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QUALITY CHARACTERISTICS AND STORAGE STABILITY OF GLUTEN-FREE CUPCAKES MADE OF BUCKWHEAT AND RICE FLOUR

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ABSTRACT

This study looked into the physicochemical and rheological properties of buckwheat (BW) and rice flour (RF) as the base ingredients for gluten-free cupcake formulations and how those properties related to the quality of the baked products. Different BW and RF ratios—10:90, 20:80, and 30:70—were used to create gluten-free cupcake recipes. Compared to wheat flour (WF), gluten-free BW, and rice-based composite flours showed substantial changes in proximate composition and declining number range, according to physicochemical and rheological analyses. The particle size of RF was finer than BW and wheat flour. When BW flour, the darkest flour, was blended with RF, the lightest flour, the resulting cupcakes were noticeably lighter than those made with wheat flour. With increasing amounts of BW flour, cupcakes received higher sensory scores overall. That increases the amount of BW flour in a product, which indicates more consumer appeal. Following the addition of more BW flour, the proximate composition and physical characteristics of cupcakes significantly changed. All of the cupcake samples showed a noticeable reduction in moisture content after 8 days of storage, but there was no discernible alteration in the amounts of fat or protein. Except for softness and stickiness, which showed just a slight difference in sensory scores after storage, all of the samples' sensory scores were significantly lower after 8 days. A non-significant ($p<0.05$) declining tendency was seen when cupcake height was compared to weight during storage.

1. Introduction

Gluten is the primary protein in flour that gives objects their forms. Additionally, it imparts elastic qualities to dough and influences the appearance and crumb shape of many baked items (Gallagher *et al*., 2004). New approaches are being developed to change the structure and subsequently, the functioning of this unique protein component to give a variety of functional features at a lower cost than competitors like milk and soy protein. The sensitivity known as celiac disease (CD) (avenin) has been linked to the prolamin of rye (secarin), barley (hordein), and possibly oats as well as the gliadin part of wheat. Celiac disease, often known as gluten intolerance, causes immunologically driven inflammatory damage to the small intestine mucosa (Arslan *et al*., 2019). All across the world, celiac disease is becoming more common. Because so little is known about this disease, which is primarily immune-based, the prevalence has increased. It has been a long time since the cause of this sharp increase trend was discovered, but it might be connected to environmental factors that can lead to a lack of tolerance to dietary gluten

(Lebwohl and Rubio-Tapia, 2020). A gluten-free diet is a component of celiac disease treatment, but it is also extensively practiced outside of patient care. It becomes obvious that the majority of those who avoid gluten do not have undiagnosed celiac disease. In recent years, gluten-free products have become very popular since they cater to both consumers who follow a gluten-free diet and those who have medical demands (Pellegrini and Agostoni, 2015). RF is one of the grains that work well for the creation of gluten-free dishes due to its pleasant taste, hypoallergenic characteristics, lack of color, low sodium content, and readily digestible carbs (Gujral *et al*., 2003; Gujral and Rosell, 2004; Lopez *et al*., 2004).

Rice proteins are unable to generate the network needed to hold the gas produced during the fermentation process and baking. Rice only contains 2.5–3.5% prolamin, hence adding water to RF does not produce a viscoelastic dough. The resulting product has a low specific volume and doesn't resemble wheat bread since it can't hold the gases produced during baking and proving (McCarthy *et al*., 2005). A pseudocereal is something that includes BW, quinoa, and amaranth. BW is a beneficial ingredient for enhancing food industry processing and marketing prospects due to its nutritious qualities (Mariotti *et al*., 2008). Up to 50% of BW protein is made up of globulin, and 25% is low molecular weight chain polypeptide (Choi *et al*., 2006). BW flour is an important dietary source of protein because of its high protein content. BW protein contains one of the highest concentrations of amino acids of any plant-based protein.

Prolamin and glutelin levels in BW flour are low, but albumin and globulin levels are high (Ikeda, 2002). Maximum levels of flavonoids and polyphenols can be found in BW. BW includes phenolic substances such as 3-flavanol, rutin, phenolic acids, and their derivatives as well as tocopherols, which may act as antioxidants (Sakac *et al*., 2011). The goal of this research was to prepare gluten-free flour by combining rice and BW flour, analyze the physical, chemical, and rheological properties of the composite flour made from rice and BW, make gluten-free cupcakes, and assess the quality and storage stability of the cupcakes.

