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Effects of partial replacement of durum wheat re-milled semolina with red bean flour on physico-chemical, nutritional, and sensory quality of bagel

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Abstract

The combination of cereal and legume flour used in baked goods products has been rising since it is known that legume flour, including red beans, can enhance the nutritional value of various baked products. The aim of this study was to investigate the potential of red beans as a partial replacement for bagels, with the goal of enhancing their nutritional composition and sensory attributes. The physicochemical analysis, which includes mineral and nutritional content, water/oil absorption, and leavening test for both durum wheat (DW) and red bean flour (RBF), was conducted. An analysis was conducted on bagels with varying percentages of RBF (5%, 10%, 15%, and 20% substitution) to assess their nutritional, physical, and sensory characteristics. The fat content showed a decreasing trend with increasing red bean flour used in bagels, whereas moisture, ash, crude fibre, and mineral content showed an increasing trend. There was also a significant difference ($p<0.05$) in the colour parameters of bagel samples in terms of L* (darkness to lightness), a* (greenness to redness), and b* (blueness to yellowness) at different formulations. Furthermore, the hardness and firmness of the bagel increased as the amount of RBF used increased. Based on the sensory evaluation, the bagel prepared with 5% RBF was rated as the most acceptable in terms of colour, aroma, texture, and taste. Therefore, the result of this study helps to understand the physicochemical, nutritional, and sensory effects of partially substituting RBF for DW flour when making bagels.

1. Introduction

Baked items, particularly bagels, are widely consumed around the world, and nowadays it become an attention to consumers. Wheat flour (WF) is their primary ingredient, as it is the only grain flour capable of forming a cohesive and viscoelastic three-dimensional protein network called gluten. In recent years, the manufacturing and consumption of baked goods have evolved. Consumers are increasingly interested in products that offer health benefits. Aside from the benefits of these new consumption trends, food makers face several hurdles, including issues with the physical, chemical, and sensory properties of the final goods, which can lead to food rejection. A viable answer is to use unique ingredients that improve the quality of conventional cuisine. Leguminosae, sometimes called the Fabaceae family, is one of the plant kingdom's most species-rich families including beans, lentils, peas, chickpeas, soybeans, and lupines (Daniela *et al*., 2023). The inclusion of legumes in traditional foods enhances human health due to their excellent nutritional profile, which includes a large level of fibre and gluten-free proteins, as well as their minimal environmental effect and cost, and, in some cases, their ability to replicate the texture properties of emulsified foods. Given the widespread consumption of bagels, enhancing their nutritional quality by adding legumes constitutes a step towards the creation of functional meals.

Red bean flour, made from ground red azuki beans, has emerged as a unique and adaptable ingredient in baked dishes, with roots in East Asian culinary traditions. It is particularly popular in Japan, China, and Korea, where it imparts a distinct flavour, texture, and nutritional profile to a variety of baked goods such as bread, cakes, cookies, and biscuits. Red bean flour is increasingly being used directly in the batter or dough of various baked items, adding a slight nuttiness and hint of sweetness. Studies have shown that incorporating red

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bean flour in biscuits improves their quality and nutrients (Bedier *et al*., 2021). Red beans contain more protein, ash, and fibre content than wheat flour, indicating antioxidant capabilities. Biscuits prepared using red bean flour were shown to be both palatable and nutritionally beneficial, potentially lowering reliance on wheat imports in specific locations. In the ever-changing environment of the food industry, there is a constant attempt to accommodate client tastes and wants, resulting in advances in food quality, distribution, and manufacturing technology. There is a previous study that focused on the characteristics of some gluten-free flour mixtures with high nutritional value by partially replacing rice flour (RF) with red bean flour (RBF), as well as to assess the nutritional and sensory properties of gluten-free bread made from these mixtures (Stoin *et al*., 2019). Also, the textural and nutritional properties of the bread incorporated with red bean flour were studied by Manonmani *et al.* (2014). These findings show that red bean flour might be used in bread recipes to generate goods with more nutritional value. However, despite studies on red bean flour in biscuits and bread, there is a scarcity of studies on its use in bagels. Therefore, in this study, the analysis of the mineral composition, water/oil absorption, physical properties of red bean and durum wheat flour and leavening test of the bagel's dough were evaluated. The analysis of bagel in terms of its nutritional, physical and sensory qualities was also evaluated, and red bean flour was used to substitute durum wheat semolina in bagel samples at different levels (5, 10, 15, and 20%).

2. Materials and methods

2.1 Materials

Red beans, wheat flour, semolina, salt, and other ingredients were purchased from the local supermarket (Lotus Hypermarket) in Kajang, Selangor.

2.2 Preparation of red bean flour

Preparation of Red bean flour (RBF) was according to the method described by Yahya *et al*. (2022). The dried beans were grounded using a commercial blade mill and then were sieved through a 40 mesh. The flour then was packed in the vacuum pack and stored at 4°C, where the relative humidity was between 50-60%.

