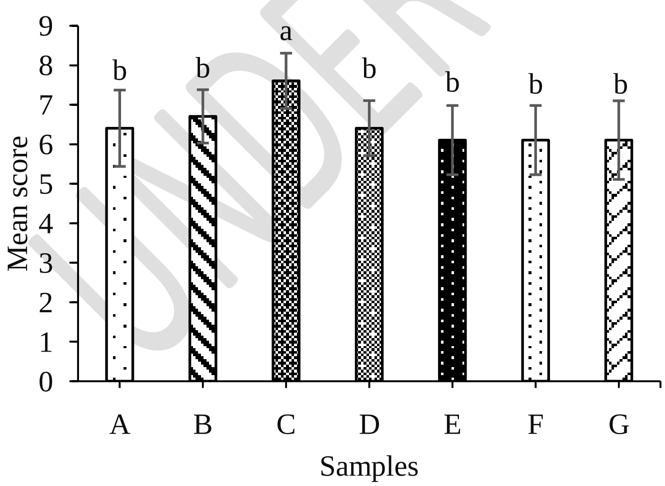

Fig 3. Mean sensory scores for the aroma of muffins of different formulations

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 muffins higher total phenolic and flavonoid content, which gave the panelists an unsatisfactory aroma or flavor aligns withUdeh et al. [56].It was discovered that sample C's flavor was well-balanced and blended overall, making it superior to other product formulations.

3.4.3 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. Moreoverwhen compared to the other samples, Sample C is deemed to have the best flavor. Sample C is discovered to differ considerably from all other samples. On the other hand, samples E, F, and G had the lowest scores out of all the formulations, suggesting that a larger percentage of malted barley flour in the formulations may decrease the product's acceptance in terms of taste [45]. Overall, sample C's composition shows that it is balanced for a decent muffin taste since the muffins have a characteristic, pleasing malty flavor.

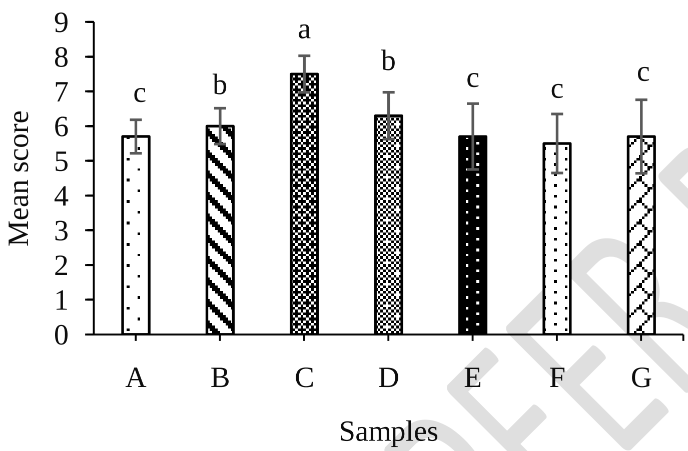

Fig 4. Mean sensory scores for taste of the muffins of different formulations

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.

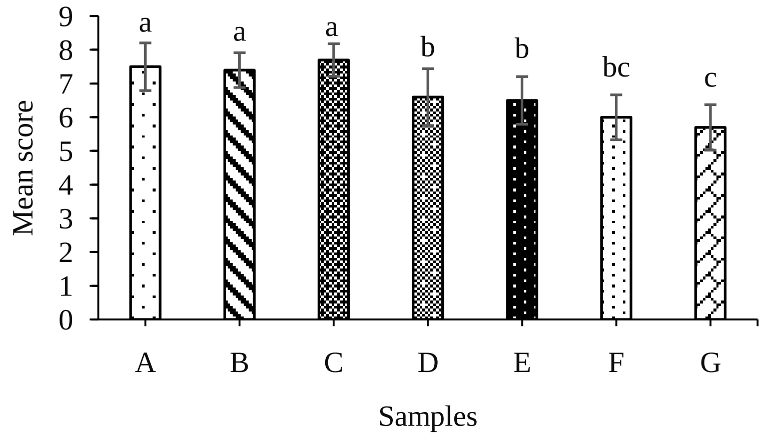

Fig 5. Mean sensory scores for texture of muffins of different formulations

Sample C got the highest score which was not significantly different ($p<0.05$) from samples A and B, however, significant difference ($p>0.05$) with samples D, E, F, and G.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. [57],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 [58].