2. Material and methods

2.1. Collection of samples and consumables

The Pakistan Agriculture Research Center, Sakardu, supplied the common BW (*Fagopyrum esculentum*). The rice (*Oryza sativa*) variety (Green super rice) was gathered at the Food Science Research Institute, NARC-Islamabad. The wheat (*Triticum aestivum*) variety (AZRC) was collected from the Crop Sciences Institute, NARC-Islamabad. Sodium hydrogen carbonate (NaHCO3), vegetable fat, sugar, eggs, and milk powder were purchased from the local market of Rawalpindi.

2.2. Milling of grains

Each grain was meticulously cleansed. 14 ml/100 g of moisture was used to condition wheat grains for one day (El-Porai *et al*. 2013). Quadrumat Senior Mill (Brabebder GmbH & Co.) was used to mill the grains of wheat and BW. Rice grains were ground using a Perten laboratory mill 3100 from Perten Instruments in Hagersten, Sweden.

2.3. Treatments plan

As a control sample, WF was used. RF and BW flour were combined in various proportions, such as 10% BW flour: 90% RF (B_1), 20% BW flour: 80% RF (B_2), and 30% BW flour: 70% RF (B_3).

2.4. Physicochemical and rheological properties

The test weight and thousand kernels weight were determined by following the previously stated procedure (Fred, 2008). Balance (SEEDBURO, Model 8800A) was used to weigh the grains. The particle size distribution of flours was evaluated by using sieves of particular pore size (>250 µm to <55µm), moisture by hot air oven (MEMMERT), ash by muffle furnace (CARBOLITE AAF 1100), wet gluten by glutomatic, dry gluten by glutork-2020, gluten index by centrifuge-2015, falling number by falling number instrument (Perten, Type

1500F), protein by behrotest[R] S5 distillation unit, fat by BUCHI Extraction System B-811 and farinographic parameters by Brabender Farinograph (Version: 3.2.6) according to reported procedures (Fred, 2008).

2.5. Cupcake preparation

The reported recipe was modified to make cupcakes (Carullo *et al.*, 2020). Cupcakes were made with substances like sugar, eggs, vegetable fat, milk powder, and sodium hydrogen carbonate (NaHCO3). A mixer was used to combine the liquid entire egg for 10 minutes. Once a transparent consistency was achieved, 100 g of sugar and 100 g of vegetable oil were added. 4g of sodium hydrogen carbonate (NaHCO3) and 100g of the flour were combined before being added to the dough. 100g of the milk powder was added towards the end of the mixing process. A cake pan was filled with 100g of the dough after it was weighed. For 30 minutes, samples were baked at 180 °C in a baking oven. Baked samples were allowed to cool at room temperature.

2.6. Storage of cupcakes

A stated procedure was used after making certain adjustments to store cupcakes (Villanueva and Trindade, 2010). At room temperature, cupcakes were kept for around 0 days, 2 days, 4 days, and 8 days. Each cupcake with a paper mold as the base was individually wrapped in an aluminum foil multilayer film and kept in plastic zip bags for storage.

2.7. Physical characteristics, sensory attributes, and proximate properties of cupcakes

Vernier calipers were used to measure width and length. Above mentioned digital weighing balance was used to weigh cupcakes (Mancebo *et al.*, 2015). After an hour of baking, cupcakes were tested for color, flavor, texture, softness, stickiness, and chew ability. Cake samples were rated on a 9-point Hedonic Scale (1 being the most disagreeable and 9 being the most agreeable). 14 judges—7 men and 7 women ranging in age from 30 to 47—scored each sample. Scorecards and polyethylene bags containing cupcakes were given out. A trained panel of 14 judges, consisting of 7 men and 7 women, aged 30 to 47, evaluated each sample for the sensory qualities of the cupcake. Each judge evaluated two cupcakes, and the average scores were determined (Yousaf *et al.*, 2020). The moisture, protein, and fat content of cupcakes were analyzed by following the reported procedures (Fred, 2008).

2.8. Statistical analysis

Following three repetitions of each test, the standard deviations for the average findings were noted. Version 16 of MINITAB software was used to conduct the statistical analysis. By creating Pearson correlation coefficients between cupcake quality measures and fine flour qualities, it was possible to assess how BW and RF quality attributes affected cupcake quality. (ANOVA) was used to determine how the samples differed. The least significant difference (LSD), a measure of the difference between mean values, was employed at a 5% level of significance.

3. Results and discussion

3.1. Test weight and thousand kernel weight

The test weight with the maximum value was found in WF, followed by BW and RF, respectively (Table 1). According to a study, Sham-3 had the lowest test weight (83.10 Kg/Hl) and Douma-29019 had the highest value (85.90 Kg/Hl) (Sakac *et al.*, 2011). A study was done to assess the qualities of different rice types. Forme Chena had the highest test weight value (769.01 4.0 kg/m^3), whereas Barkat Chena had the lowest value (502.00 62.48 kg/m^3) (Rather *et al.*, 2016).

