Improvement of nutritional properties of cake with wheat germ and resistant starch

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SUMMARY

Wheat germ (WG) and resistant starch (RS) are important functional ingredients for cereal products. In this study, WG (0%, 10% and 20%) and commercial RS (0%, 5%, 10% and 15%) were used to replace wheat flour in cake formulation and their effects on nutritional, physical and sensory properties of cakes were investigated. WG replacement increased ash, protein, lipid, crude fibre, Ca, Fe, K, Mg, P and Zn contents of the cakes. Rich phytic acid (PA) composition of WG increased the PA content of the cakes from 1001.2 mg·kg^{-1} up to 2908.2 mg·kg^{-1}. High replacement level of wheat flour by RS (15%) caused a significant ($p < 0.05$) decrease in protein, PA, Mg and P contents of the cakes. RS contents of the cakes varied between 7.2 g·kg^{-1} and 49.0 g·kg^{-1}, and approached the highest value with 15% RS addition. Combination of WG and RS at high replacement levels adversely affected volume index and firmness of the samples. WG increased the darkness and yellowness of the crust and crumb of cakes. WG at 20% alone or in combination with 5% RS gave similar pore structure, taste, odour and overall acceptability score compared to control cake.

Keywords

wheat germ; resistant starch; cake; minerals; phytic acid

Wheat grain consists of endosperm, bran and germ fractions. During the production of flour from wheat grain, bran and germ are separated as by-products. Wheat germ (WG) contains high amounts of protein, dietary fibre, unsaturated fatty acids, tocopherols, B group vitamins, minerals and bioactive components [1–6]. WG protein is rich in essential amino acids, in particular lysine, methionine and threonine, which are deficient in many cereal grains. It is possible to compensate these essential amino acid deficiencies of cereal foods by the usage of WG [7]. The presence of lipase and lipoxygenase enzymes, together with high levels of unsaturated fatty acids in raw WG, cause bitter taste and rancid flavour development during storage [8, 9]. Roasting, autoclaving and microwave heating can be used to provide stabilization of WG. These processes inactivate enzymes and improve the microbiological quality and shelf life of raw WG [5, 10]. WG processed by different methods was used in cereal foods such as cookie [11, 12], macaroni [9], bread [13, 14] and tarhana [15]. In the study conducted by Majzoobi et al. [16], 15% WG was found as the highest level for maintaining cake sensory quality.

Resistant starch (RS) is a portion of starch and starch products that resist digestion in the small intestine, being digested in the colon [17–19]. RS has positive impact on colonic health, microbial flora, plasma cholesterol, postprandial glycemic and insulinemic responses and reduces the risk of diabetes, cancer, atherosclerosis and/or obesity-related complications [18, 20]. RS has a white colour, 10–15 μm particle size and lower water-holding capacity, and thus it has lower impact on the sensory properties of food compared to conventional fibres [18, 21]. RS was used for increasing the functional quality of breads [22, 23], muffins and cake [24–28], spaghetti and pasta [29, 30], biscuits and cookie [31–33], granola bars and cereals [34]. In the cake/muffin studies, Lin et al. [24] found that replacing 15% of flour by RS (without reducing the amount of shortening) had no significant effect on cake quality. Baixauli et al. [26] report-

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ed that acceptance score of appearance was decreased at above 10% levels of RS in muffins.

The objective of this study was to determine the suitability of WG and RS for improvement of nutritive quality of cake.

MATERIALS AND METHODS

Materials

Whole egg, sugar, all-purpose shortening, skimmed milk powder, corn starch and baking powder were purchased from local markets in Konya, Turkey. Wheat flour and WG was obtained from commercial wheat flour company (Selva Food Industry, Konya, Turkey). WG was stabilized in home-type rotating microwave oven (Arçelik-ARMID 2450 Hz, 700 W, Istanbul, Turkey) for 5 min. After microwave heating, WG was ground with coffee grinder. RS (C*ActiStar 11700) was purchased from Cargill Foods, Istanbul, Turkey.

Cake preparation

Cake samples were prepared according to our previous study [35]. A cake batter recipe contained 100% wheat flour, 75% shortening, 75% sugar, 75% whole egg, 10% corn starch, 5% skimmed milk powder, 0.5% salt, 4.5% baking powder and 0.5% sodium stearoyl-2-lactylate. All percentages are given on flour basis. WG (0%, 10% and 20%) and RS (0%, 5%, 10% and 15%) replaced wheat flour in cake recipe. WG and RS ratios were selected according to results in the literature [16, 24, 26]. The water amount used in the recipe varied between 23 ml and 37 ml, based on results of preliminary trials. Cake trials were conducted according to 3×4 factorial design. Each formulation was prepared and measured in duplicate.