2.3 Analysis of flour

2.3.1 Nutritional composition analysis

2.3.1.1 Moisture content

The moisture content was determined by following AOAC Official Method 925.10. The moisture content was determined by drying in an oven at 100-107°C to constant weight. After drying, the dish was transferred with partially covered lid to the desiccator to cool. The dish and its dried samples were reweighted (AOAC INTERNATIONAL, 2000).

2.3.1.2 Protein content

The crude protein content was determined by following AOAC Official Method 945.18-B, digestion of the sample using Kjeldahl's method (AOAC INTERNATIONAL, 2005).

2.3.1.3 Fat content

The crude fat was determined by continuous extraction in a Soxhlet apparatus for 18 hrs using hexane as solvent as stated in AOAC Official Method 920.39 (AOAC INTERNATIONAL, 2000).

2.3.1.4 Ash content

Ash content was determined by incinerating in a furnace at 550°C by following AOAC Official Method 942.05. (AOAC INTERNATIONAL, 2000).

2.3.1.5 Crude fibre content

Crude fibre was determined by sequential hot digestion of the defatted samples with dilute acid and alkaline solutions by following AOAC Official Method 962.09 (AOAC INTERNATIONAL, 1998).

2.3.1.6 Carbohydrate content

Total carbohydrate was determined from the difference [100- (% moisture + % ash + % protein + % fat)] by following AOAC Official Method 2020.07 (AOAC INTERNATIONAL, 2020).

2.3.2 Mineral composition analysis

All analysed flour products were homogenized using homogenizer (ErgoMixx, Bosch, Germany) and a 5.0 g portion was mixed with 30 mL of 65% nitric acid (AR; CAS No: 7697-37-2). Samples were filtered to the certified polymethyl pentene flasks and refilled to 50 mL with demineralized (Hydrolab System, Poland) and deionized water (Millipore HA filter 0.45 µm, Waters, USA). Samples were stored maximally for up to 2 weeks at 4°C in the dark. All samples were prepared in six replicates (three replicates from each production batch) (Rybicka and Gliszczyńska-Świgło, 2017).

The concentrations of calcium (Ca) and magnesium (Mg) were determined using an Atomic Absorption Spectrophotometer (Perkin Elmer model 500). For each determination, at least two 7-point calibration curves were prepared, each adjusted to the expected concentration of appropriate minerals in the analysed sample.

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2.3.3 Water/oil adsorption capacity

Water/Oil adsorption capacity was done according to the method by Ratnawati *et al*. (2019). Approximately 0.25 g of flour was vortex-blended for 30 s with 5 mL of distilled water or oil in a pre-weighed centrifuge tube. The material was centrifuged for 15 mins at 3000 rpm after standing at room temperature (20-25°C) for 15 mins. The centrifuge tubes plus the precipitate were reweighed after the supernatant was decanted following centrifugation. The water absorption capacity (WAC) and oil absorption capacity (OAC) were estimated based on the grams of water/oil absorbed per gram of the sample.

2.3.4 Leavening test

The leavening test of dough was conducted according to the method by Obasi *et al*. (2017). The difference between the final dough volume and the initial reading obtained at zero min is used to calculate the proof heights for each fermented dough.

2.4 Production of bagels using different ratios of durum wheat semolina and red bean flour

The bagels were made using varying proportions of durum wheat semolina (DWS) and red bean flour (RBF) (100:0, 95:5, 90:10, 85:15, and 80:20), as specified in Table 1.

2.5 Analysis of bagels

2.5.1 Nutritional composition analysis

The procedures are the same as in *2.3.1.*

2.5.2 Physical properties

The colour properties of the bagel (hues of the crust and crumb) were according to Noroul-asyikeen *et al*. (2018) using a Konica Minolta spectrophotometer, model CR-400 (Japan).

The hardness of the bagel samples was assessed using a Texture Analyzer from Stable Micro Systems Ltd (Surrey, UK) equipped with a 75 mm Compression platen probe, following the methodology described by Hassan (2015). The probe was specifically engineered to reduce the size of the samples from 45 mm to 23 mm, which is equivalent to half of the typical height of a bread sample. The firmness of the bagel was evaluated using a test speed of 1.7 mm/s and a strain of 40%. The speeds before and after the test were both 1.0 mm/s. The researchers selected a trigger force of 5 grammes (Chompoorat and Phimphimol, 2019).

2.5.3 Sensory quality analysis

Thirty untrained panellists were used to conduct sensory evaluations. Bagels were cut into pieces after cooling, and five random numbers were then randomly assigned to separate plastic bags. The panellists assessed the bagels' taste, flavour, colour, texture, and general appeal. A nine-point hedonic scale score was used for each attribute: 1-dislike extremely, 2-dislike very much, 3-dislike moderately, 4-dislike slightly, 5-neither like nor dislike, 6-like slightly, 7-like moderately, 8-like very much and 9-like extremely.

2.6 Statistical analysis

The experiments were run in a randomised fashion with at least three duplicates. Analysis of variance (ANOVA) was employed to examine the variations between samples. The significances within treatments were determined using Duncan's multiple range test ($p<0.05$). Data was statistically analysed using the SPSS program (SPSS, Inc., USA).