As a result of the larger size of wheat grains compared to BW and rice grains, wheat had the highest value of a thousand kernel weight while BW and rice had the lowest (Table 1). Previous research comparing the physical and chemical characteristics of two BW varieties (commercial BW and the Guneş variety) revealed that the thousand kernel weight of commercial BW was 19.98±1.21g and that of the Guneş variety was 21.74±0.81g (Unal *et al*., 2017).

3.2. Moisture and ash content

The addition of BW to other flour led to an increase in moisture content, which was seen over time. BW had the highest moisture content, which was followed by WF and RF (Table 1). The examination of the physical and chemical properties of BW, and WF used in gluten-free cookies revealed increased values of moisture % by the inclusion of BW flour (Ulfat *et al*., 2015). Compared to RF flour, which had the lowest percentages of ash, BW flour had the highest amount of ash. By increasing the ratios of BW flour, the ash content of blended flours was raised (Table 1). A study showed the impact of process variables on gluten-free rice-BW pasta made by a single-screw extrusion cooker, higher ash content values were found in BW flour (Bouasla and Wojtowicz, 2019). Research findings revealed an increasing trend in ash levels while examining the mineral content, antioxidant activity, and sensory evaluation of gluten-free rice and BW biscuits (Sakac *et al*., 2015).

3.3. Gluten and falling number

WF had a noticeable amount of gluten, whereas BW flour and RF had no gluten content. WF was found to have a sizable gluten strength (gluten index) (Table 1). The maximum amount of dry gluten (9.060.30%) was found in wheat flour, however, there was no gluten found when the nutritional characteristics of common BW from four separate Gilgit-Baltistan communities were studied (Kaushik *et al*., 2015). A declining tendency to falling numbers was noted in the RF and BW flour blends by increasing the BW percentage. The analysis of the highest falling number was done in RF, followed by B_1 and B_2, and the lowest value was discovered in BW (Table 1). The ultimate values of falling numbers may be affected by the RF pasting attribute. While researching the preparation of gluten-free biscuits and the impact of gluten-free flour on its physical qualities, a higher falling number was evaluated in rice (Mancebo *et al*., 2015). Similar results were obtained in a study on wheat gluten regeneration characteristics (Kaushik *et al*., 2015).

3.4. Protein and fat content

The highest protein content values were found in BW and the lowest in RF. In formulation, the BW percentage was raised to boost the protein content (Table 1). The inclusion of BW flour in the test recipe for gluten-free bread was found to significantly improve the proteins (KrUpa-KozaK *et al*., 2011). BW had the highest value of fat content, while WF had the lowest (Table 1). The addition of BW steadily raised the fat content of blended flours. After adding BW flour to gluten-free tarhana, the values of the fat contents were examined. According to the approximate composition of the flours, BW flour contained 1.81±0.03% fat, and refined WF included 1.78±0.08% fat (Bilgicli, 2009[a]).

3.5. Farinographic properties

Results showed that blend B_3 required more time for dough development, whereas blend WF required less time (Table 1). By adding BW to other flour, a rising tendency in dough development time was observed. Regarding the impact of using BW flour instead of WF on the production of pasta and cookies, our results values were in agreement with the earlier study. The trend of increase in dough development time was recorded after substituting wheat flour with millet and sorghum flour from 10% to 30% during a study on rheology and quality of composite flours (Torbica *et al*., 2012). Maximum water absorption was reflected in WF and minimum in B_3 (Table 1). There was a trend toward less water absorption during the addition of BW. When examining several quality indicators of bread and dough made with WF but substituted with BW flour and millet flour, a similar trend of declining water absorption was observed. In comparison to WF which contained 30% BW flour and reflected a value of 52.6%, WF had a greater water absorption rate (54.8%) (Izydorczyk *et al*., 2013).