3.4.5 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 partial substitution of malted barley flour.

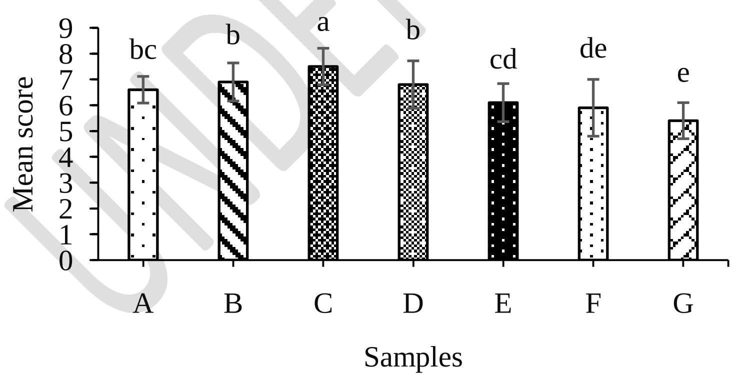

Fig 6. Mean sensory scores for the overall acceptability of muffins of different formulations

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 [45]. 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. The sample formulation is thought to be optimal.

3.5 Proximate composition of control and best-formulated bread

Applying statistical sensory analysis, the best product was found to be sample C, which was made 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.

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 were the means ± standard deviations of the three determinations. Mean sharing same the 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

The optimal formulation's moisture content and crude fat were determined to be not appreciably different from the control muffin's ($p>0.05$). The moisture content of the control muffin and the best-formulated 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 ofsoluble dietary fiber (SDF) than wheat flour [43]. 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, theslightly higher fat content in the best-formulated muffin (C) is due to the malted barley flour contributing to therise in fat.

Comparing the best formulation to the control muffin, it was discovered that the crude protein, crude fat, crude fiber, total ash, carbohydrate, antioxidant activity, calcium, and iron were considerably greater ($p<0.05$). The protein content increased in the partial addition of malted barley flour to the control muffin from 16.92 to 18.1 which is due to the increase in albumins and globulins content during the malting process [59]. 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 thegermination process aligns with Aly et al. [60].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. [30].

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 because MBF contains numerous polyphenols, which can have anti-inflammatory, anti-oxidative, and anticarcinogenic properties aligningwith Aly et al.[60].Eating foods high in antioxidant activity is linked to better health outcomes. Similarly, the muffin with malted barley flour observed an increasein iron and calcium content to wheat bread similar report revealed by [61].

3.6 Recommendations

1. Entrepreneurs may increase the nutritious content of regular muffins by applying malted barley flour up to 16.67 parts without hampering consumer acceptance.
2. Research might be done on baking different baked goods, such as breads, by combining malted barley flour with wheat flour.
3. Muffin shelf life and packaging materials might be studied.

4. CONCLUSION

In conclusion, malted barley flour (MBF) was observed to raise crude protein, crude fiber, total ash, reducing sugar, antioxidant activity, iron, and calcium, which enhance the nutritional attributes of MBF incorporated muffin. The findings of sensory evaluation highlighted that muffin prepared from (83.33% WF:16.67% MBF) was 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 muffin (100% WF). According to statistical analysis, when comparing the wheat flour muffin sample A to the barley flour substitute muffin sample C showed enhance in nutritional attributes including protein, fiber, ash, antioxidant activity, and minerals content.

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