Chemical analysis

The AACC methods were used for determination of ash (method 08-01), protein (method 46-12), crude fibre (method 32-10) and lipid (method 30-25) [36]. For analysing the mineral contents of the samples, approximately 0.3 g of ground samples were put into a burning cup and mixed with 10 ml pure HNO_3 (100450; Merck, Darmstadt, Germany). The samples were incinerated in a microwave oven (MARS-5; CEM, Matthews, North Carolina, USA) at 200 °C and the dissolved ash was diluted to 25 ml with ultra-demineralized water. Contents were determined with an inductively coupled plasma atomic-emission spectrometer (ICP-AES) Vista (Varian, Melbourne, Australia) [37]. Working conditions of the instrument are given in Tab. 1. Phytic acid (PA) content of the samples was measured by a colorimetric method [38]. PA in the sample was extracted using a solution of HCl (0.2 mol·l^{-1}) and precipitated by acidic solution of ammonium iron (III) sulphate dodecahydrate. RS contents of the samples were measured using Megazyme Resistant Starch Kit (Megazyme International, Wicklow, Ireland) according to AACC Approved Method 32-40 [39].

Physical measurements

Volume, symmetry and uniformity index values were calculated according to AACC method 10-91 [36]. Firmness was determined by a TA-XT2 Texture Analyzer (Texture Technologies, Godalming, United Kingdom) at room temperature. An aluminium P36/R cylinder probe was used for measurement. The optimal test conditions in this study were: strain was 25%, and the pre-test, test and post-test speeds were 1.0, 1.0 and 10.0 mm·s^{-1}, respectively. Firmness was measured as the peak compression force (*g*) during the penetration of the sample.

Crust and crumb colours were measured by Minolta CR-400 (Minolta Camera, Osaka, Japan). Colour values were determined according to the CIELab colour space system, where L^* corresponds to light/dark chromaticity, a^* to green/red chromaticity and b^* to blue/yellow chromaticity. The instrument was calibrated with a white reference tile before the measurements. Colour values were measured at five different points on samples. Values are the mean of five determinations.

Sensory analysis

For sensory analysis, twenty panelists from the Food Engineering Department of Necmettin Erbakan University, Turkey (both males and females) were selected. The order of presentation of samples to the panelists was randomized. Colour, appearance, pore structure, taste, odour and overall acceptability of samples were rated on a 1–9 scale (1 – dislike extremely, 2 – dislike very much, 3 – dislike moderately, 4 – dislike slightly,

Tab. 1. Working conditions for ACP-AES.

Power	1400 W
Gas exit	13.50 l·min^{-1}
Gas flow rate	1.50 ml·min^{-1}
Nebulizer gas flow rate	0.90 ml·min^{-1}
Sample intake (aspiration) rate	2.25 ml·min^{-1}
Preflow time	45 s
Reading time	3 × 24 s

Tab. 2. Chemical properties of cake samples.

	Wheat germ [%]	Resistant starch [%]			
		0	5	10	15
Ash [g·kg-1]	0	13.8 ± 0.3 Ca	13.6 ± 0.3 Ca	13.4 ± 0.3 Ca	13.3 ± 0.3 Ca
	10	16.4 ± 0.1 Ba	16.2 ± 0.4 Ba	16.0 ± 0.3 Ba	16.0 ± 0.4 Ba
	20	18.4 ± 0.6 Aa	18.4 ± 0.4 Aa	18.1 ± 0.4 Aa	18.0 ± 0.3 Aa
Protein [g·kg-1]	0	79.6 ± 0.8 Ca	77.0 ± 0.7 Cb	74.1 ± 0.7 Cc	69.8 ± 0.6 Cd
	10	87.1 ± 0.7 Ba	84.7 ± 0.7 Bb	82.0 ± 0.7 Bc	79.3 ± 0.8 Bd
	20	94.8 ± 1.0 Aa	92.2 ± 0.7 Ab	89.7 ± 0.7 Ac	87.2 ± 0.6 Ad
Crude fibre [g·kg-1]	0	5.0 ± 0.4 Ca	5.1 ± 0.6 Ca	5.1 ± 0.3 Ca	5.1 ± 0.4 Ca
	10	8.3 ± 0.3 Ba	8.2 ± 0.3 Ba	8.4 ± 0.3 Ba	8.5 ± 0.3 Ba
	20	10.9 ± 0.6 Aa	11.0 ± 0.3 Aa	10.9 ± 0.6 Aa	11.0 ± 0.3 Aa
Lipids [g·kg-1]	0	284.5 ± 0.4 Ca	284.3 ± 0.8 Ca	284.4 ± 0.7 Ca	284.0 ± 1.0 Ca
	10	290.5 ± 0.7 Ba	290.6 ± 0.8 Ba	290.5 ± 0.7 Ba	290.7 ± 0.7 Ba
	20	297.4 ± 0.7 Aa	297.5 ± 0.7 Aa	297.3 ± 0.7 Aa	297.5 ± 0.7 Aa
Phytic acid [mg·kg-1]	0	1 001.2 ± 26.6 Ca	943.2 ± 23.8 Cab	884.2 ± 23.2 Cbc	840.9 ± 26.6 Cc
	10	1 981.2 ± 26.6 Ba	1 951.5 ± 26.2 Ba	1 905.6 ± 34.5 Bab	1 864.5 ± 26.6 Bb
	20	2 908.2 ± 29.8 Aa	2 862.5 ± 38.9 Aab	2 813.6 ± 23.2 Abc	2 759.5 ± 29.0 Ac
Resistant starch [g·kg-1]	0	7.2 ± 0.3 Ad	19.1 ± 0.6 Ac	31.9 ± 0.7 Ab	48.7 ± 0.3 Aa
	10	6.2 ± 1.0 Ad	19.2 ± 0.6 Ac	31.3 ± 1.0 ABb	49.0 ± 0.8 Aa
	20	6.0 ± 1.0 Ad	17.2 ± 0.4 Bc	28.9 ± 0.6 Bb	44.5 ± 0.7 Ba