Table 1. Physicochemical and rheological properties of flour

Sample	FC	PC	MC	Ash	FN	WG	DG	TW (Kg/ Hl)	TGM (g)	WA (%)	DDT (min)	DST (min)	MTI (BU)
WF	1.99a ±0.10	10.71b ±0.22	13.74d ±0.17	0.43b ±0.02	368c ±1.50	25.48a ±0.58	9.06a ±0.30	82.00c ±1.20	53.05c ±1.08	63.10 e±0.18	5.00a ±0.17	6.10a ±0.22	63.00a ±1.70
BW	3.57a ±0.14	11.21b ±0.13	15.88e ±0.15	1.70e ±0.03	226a ±1.60	0	0	78.40b ±1.18	29.00b ±1.03	61.3f ±0.25	19.5c ±0.08	18.1f ±0.13	390.0b±2.30
RF	2.13a ±0.24	8.64a ±0.17	11.82a ±0.20	0.31a ±0.01	611f ±1.50	0	0	57.00a ±1.24	19.00a ±1.06	53.2b ±0.31	19.9d ±0.15	13.2b ±0.20	507.0d ±1.50
B_1	2.15a ±0.19	10.76b ±0.15	12.77b ±0.14	0.38b ±0.04	509e ±1.80	0	0	N/A	N/A	57.6d ±0.16	16.5b ±0.25	14.0c ±0.17	507.0d±3.00
B_2	2.41a ±0.9	10.80b ±0.23	13.02bc ±0.19	0.50c ±0.03	432d ±1.90	0	0	N/A	N/A	54.1c ±0.22	19.5c ±0.14	15.5d ±0.10	488.0c±2.70
B_3	2.79a ±0.15	10.84b ±0.14	13.24c ±0.23	0.68d ±0.05	359b ±1.70	0	0	N/A	N/A	52.1a ±0.29	20.0d ±0.09	16.1e ±0.19	505.0d ±1.90

The mean value of replications (n=4) in a column differs significantly $p<0.05$, *FC* Fat content, *PC* Protein content, *MC* Moisture content, *FN* Falling number, *WG* Wet gluten, *DG* Dry gluten, *TW* Test weight, *TGM* Thousand Kernel weight, *WA* water absorption, *DDT* dough development time,
DST dough stability time, *MTI* mixing tolerance index, *WF* Wheat flour, *BW* Buckwheat flour, *RF* Rice flour, B_1 10% BW flour: 90% RF, B_2 20% BW flour: 80% RF, B_3 30% BW flour: 70% RF

Table 2. Sensory characteristics and physical properties of cupcakes

Sample	Color	Taste	Flavor	Texture	Softness	Stickiness	Chew ability	Weight (g)	Height (cm)	Volume (ml)
WF	7.50bc ±1.08	8.00b ±1.24	7.90b ±1.05	5.50b ±1.21	3.00a ±1.01	2.00a ±1.30	9.00a ±1.43	90.00c ±0.47	4.90a ±0.29	281.0f ±0.43
BW	5.00a ±0.97	6.30ab ±0.97	6.20ab ±1.20	4.80ab ±1.04	2.50a ±1.31	3.00a ±1.08	8.50a ±1.71	90.40d ±0.29	4.80a ±0.43	266.1e ±0.19
RF	8.00c ±0.88	5.00a ±1.16	5.10a ±0.85	3.20a ±1.09	2.00a ±0.99	4.00a ±1.99	7.20a ±1.09	88.00a ±0.51	4.70a ±0.37	231.3a± 0.26
B_1	6.00ab ±1.04	5.90ab ±1.31	5.70a ±1.04	4.00ab ±1.11	2.20a ±1.25	3.40a ±1.57	8.00a ±1.68	89.00b ±0.73	4.73a ±0.18	238.3b ±0.28
B_2	6.80abc ±1.15	6.60ab ±0.89	6.40ab ±1.22	4.40ab ±0.99	2.30a ±1.09	3.30a ±0.86	8.30a ±1.19	89.40bc ±0.44	4.76a ±0.32	246.8c ±0.35
B_3	7.00bc ±0.99	6.50ab ±1.05	6.60ab ±0.91	4.60ab ±1.14	2.40a ±1.51	3.20a ±1.25	8.60a ±1.03	89.70bc ±0.31	4.78a ±0.41	250.5d ±0.21

The mean value of replications (n=4) in a column differs significantly $p<0.05$, *WF* wheat flour, *BW* buckwheat flour, *RF* rice flour, B_1 10% BW flour: 90% RF, B_2 20% BW flour: 80% RF, B_3 30% BW floor: 70% RF

When compared to wheat flour, BW flour demonstrated greater dough stability over a longer period (Table 1). BW was added to RF, and an increase in dough stability time was observed. A research work reflected that the dough stability was significantly higher, particularly for dough with a buckwheat flour percentage of 30 g/100 g, which was 4.6 min compared to dough with only wheat flour at 0.3 min (Nada *et al*., 2011). The minimum value of the mixing tolerance index was visible in the dough made from wheat flour. In the RF and BW, the highest values of the mixing tolerance index were found respectively (Table 1). According to a study, water absorption values and the mixing tolerance index for resistant starch-wheat flour blends increased significantly as the quantity of resistant starch increased from 0 to 20% (Lei *et al.*, 2008).