3. Results and discussion

3.1 Nutritional and mineral content of durum wheat semolina and red bean flour

The proximate analysis of the durum wheat semolina (DWS) and red bean flour (RBF) is shown in Table 2. The results showed a significant difference ($p<0.05$) in moisture content between the DWS and RBF and this might be due to the low moisture content in red bean flour that is attributed to the drying process of the beans prior to grinding (Wati *et al*., 2023). The moisture level of red bean flour was found to be 7.60% (Ratnawati *et al*., 2019), while prior studies have revealed a moisture content of 13.93% for durum wheat semolina (Sanfilippo *et al*., 2023). For ash content, RBF exhibited significantly higher ($p<0.05$) than DWS and a high content of ash in RBF may be due to the addition of the

Table 1. Formulation of bagel samples based on the percentage of flour weight basis.

Ingredients (g)	Weight (based on percentage flour weight basis)				
	Control	F1	F2	F3	F4
Durum wheat semolina	62.49	59.38	56.25	53.13	50.00
Red bean flour	-	3.13	6.25	9.38	12.50
Brown sugar	2.74	2.74	2.74	2.74	2.74
Instant dry yeast	0.86	0.86	0.86	0.86	0.86
Water	33.53	33.53	33.53	33.53	33.53
Salt	0.37	0.37	0.37	0.37	0.37

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epidermis of red beans when the grinding process was conducted (Wati *et al*., 2023). This assertion is substantiated by the study conducted by Hadi *et al*. (2020), which revealed that the ash content of red beans with skin powder was 4.23%, whereas the ash content of red beans without epidermis was 3.07%. This indicates that the presence of the epidermis significantly contributes to the overall ash content, as depicted in the aforementioned table.

Table 2. Proximate analysis of durum wheat semolina (DWS) and red bean flour (RBF).

	DWS	RBF
Moisture (%)	12.10±0.13^{a}	8.78±0.05^{b}
Ash (%)	0.62±0.02^{b}	4.91±0.00^{a}
Crude fat (%)	1.10±0.05^{a}	1.14±0.05^{a}
Crude protein (%)	3.30±0.03^{b}	8.19±0.06^{a}
Crude fiber (%)	1.08±1.70^{b}	4.03±0.21^{a}
Carbohydrate (%)	82.86±0.10^{a}	76.96±0.06^{b}

Values are presented as mean±SD of triplicate. Values with different superscripts within the same row are statistically significantly different (p<0.05).

As shown in Table 2, there is no significant difference in terms of fat content between DWS and RBF where both are predominantly carbohydrate-based ingredients, with relatively low-fat content. This was supported by Bedier *et al.* (2021) where 1.16% and 1.08% of crude fat content was found in RBF and DWS each respectively. The results for protein analysis tabulated in Table 2 showed that there is a significant difference (p<0.05) between RBF and DW where RBF contained higher protein content than DWS. The protein level of durum wheat semolina was observed to be reduced, potentially as a result of the removal of wheat bran. Alzuwaid and Fellows (2019) state that wheat bran, a byproduct of wheat milling, is the primary and significant source of high-quality proteins, comprising more than 15% of its composition. As shown in Table 2, carbohydrate content in DWS is significantly higher (p<0.05) as compared to RBF. Legumes are known to be a high-protein, low-carbohydrate flour (Wójcik *et al*., 2021). In crude fibre content, RBF (4.03±0.21%) showed a higher value than DWS (1.08±1.70%). The variation in flour processing can impact the quantity of crude fibre present in the samples. This discrepancy is evident in the results, where DWS exhibits a lower crude fibre content compared to RBF. This disparity arises because the term "bran" denotes the fibrous outer layer of cereal grains, which is separated from the flour during the refining process (Saccotelli *et al*., 2017).

As shown in Table 3, the RBF was found to have higher significant (p<0.05) mineral content than DWS and this is supported by a previous study where traditional legumes tend to have higher micronutrient content than yielding cereal cultivars (Grant *et al*., 2012).

Table 3. Mineral contents of durum wheat semolina (DWS) and red bean flour (RBF).

Mineral content (mg/100 g)	DWS	RBF
Calcium (Ca)	94.95±2.42^{b}	187.53±0.10^{a}
Magnesium (Mg)	45.96±1.18^{b}	91.65±0.84^{a}

Values are presented as mean±SD of triplicate. Values with different superscripts within the same row are statistically significantly different (p<0.05).

3.2 Water/oil adsorption capacity

The results of water absorption capacity (WAC) and oil absorption capacity (OAC) of both flours were tabulated in Table 4. The water absorption capacity (WAC) of flour is crucial in the food preparation process as it determines other functional and sensory aspects (Du *et al*., 2014). As shown in Table 4, the WAC of RBF was significantly higher (p<0.05) as compared to DWS. The increased water absorption of the RBF is mostly attributed to the protein concentration of the flour. A higher protein content results in a greater capacity for water absorption in the RBF.

Table 4. Water and oil adsorption capacity of durum wheat semolina (DWS) and red bean flour (RBF).