3.6. Physical properties of cupcakes

With the addition of BW flour to RF, a rising weight trend was observed. The height and volume of the cupcake were reduced as compared to the control sample (Table 2). These findings are consistent with previous research on the textural and physical properties of millet-based muffins. The height of control muffins (no barnyard millet flour) was 33.88 mm. When refined wheat flour was replaced with barnyard millet flour, the height was reduced from 33.22 mm to 28.20 mm (Goswami *et al.*, 2015). The decrease in height of the bread containing BWF may be attributed to the poor air bubble retention capacity and limited CO_2-holding ability of the buckwheat dough during baking (Mariotti *et al.*, 2013).

3.7. Sensory characteristics of cupcakes

The results of the sensory attributes of cupcakes are shown in Table 2. WF cupcakes received the highest scores for taste, flavor, texture, softness, and chew ability, whereas RF cupcakes received the lowest scores for taste. Research on the physical qualities and quality traits of gluten-free biscuits produced similar findings. WF biscuits received the highest taste rating, 18.80 out of 20, followed by blended flour made from rice, sorghum, and corn (1:1:1), which received an 18.00 out of 20 (Mancebo *et al.*, 2015). The same flavor ratings were obtained when examining the quality attributes of cookies made with BW and RF. In this investigation, sensory qualities were graded on a hedonic scale of 1 to 5 (1 being much disliked, and 5 being very liked) (Torbica *et al.*, 2012). A study on the quality traits and physical characteristics of gluten-free biscuits investigated textural differences. Biscuits were made with rice, sorghum, and corn flour, with WF serving as a standard (Mancebo *et al.*, 2015). Similar results were found in earlier studies of the quality of steamed cakes supplemented with ordinary and tartary BW. The sensory qualities of steamed cakes were evaluated using a 7-point Hedonic scale (Cho *et al.* Earlier studies looking at the qualitative features of cookies made with BW and RFs revealed equal chew ability results. In this study, sensory qualities were graded on a hedonic scale with 1 being much disliked and 5 being much liked. Cookies made with rice and BW flour (80:20) received the highest chew ability rating of 4.22 (Torbica *et al.*, 2012).

Cupcakes made by RF received the highest grade for stickiness, and cupcakes made by WF received the lowest score. The results of the present experiment are consistent with previous studies on the impact of BW flour on the sensory attributes and quality of eriste, Turkish noodles. A five-point scale (1-extremely detest, 3-acceptable, and 5-extremely like) was used to grade the cooked eriste that was produced (Bilgicli, 2009[b]). Cupcakes made by RF had the highest color score while BW received the lowest color score. The impact of whole BW flour and debittered lupin flour on the nutritional and sensory quality of the gluten-free cake had a significant finding that was closely related to previous research. On a scale of 1 to 5, the sensory qualities of cake samples were rated: 1 equaled a strong dislike, 3 an acceptable rating, and 5 a strong liking (Levent and Bilgicli, 2011).

3.8. Storage stability of cupcakes

3.8.1. Proximate composition

Table 3 shows the close composition and physical characteristics of cupcakes when they are being stored. The cupcakes made by BW had the highest moisture content on the first day, whereas B_1 had the lowest. During storage, cupcakes' moisture content progressively drained out. On the eighth day of storage, the range of moisture loss was highest in cupcakes made by WF and lowest in cupcakes made by RF. All of the other samples showed the same pattern. A similar pattern for moisture content after storage was seen in research on the storage study of pan bread. The moisture content was decreased in the crumb of pan bread during storage at 15ºC (Besbes *et al.*, 2014). Protein content marginally but not dramatically decreased after storage. According to a study on the impact of replacing xylitol in cookies, protein content barely changed over 60 days of storage. According to a previous study, the fat content of cupcakes cooked by BW had the greatest value on the first day, measuring 23.10±0.22%, while those made by RF had the lowest value, 20.04±0.21% (Mushtaq *et al.*, 2010). The fat content of cupcakes made by WF marginally altered throughout the storage; it reduced on the eighth day.

Table 3. Proximate composition and physical properties of cupcakes at storage

Samples	D	MC	PC	FC	Weight(g)	Height (cm)	Volume (ml)
WF	0	15.73a±0.17	6.71a±0.22	21.30cc±0.13	90.00cd±0.47	4.90a±0.29	281.00f±0.43
	2	15.45a±0.18	6.72ab±0.23	21.31a±0.12	90.00cd±0.21	4.89c±0.73	280.98f±0.15
	4	15.00a±0.14	6.70b±0.21	21.26ac±0.20	89.91ad±0.61	4.79a±0.37	280.81f±0.30
	6	14.50ab±0.15	6.67a±0.17	21.21ab±0.21	89.60ac±0.66	4.67b±0.65	280.52e±0.41
	8	13.69a±0.12	6.60a±0.15	21.16a±0.19	89.20c±0.38	4.44a±0.34	280.29e±0.42
BW	0	17.87b±0.15	7.21c±0.13	23.10a±0.22	90.40d±0.29	4.80a±0.43	266.07e±0.19
	2	17.58b±0.11	7.20c±0.18	23.10c±0.13	90.38e±0.38	4.71ad±0.74	265.86ab±0.21
	4	17.00ab±0.14	7.20a±0.15	23.07d±0.17	90.25e±0.49	4.65d±0.55	265.65cd±0.22
	6	16.58bc±0.11	7.19d±0.10	23.06f±0.12	89.99ae±0.56	4.55c±0.63	265.37ef±0.43
	8	16.02a±0.12	7.16ad±0.20	23.02f±0.14	89.75f±0.62	4.43a±0.38	265.11ac±0.41
RF	0	13.79a±0.20	4.64abc±0.17	20.04e±0.21	88.00a±0.51	4.70a±0.37	231.3a±0.26
	2	13.49ab±0.17	4.63a±0.13	20.04a±0.15	87.95ab±0.67	4.65a±0.62	231.07f±0.32
	4	13.03ac±0.16	4.64bc±0.20	20.02f±0.18	87.78b±0.46	4.50b±0.72	230.96cf±0.23
	6	12.49a±0.18	4.62bc±0.19	20.00a±0.12	87.56b±0.53	4.47c±0.30	230.77e±0.34
	8	12.05b±0.14	4.60a±0.17	19.99b±0.16	87.35b±0.71	4.23c±0.52	230.59f±0.31
B_1	0	13.78ab±0.14	5.76ab±0.15	20.10ab±0.19	89.00b±0.73	4.73a±0.18	238.30b±0.28
	2	13.34b±0.15	5.78ac±0.10	20.10c±0.22	88.97c±0.25	4.65ab±0.61	238.04ab±0.42
	4	13.01b±0.11	5.75a±0.16	20.08a±0.21	88.79c±0.39	4.62abc±0.77	237.85c±0.26
	6	12.47ab±0.12	5.71c±0.18	20.04b±0.22	88.57ac±0.46	4.43ac±0.53	237.68e±0.15
	8	12.00c±0.17	5.66d±0.11	20.00ab±0.18	88.48e±0.52	4.21a±0.48	237.41f±0.19
B_2	0	14.03ab±0.19	5.80b±0.23	20.30cd±0.17	89.40bc±0.44	4.76a±0.32	246.75c±0.35
	2	13.71ac±0.16	5.81abc±0.17	20.29cd±0.18	89.31c±0.61	4.61c±0.65	246.56e±0.29
	4	13.25bc±0.09	5.79c±0.22	20.25e±0.14	89.19d±0.59	4.52a±0.76	246.22f±0.28
	6	12.77b±0.18	5.75e±0.21	20.25e±0.11	89.02d±0.27	4.45ab±0.38	246.10c±0.35
	8	12.26a±0.14	5.70b±0.18	20.21a±0.21	88.99d±0.67	4.23abd±0.29	245.83d±0.31
B_3	0	14.25ab±0.23	5.84e±0.14	20.41ab±0.15	89.70bcd±0.31	4.78ac±0.41	250.50d±0.21
	2	14.01ab±0.22	5.85ac±0.21	20.41a±0.21	89.59abc±0.77	4.63c±0.72	250.28a±0.34
	4	13.61b±0.20	5.81e±0.22	20.37c±0.14	89.44ac±0.48	4.54b±0.64	250.03ad±0.41
	6	13.11a±0.18	5.80d±0.18	20.31ab±0.17	89.28bc±0.38	4.39b±0.45	249.81d±0.26
	8	12.66a±0.14	5.78f±0.11	20.31bc±0.11	89.06b±0.45	4.21b±0.39	249.66e±0.23

The mean value of replications (n=4) in a column differs significantly $p<0.05$, *MC* moisture content, *FC* fat content, *PC* protein content, *WF* wheat flour, *BW* buckwheat flour, *RF* rice flour, B_1 10% BW flour: 90% RF, B_2 20% BW flour: 80% RF, B_3 30% BW flour: 70% RF, *D* days.