	DWS	RBF
WAC (g/g)	1.95±0.21^{b}	2.83±0.09^{a}
OAC (g/g)	2.93±0.12^{a}	3.06±0.05^{a}

Values are presented as mean±SD of triplicate. Values with different superscripts within the same row are statistically significantly different (p<0.05). WAC: Water adsorption capacity, OAC: oil adsorption capacity.

The OAC of both flours showed no significant difference. According to a study by Du *et al*. (2014), the oil-absorbing process utilizes capillarity interaction to enable the retention of absorbed oil. Hydrophobic proteins play a crucial role in absorbing oil, and some legume flour with higher oil absorption capacity (OAC) is likely to have protein molecules with more easily accessible non-polar side chains (Du *et al*., 2014). However, RBF may not have enough hydrophobic protein and thus showed no significant difference with DWS.

3.3 Leavening test of different bagel formulations

The leavening ability of yeast in the five different formulations was observed as shown in Figure 1. During the observation, the height of each formulation's dough was noted every 30 mins for 2 hrs. The leavening test was conducted on the control (DWS-100%) sample as well as on four different ratios of mixes between DWS

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and RBF. The results of this test are depicted in Figure 1. The yeast in all five formulations showed a better leavening activity at 30 mins where control (90.6-100 ml), F1 (80.6-90.6 ml), F2 (80-90 mL), F3 (70.6-80 mL) and F4 (70.4-70.6 mL) and declined at 90 mins where leavening ability in all five formulations become constant. The figure shows that the leavening ability of commercial yeasts in the control formulation is the highest, meanwhile leavening capacity in F4 is the lowest. The change in the leavening profile of the dough was attributed to the increased proportion of RBF flour in the dough. The inclusion of RBF reduced the leavening profile of the dough. This occurrence can be elucidated by the correlation between the decrease in wheat flour concentration in each formulation and the concomitant decrease in wheat gluten concentration.

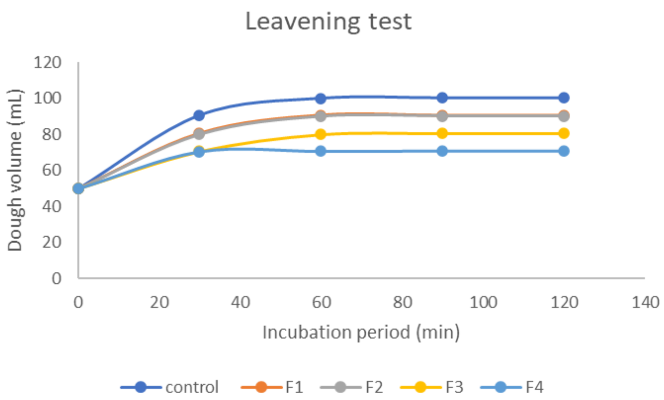

Figure 1. Leavening profile of control, F1, F2, F3 and F4's dough.

3.4 Nutritional and mineral content of bagels

As shown in Table 5, the crude fat content of bagels was significantly ($p<0.0.5$) decreased between F1 (1.17±0.01%), F2 (0.94±0.09), F3 (0.77±0.03%) and F4 (0.75±0.01%). According to research conducted by Keskin (2022), red beans are commonly referred to as the "weight loss bean" because of their low fat level. This aligns with the findings mentioned above, which demonstrate that the higher the amount of red bean flour used in bagels, the lower the fat content.

As for moisture content, the moisture content of bagels experienced an increment from control (33.89±0.21), F1 (34.57±0.12), F2 (34.67±0.14), F3 (35.19±0.41) and F4 (36.17±0.83) where the increment increased as the percentage of RBF increase in bagel formulation. This might be due to the particle size of the red bean flour that contributes to the higher rate of water adsorption as in Table 4, where the water adsorption capacity of RBF is much higher than DWS. The trend was the same for ash content where it significantly increased ($p<0.05$) with the increment of the percentage of RBF in bagels. As mentioned previously in Table 2, the ash content of RBF was higher due to the addition of the epidermis of red beans that were ground together during the powdering process (Wati *et al*., 2023). In contrast, the crude fibre content of F1 showed no significant difference with the control meanwhile crude fibre content showed a significant difference ($p<0.05$) between F2 (1.46±0.04%), F3 (1.45±0.01%) and F4 (1.52±0.07%). This may be attributed to the incorporation of RBF, which resulted in an increase in accordance with the formulas. Consequently, the quantity of red bean epidermis also increased, leading to a subsequent rise in the crude fibre content of bagels.

The mineral compositions (mg/100 g) of all different bagels are shown in Table 6. Based on the Table 6, the mineral contents of bagels were significantly increased as the increment of the percentage of RBF was increased in the bagels. This is supported by the ash percentage in RBF reported previously is greater than that of DWS, therefore, it is prominent that the ash content has a significant impact on the mineral content.

Table 6. Mineral content of five formulations of bagel.