Weight loss was less in cupcakes based on RF as compared to BW flour and WF during storage (Table 3). Similar results were noted in a study on the quality of gluten-free bread. Bread made of rice flour and corn had 47.42% and 45.27% moisture content during the storage period of 01 to 03 days (UCok and Hayta, 2015). The same findings were reported in research on muffin coating with starch-based bio-composite films, the edible muffin line performed best with 2% potato starch-based films integrating 5% CNF and 30% glycerol (w/w starch) (Shih and Zhao, 2021). Volume values for all of the samples dropped considerably after storage. Similar findings were made when examining how long cupcakes were stored frozen and after par-baking. After storage, the specific volumes for cakes par-baked for 15 and 20 minutes decreased from 2.5±0.12a to 2.32±0.02b (cm^3g^{-1}) and 2.51±0.03a to 2.33 ± 0.02b (cm^3g^{-1}) respectively (Karaoglu *et al*., 2008).

3.8.2. Sensory characteristics of cupcakes in storage

Table 4 provides the average sensory ratings given to cupcakes following storage. After 8 days of storage, scores for color were lower for all cupcake samples. The cupcakes made with RF received the highest rating, followed by those made with WF and BW flour. For every other cupcake, the same scoring trend was seen.

Table 4. Sensory properties of cupcakes at storage

Samples	D	Color	Taste	Flavor	Texture	Softness	Stickiness	Chewability
WF	0	7.50bc±1.08	8.00b±1.24	7.90b±1.05	5.50b±1.21	3.00a±1.01	2.00a±1.30	9.00a±1.43
	2	7.77a±1.02	8.00a±1.28	7.75bc±1.29	5.29ac±1.29	3.02ba±1.11	2.01b±1.27	8.90b±1.77
	4	7.30ab±0.99	7.55a±1.08	7.46bc±1.09	5.00bc±0.87	3.05±1.09	1.99cf±0.97	8.69b±0.72
	6	7.00a±1.01	7.11b±1.04	7.21d±1.03	4.75b±1.29	2.99a±0.91	1.95c±1.44	8.54b±1.56
	8	6.79a±1.05	6.57bc±0.93	7.00ad±0.99	4.53b±1.22	2.80cd±0.82	1.90c±1.32	8.17b±1.67
BW	0	5.00a±0.97	6.30ab±0.97	6.20ab±1.20	4.80ab±1.04	2.50a±1.31	3.00a±1.08	8.50a±1.71
	2	5.08a±0.91	6.00e±0.91	6.05ab±1.08	4.70a±1.33	2.52a±1.23	2.99e±1.02	8.40a±1.76
	4	5.00b±0.94	5.59e±1.12	5.77ac±1.28	4.39a±1.20	2.47ab±0.89	2.95f±1.26	8.00a±1.42
	6	4.91b±1.03	5.13a±1.21	5.39c±1.31	4.00a±1.19	2.25c±0.99	2.80c±0.96	7.82c±0.69
	8	4.66b±1.05	4.68a±1.15	5.00a±1.34	3.74ab±1.04	2.05c±1.20	2.65c±1.29	7.69d±1.61
RF	0	8.00c±0.88	5.00a±1.16	5.10a±0.85	3.20a±1.09	2.00a±0.99	4.00a±1.99	7.20a±1.09
	2	8.05a±0.94	4.79d±0.89	5.02b±0.81	3.12c±0.90	2.01bc±0.82	3.99ac±1.37	7.07b±1.88
	4	8.00ac±1.02	4.33ad±1.27	4.77b±0.86	3.00a±0.83	1.98bc±0.97	3.85b±0.87	6.99ab±1.02
	6	7.89ab±1.09	4.00ac±1.19	4.48a±0.86	2.86a±1.33	1.92c±1.23	3.81b±1.36	6.77c±0.91
	8	7.60a±0.98	3.67c±1.14	4.15a±1.09	2.59a±1.26	1.78c±1.08	3.72bc±1.55	6.55e±1.48
B_1	0	6.00ab±1.04	5.90ab±1.31	5.70a±1.04	4.00ab±1.11	2.20a±1.25	3.40a±1.57	8.00a±1.68
	2	6.07ac±1.11	5.92c±1.18	5.69ab±1.21	3.99bc±0.91	2.12a±1.09	3.32bc±1.31	7.95ae±1.88
	4	5.95b±1.09	5.55c±1.32	5.31ab±1.08	3.65bc±1.29	2.01a±1.02	3.18bc±0.78	7.66f±1.92
	6	5.69b±0.99	5.11b±0.97	5.11c±1.35	3.37cd±1.27	1.95a±0.91	3.04a±1.01	7.37a±1.72
	8	5.50e±0.87	4.77b±1.06	4.00bd±1.26	3.00d±1.09	1.81a±0.90	2.91a±0.78	7.13cd±0.90
B_2	0	6.80bc±1.15	6.60ab±0.89	6.40ab±1.22	4.40ab±0.99	2.30a±1.09	3.30a±0.86	8.30a±1.19
	2	6.80e±1.11	6.40bc±0.82	6.12e±1.31	4.36cd±1.00	2.21a±1.02	3.21c±1.66	8.15b±1.27
	4	6.65e±1.17	6.00a±1.26	6.00f±1.26	4.16ad±1.29	2.11cd±1.21	3.01c±1.29	8.02cd±1.36
	6	6.46a±0.95	5.76c±1.18	5.70e±0.88	4.00ac±0.91	1.98d±1.19	2.93e±1.37	7.82c±0.77
	8	6.20a±1.05	5.39c±1.10	5.33c±0.82	3.88b±1.22	1.86d±1.28	2.81e±1.63	7.39c±1.28
B_3	0	7.00bc±0.99	6.50ab±1.05	6.60ab±0.91	4.60ab±1.14	2.40a±1.51	3.20a±1.25	8.60a±1.03
	2	6.99c±0.98	6.44d±1.03	6.50c±0.92	4.44a±0.91	2.25e±1.20	3.04ab±0.94	8.48b±1.28
	4	6.86e±0.87	6.01d±0.93	6.19c±0.94	4.21a±1.28	2.11ae±0.85	2.92b±1.67	8.24a±1.23
	6	6.59a±1.17	5.68d±1.02	6.02d±1.22	4.00a±1.33	2.02c±1.42	2.81a±1.22	8.00a±0.99
	8	6.38d±1.09	5.32d±1.09	5.76a±1.28	3.78c±1.21	1.92a±1.40	2.67ae±1.87	7.79b±1.59

The mean value of replications (n=4) in a column differs significantly $p<0.05$, *WF* wheat flour, *BW* buckwheat flour, *RF* rice flour, *B_1* 10% BW flour: 90% RF, *B_2* 20% BW flour: 80% RF, *B_3* 30% BW flour: 70% RF), *D* days

On the first and second days of storage, scores for taste and flavor of cupcakes made by WF were maintained, and then they started to decline. Cupcakes made with WF received the highest flavor rating on the eighth day of storage, followed by those made with BW flour and RF. After storage, cupcakes made with WF received the greatest scores for softness, stickiness, and chew ability, followed by those made with BW flour and RF. The cupcakes made by WF and B_3 received the highest ratings during the organoleptic examination.

Similar outcomes were determined in a prior investigation employing acceptance tests to examine the sensory characteristics of chocolate and carrot cupcakes. After 180 days of storage, scores for texture and flavor were much worse. After 180 days of storage, the mean scores for texture and flavor decreased from 7.4 to 4.2 and 7.1 to 4.9, respectively (Villanueva and Trindade, 2010). A previous study on the sensory aspect of biscuits reflected panelists' assessment of general acceptability as well as the attributes for which substantially different scores were assigned to each formulation. The evaluation of odor, aroma, and mouth-feel qualities yielded mean scores ranging from 5.27-5.61, 4.75-5.63, and 5.05-5.69, respectively (Oksuz *et al*., 2016). The impact of flaxseed on bread production was documented in a study.

The sensory scores for the softness of linseed rolls and linseed cinnamon rolls (bakery products) decreased from 7.3 to 5.3 and 6.3 to 2.9, respectively, after 6 days of storage (Pohjanheimo *et al*., 2006).

4. Conclusions

A significant difference ($p \leq 0.05$) was recorded in the physicochemical, rheological, and sensory properties of BW flour, RF, flour blend, and wheat flour. Cupcakes prepared with BW flour resulted in maximum moisture, fat, and protein content compared to cupcakes prepared with RF and WF. Overall sensory properties of cupcakes prepared by BW flour and RF increased the quality, sensory scores, and acceptability. RF contained more BW flour resulting in maximum weight, height, and volume of cupcakes. Sensory scores for cupcakes prepared by BWF and RF blends were significantly decreased at 8 days of storage whereas, softness and stickiness decreased non-significantly. A non-significant decreasing trend was noticed in the height of cupcakes as compared to weight during storage. RF and BW flour blends are applicable substitutes for gluten-containing flours. Blend B_3 was evaluated as most suitable for gluten-free cupcakes based on quality parameters and sensory attributes. Research findings can be utilized for other products to explore functional properties.

5. References

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