Formulation	Calcium (Ca)	Magnesium (Mg)
C	$27.51±2.61^{c}$	$4.59±0.26^{d}$
F1	$21.85±2.11^{d}$	$3.41±0.10^{e}$
F2	$36.61±0.53^{b}$	$7.41±0.64^{c}$
F3	$44.92±0.72^{a}$	$8.87±0.51^{b}$
F4	$46.19±2.10^{a}$	$12.02±1.13^{a}$

Values are presented as mean±SD of triplicate. Values with different superscripts within the same column are statistically significantly different ($p<0.05$). C: 100% DWS, F1: 5% RBF, F2: 10% RBF, F3: 15% RBF, F4: 20% RBF.

Table 5. Nutritional composition of five formulations of bagel.

Formulation	Crude Fat (%)	Moisture (%)	Ash (%)	Crude Fiber (%)
C	$0.92±0.01^{b}$	$33.89±0.21^{c}$	$0.82±0.01^{d}$	$0.11±0.01^{b}$
F1	$1.17±0.01^{a}$	$34.57±0.12^{bc}$	$0.83±0.01^{d}$	$0.05±0.01^{b}$
F2	$0.94±0.09^{b}$	$34.67±0.14^{bc}$	$0.93±0.01^{c}$	$1.46±0.04^{a}$
F3	$0.77±0.03^{c}$	$35.19±0.41^{b}$	$1.05±0.01^{b}$	$1.45±0.01^{a}$
F4	$0.75±0.01^{c}$	$36.17±0.83^{a}$	$1.12±0.01^{a}$	$1.52±0.07^{a}$

Values are presented as mean±SD of triplicate. Values with different superscripts within the same column are statistically significantly different ($p<0.05$). C: 100% DWS, F1: 5% RBF, F2: 10% RBF, F3: 15% RBF, F4: 20% RBF.

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3.5 Physical properties of bagels

The colour of the bagels' crust and crumb were measured according to the colour system of CIE L*, a*, b* by using a chromameter. The results obtained in Table 7 show that the bagels' crust and crumb experienced a decrease in L* and b* values but increased in a* values with the increased percentage of RBF. Based on the data, the results show that the crust and crumb of the bagels that had been incorporated with RBF experienced a significant decrease in L* values and showed a significant difference between each formulation. The colour of bagels was related to the physicochemical properties of the raw dough as well as chemical processes that occur during baking that are dependent on operating circumstances, such as Maillard reactions and caramelization, which induce browning of baked products during baking (Manonmani *et al*., 2014).

The values of a* also exhibited a substantial increase as the percentage of RBF in the bagels increased. This could be attributed to the red pigment in the bagels, which can be linked to the visible red bran particles present in the flour, as mentioned in a study conducted by another researcher (Hassan, 2015). In contrast to b* values, Table 7 shows that the crust of the bagels exhibited a decrement of b* values with the increment of the percentage of RBF in the bagel formulation. The crust and crumb of the bagels exhibited a gradual decrease in the b* values, which can be attributed to the presence of red bean seed coat in the flour used in all formulations, as reported by Manonmani *et al*. (2014). Therefore, RBF affects the bagels' colour characteristics.

Table 7. Colour analysis of bagels.

Formulation	(Crust)		
	L*	a*	b*
C	65.11±0.50^a	3.26±0.29^c	19.67±1.40^a
F1	62.79±0.30^b	2.98±0.61^c	16.55±0.93^b
F2	60.90±0.43^c	3.55±0.08^c	14.64±0.08^c
F3	53.52±0.36^d	4.34±0.36^b	14.26±0.55^c
F4	50.19±1.08^e	5.01±0.14^a	9.89±0.88^d
Formulation	Crumb		
	L*	a*	b*
C	67.49±0.33^a	-0.68±0.10^d	12.98±0.26^a
F1	60.81±0.19^b	1.22±0.09^c	10.73±0.41^b
F2	56.05±0.55^c	2.38±0.09^b	10.28±0.46^b
F3	54.58±0.26^d	3.21±0.32^a	7.15±0.04^c
F4	53.05±0.61^e	3.28±0.18^a	6.25±0.42^d

Values are presented as mean±SD of triplicate. Values with different superscripts within the same row are statistically significantly different (p<0.05). C: 100% DWS, F1: 5% RBF, F2: 10% RBF, F3: 15% RBF, F4: 20% RBF.

The hardness and firmness of the bagels were increased with an increment in RBF as shown in Table 8. However, no significant difference was seen for control and F1. The findings indicated a positive correlation between hardness and food texture, meaning that as hardness increases, the texture becomes stiffer and harder. Thus, more energy is required to deform the food (Mahat *et al*., 2020). The crumb texture of control bagels was relatively softer than bagels made with a mixture of RBF and DWS. This difference in texture could be attributed to the reduction of gluten content in the RBF, which in turn leads to decreased bread volume (Yaver and Bilgiçli, 2018). This assertion is further corroborated by other researchers who reported a decline in physical attributes with an increase in RBF substitution. This can be attributed to a reduction in gluten content in the blends, which hinders the formation of the desired bread porosity structure (Manonmani *et al*., 2014). Hassan (2015) discovered that fibre has a substantial influence on the firmness of bread's interior. Among the bagel formulations in this study, F4 exhibited the highest fibre content and displayed the greatest level of firmness.

Table 8. Hardness and firmness of bagels.

Formulation	Hardness (kg)	Firmness (kg)
C	12.47±1.03^d	2.01±0.18^d
F1	11.93±0.92^d	2.23±0.08^d
F2	19.09±1.02^c	2.56±0.05^c
F3	27.89±0.24^b	2.89±0.16^b
F4	34.38±0.68^a	3.24±0.08^a

Values are presented as mean±SD of triplicate. Values with different superscripts within the same row are statistically significantly different (p<0.05). C: 100% DWS, F1: 5% RBF, F2: 10% RBF, F3: 15% RBF, F4: 20% RBF.

3.6 Sensory evaluation of bagel

A sensory evaluation was conducted at the Sensory Laboratory of the Faculty of Applied Sciences at Universiti Teknologi MARA, UiTM Shah Alam. The acceptability of the formulations is shown in Table 9. According to the collected data, bagels with 10% RBF in F2 had the highest colour score (7.07±1.04). This means that more panellists preferred the colour of bagels in F2 because it had a balanced colour between creamy and red, unlike the control group which had a very bright colour that could negatively impact the acceptability of the bagel's colour. While F4 had the lowest average score (6.23±1.77), this might be attributed to the increased inclusion of red bean flour, which results in a darker product due to the larger concentration of red bean particles.

The percentage of ingredients in a food product has a significant impact on the aroma score. Aroma is a crucial

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factor in sensory evaluation and can greatly influence how a product is perceived. As shown in Table 9, F2 (7.07±1.05) exhibited the highest means score in terms of aroma attribute whereas F1 bagel has the lowest means score which is 6.17±1.91. F2 demonstrated a more potent aroma compared to the control and F1, which was deemed acceptable by the panellists. In contrast, bagels F3 and F4 emitted a greater aroma that was perceived as unpleasant by the panellists, likely due to the overpowering beany aroma from the red bean.

As for texture attributes, control bagels which have 100% DWS scored the highest (6.27±1.78). The decrease in textural properties perceived by the panellists could be attributed to the increment in RBF added. This is closely related to the texture analysis results discussed in Table 8, as the percentage of RBF is added to the formulations, the crumb hardness of the bagel also increases as well as crumb firmness. The crumb texture of control bagels was less firm compared to bagels made with a combination of RBF and DWS. The difference can be related to the low content of gluten, which decreases the volume of bread when red bean flour is added (Yaver and Bilgiçli, 2018).

In terms of taste attributes, F1 (6.37±1.84) which contains 5% of RBF in the bagel formulation scored the highest mean. The incorporation of red bean flour in bagels may offer an interesting taste experience for some customers. The intensity of the bean flavour throughout the tasting process is directly proportional to the percentage of red bean flour utilised. Manonmani *et al.* (2014) found that the flavour of the bread was hindered due to the strong and distinct flavour of beans. The factors that lead to people discontinuing from consuming dry beans is the presence of the "beany" flavour. Therefore, the primary factor that determines the acceptability of a food product is its flavour.

In terms of overall acceptability, there is no significant difference between all the formulations and could be concluded that all bagels can be accepted by the consumer but as in the table, bagels with 5% of RBF had the highest mean score (6.27±2.02) in which panelists preferred this formulation over the others due to its consistent colour, aroma, texture and taste. These results may be attributed to the fact that F1 has the best colour, where there is a balance between the red colour from the beans and the brown colour from the Maillard reaction. Bagels from F1 exhibited a moderate coloration and in addition, bagels containing 5% RBF had a distinctively fragrant aroma reminiscent of whole grain and red beans. This aroma was characterised by a moderate intensity of beany notes, which were not too overpowering as observed in alternative formulations. The bagel's texture is a key factor in determining its overall acceptability, as it contributes to the overall quality of the bagel F1. Bagel from F1 has the most desirable texture compared to the other formulations. This is because the texture of the F1 bagel is dense but not excessively tough to chew. Thus, sensory evaluation data, showed that colour, along with texture and flavour, influences consumer preference for new formulations of bagels.

4. Conclusion

In conclusion, the RBF has higher nutritional and mineral content. RBF showed better water/oil adsorption capacity. The physical properties of the bagels' formulation indicate that an increase in the amount of RBF leads to an increase in both hardness, and firmness, and decreased the lightness (L*) of the bagels. In sensory evaluation, the inclusion of 5% RBF in the bagel formulations is the most acceptable for panellists. Therefore, 5% RBF in the bagel formulations improved the physico-chemical, nutritional, and sensory quality of the bagel.

Conflict of interest

The authors have no conflict of interest.

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Table 9. Sensory analysis of bagels.

Formulation	Colour	Aroma	Texture	Taste	Overall Acceptability
C	$6.90±1.82^{a}$	$6.23±1.59^{b}$	$6.27±1.78^{a}$	$6.20±1.56^{a}$	$6.17±1.66^{a}$
F1	$6.77±1.89^{a}$	$6.17±1.91^{b}$	$6.17±2.07^{a}$	$6.37±1.84^{a}$	$6.27±2.02^{a}$
F2	$7.07±1.04^{a}$	$7.07±1.05^{a}$	$5.73±1.82^{ab}$	$6.13±1.50^{a}$	$6.23±1.57^{a}$
F3	$6.87±1.20^{a}$	$6.37±1.00^{ab}$	$4.97±1.54^{b}$	$5.80±1.45^{a}$	$5.90±1.09^{a}$
F4	$6.23±1.77^{a}$	$6.27±1.39^{b}$	$5.10±1.83^{b}$	$5.83±1.42^{a}$	$5.67±1.60^{a}$

Values are presented as mean±SD of triplicate. Values with different superscripts within the same row are statistically significantly different ($p<0.05$). C: 100% DWS, F1: 5% RBF, F2: 10% RBF, F3: 15% RBF, F4: 20% RBF.

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References

Alzuwaid, N.T. and Fellows, C.M. (2019). Nutritional and functional properties of durum wheat bran protein concentrate. *Cereal Chemistry*, 97(2), 304-315. https://doi.org/10.1002/cche.10246

AOAC INTERNATIONAL. (1998). Determination of Crude Fibre (AOAC Official Method 962.09). Official Methods of Analysis of AOAC INTERNATIONAL. 16th ed. Maryland, USA: AOAC INTERNATIONAL.

AOAC INTERNATIONAL. (2000). Determination of Moisture Content (AOAC Official Method 925.10). Official Methods of Analysis of AOAC INTERNATIONAL. 17th ed. Washington, DC, USA: AOAC INTERNATIONAL.

AOAC INTERNATIONAL. (2000). Determination of Fat Content (AOAC Official Method 920.39). Official Methods of Analysis of AOAC INTERNATIONAL. 17th ed. Washington, DC, USA: AOAC INTERNATIONAL.

AOAC INTERNATIONAL. (2000). Determination of Ash Content (AOAC Official Method 942.05). Official Methods of Analysis of AOAC INTERNATIONAL. 17th ed. Washington, DC, USA: AOAC INTERNATIONAL.

AOAC INTERNATIONAL. (2005). Determination of Protein Content (AOAC Official Method 945.18-B). Official Methods of Analysis of AOAC INTERNATIONAL. Gaithersburg, USA: AOAC INTERNATIONAL.

AOAC INTERNATIONAL. (2020). Determination of Carbohydrate Content (AOAC Official Method 2020.07). Official Methods of Analysis of AOAC INTERNATIONAL. 20th ed. Washington, DC, USA: AOAC INTERNATIONAL.

Bedier, D., Salem, R., Almashad, A. and Barakat, E. (2021). Quality assurance of functional biscuits produced from red kidney beans flour. *Archives of Agriculture Sciences Journal*, 4(3), 251-264. https://doi.org/10.21608/aasj.2021.103866.1093

Chompoorat, P. and Phimphimol, J. (2019). Development of a Highly nutritional and functional gluten free cupcake with red kidney bean flour for older adults. *Food and Applied Bioscience Journal*, 7 (3), 16-26. https://li01.tci-thaijo.org/index.php/fabjournal/article/view/176596

Daniela, C.A., Victoria, S.M. and Cecilia, P.M. (2023). Production of legume-wheat dough of optimum quality for breadmaking: essential analyses required. *Current Opinion in Food Science*, 49, 100970. https://doi.org/10.1016/j.cofs.2022.100970

Du, S.-K., Jiang, H., Yu, X. and Jane, J.-L. (2014). Physicochemical and functional properties of whole legume flour. *LWT*, 55(1), 308-313. https://doi.org/10.1016/j.lwt.2013.06.001

Grant, C., Cubadda, F., Carcea, M., Pogna, N.E. and Gazza, L. (2012). Vitamins, Minerals, and Nutritional Value of Durum Wheat. Durum Wheat Chemistry and Technology. 2nd ed. USA: Woodhead Publishing and AACC International Press. https://doi.org/10.1016/B978-1-891127-65-6.50012-X

Hassan, Z. (2015). Physicochemical and Textural Properties of White Bread Made From Different Commercial Brands of High Gluten Flours. *International Journal of Review in Applied and Social Sciences*, 1(8), 17-30. https://doi.org/10.17756/jfcn.2023-159

Hadi, S.K., Andoyo, R. and Rialita, T. (2020). Isolation and characterization of red bean and green bean protein using the extraction method and isoelectric pH. *Science Medicine Journal*, 2(2), 77-85. https://doi.org/10.28991/SciMedJ-2020-0202-5

Jide, A.O., Alademeyin, J.O. and Ajongbolo, K.F. (2023). Adzuki (*Vigna angularis*) beans as food: chemical composition, nutrition and quality identities. *Journal of Advanced Education and Sciences,* 3(3), 5-8.

Keskin, S.O., Ali, T.M., Ahmed, J., Shaikh, M., Siddiq, M. and Uebersax, M.A. (2022). Physico-chemical and functional properties of legume protein, starch, and dietary fiber—A review. *Legume Science,* 4(1), e117. https://doi.org/10.1002/leg3.117

Manonmani, D., Bhol, S. and Bosco, S.J.D. (2014). Effect of Red Kidney Bean (*Phaseolus vulgaris* L.) Flour on Bread Quality. *Open Access Library Journal*, 1, e366. https://doi.org/10.4236/oalib.1100366

Mahat, M.M., Mohamad Sabere, A.S., Shafiee, S.'A., Nawai, M.A., Hamzah, H.H., Md Jamil, M.A.F., Che Roslan, N., Abdul Halim, M.I. and Safian, M.F. (2020). The Sensory Evaluation and Mechanical Properties of Functional Gummy in the Malaysian Market. *Preprints*, 2020100213. https://doi.org/10.20944/preprints202010.0213.v1

Noroul-asyikeen, Z., Suraya, H., Zubir, M. and Hoon, H. L. (2018). Nutritional Value and Physicochemical Properties of White Bread Incorporated with *Hevea brasiliensis* (Rubber Seed) Flour. *Journal of Agrobiotech*, 9, 102-113. https://core.ac.uk/download/pdf/267943207.pdf

Obasi, B.C., Whong, C.M.Z., Ado, S.A. and Abdullah, I.O. (2017). Leavening Ability Of Some Wild Yeasts and the Mutant Species Isolated from Fermented Orange Juice in Bakery Product (Bread). *FUW*

Trends in Science and Technology Journal, 2(1), 596 -608.

Ratnawati, L., Desnilasari, D., Surahman, D.N. and Kumalasari, R. (2019). Evaluation of Physicochemical, Functional and Pasting Properties of Soybean, Mung Bean and Red Kidney Bean Flour as Ingredient in Biscuit. *IOP Conference Series: Earth and Environmental Science*, 251(1), 012026. https://doi.org/10.1088/1755-1315/251/1/012026

Rybicka, I. and Gliszczyńska-Świgło, A. (2017). Minerals in grain gluten-free products. The content of calcium, potassium, magnesium, sodium, copper, iron, manganese, and zinc. *Journal of Food Composition and Analysis,* 59, 61-67. http://dx.doi.org/10.1016/j.jfca.2017.02.006

Saccotelli, M.A., Conte, A., Burrafato, K.R., Calligaris, S., Manzocco, L. and Del Nobile, M.A. (2017). Optimization of durum wheat bread enriched with bran. *Food Science and Nutrition*, 5(3), 689-695. https://doi.org/10.1002/fsn3.448

Sanfilippo, R., Canale, M., Dugo, G., Oliveri, C., Scarangella, M., Strano, M.C., Amenta, M., Crupi, A. and Spina, A. (2023). Effects of Partial Replacement of Durum Wheat Re-Milled Semolina with Bean Flour on Physico-Chemical and Technological Features of Doughs and Breads during Storage. *Plants*, 12(5), 1-21. https://doi.org/10.3390/plants12051125

Stoin, D., Petrovich, L.I., Velciov, A.B., Trasca, T., Rivis, A. and Jianu, C. (2019). Red kidney bean and rice flours : potential ingredients in the production of gluten-free bread with functional quality. *Journal of Agroalimentary Processes and Technologies*, 25(3), 147-152. https://doi.org/10.21608jedu.2022.149554.1711

Taghdir, M., Mazloomi, S.M., Honar, N., Sepandi, M., Ashrpour, M. and Salehi, M. (2017). Effect of soy flour on nutritional, physicochemical, and sensory characteristics of gluten-free bread. *Food Science and Nutrition*, 5(3), 439-445. https://doi.org/10.1002/fsn3.411

Wati, L., Hari, P.D. and Qurrota, A. (2023). The Effect of the Addition of Red Kidney Bean Skin Powder (*Phaseolus vulgaris* L.) on the Physical, Chemical, and Organoleptic Characteristics of Red Kidney Bean Tempeh. *Asian Journal of Applied Research for Community Development and Empowerment*, 7 (3), 143-149. https://doi.org/10.29165/ajarcde.v7i3.348

Wiesinger, J.A., Cichy, K.A., Hooper, S.D., Hart, J.J. and Glahn, R.P. (2020). Processing white or yellow dry beans into a heat-treated flour enhances the iron bioavailability of bean-based pastas. *Journal of Functional Foods*, 71(May), 104018. https://doi.org/10.1016/j.jff.2020.104018

Wójcik, M., Różyło, R., Schönlechner, R. and Berger, M.V. (2021). Physico-chemical properties of an innovative gluten-free, low-carbohydrate and high protein-bread enriched with pea protein powder. *Scientific Reports*, 11, 14498. https://doi.org/10.1038/s41598-021-93834-0

Yahya, F., Xiang, Y.K., Zainol, M.K. and Hasmadi, M. (2022). Effect of different ratios of wheat flour to black bean (*Phaseolus vulgaris* L.) flour on physicochemical properties and sensory acceptability of cooked noodle. *Food Research*, 6(2), 457-464. https://doi.org/10.26656/fr.2017.6(2).315

Yaver, E. and Bilgiçli, N. (2018). Utilisation of cereal-legume flour blends in commercial and traditional bread. *Quality Assurance and Safety of Crops and Foods*, 10(3), 297-306. https://doi.org/10.3920/QAS2018.127

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