Values with the same small letter within row are not significantly different from each other ($p < 0.05$). Values with the same capital letter within column are not significantly different from each other ($p < 0.05$). Results are expressed on dry-weight basis.

5 – neither like nor dislike, 6 – like slightly, 7 – like moderately, 8 – like very much, 9 – like extremely).

Statistical analysis

The analyses of variance (ANOVA) were performed using the Statistical software JMP 5.0.1 (SAS Institute, Cary, North Carolina, USA). The comparison of the means was made by using Student's t comparison test. Significant differences were based on $p < 0.05$.

RESULTS AND DISCUSSION

Chemical properties of cake samples

Ash, protein, crude fibre and lipid content were found as 5.2 g·kg^{-1}, 104.2 g·kg^{-1}, 6.1 g·kg^{-1} and 8.7 g·kg^{-1} for wheat flour and 41.7 g·kg^{-1}, 244.8 g·kg^{-1}, 36.1 g·kg^{-1} and 81.3 g·kg^{-1} for WG, respectively. While crude fibre and lipid were not determined in RS, ash and protein content of RS were found as 3.7 g·kg^{-1} and 2.0 g·kg^{-1}, respectively. Chemical properties of cake samples are given in Tab. 2. WG addition increased ($p < 0.05$) ash and protein contents of the samples at all replacement levels of RS. As expected, rich ash and protein content of WG improved the final product composition in terms of ash and protein. Compared to cake without WG and RS, 20% replacement level of WG increased the ash and protein contents of the cakes 1.33-and 1.19-times, respectively. Increasing RS replacement level had a significant ($p < 0.05$) effect on protein content and caused its decrease at all WG replacement levels. This decrease might have been caused by the low protein content of RS compared to wheat flour or WG. Aigster et al. [34] reported that the protein contents of granola bars and granola cereals decreased from 6.4% and 6.0% to 5.8% and 4.5%, respectively, when supplemented with RS at a level of 15%. Crude fibre and lipid contents were affected ($p < 0.05$) only by WG replacement levels, crude fibre content increasing up to 11.0 g·kg^{-1} and lipid content up to 297.5 g·kg^{-1} at 20% WG replacement level. Increase in the ash, protein and lipid contents was reported when WG was used in various cereal products [11, 12, 40]. PA is known to bind minerals and proteins, altering their solubility, functionality, digestibility and absorption [41–44]. PA contents of wheat flour, WG and RS were 2 980 mg·kg^{-1}, 24 530 mg·kg^{-1} and 0 mg·kg^{-1}, respectively. PA content of the cake samples varied between 840.9 mg·kg^{-1} and 2908.2 mg·kg^{-1} (Tab. 2). PA content increased with the increasing content of WG, while RS replacement at a level of 15% caused a significant ($p < 0.05$) decrease in PA content of cakes compared to control without WG and RS. Nutritionists try to decrease the PA level, which is an anti-nutrient substance in the diet [44]. As expected, increasing the RS replacement levels in cake formulation increased also the RS content of the cake samples up to 49.0 g·kg^{-1}. Öztürk et al. [23] replaced wheat flour with three different types of commercial RS in the bread dough at up to 30% levels and found RS content of breads between 41.0 g·kg^{-1} and 127.9 g·kg^{-1}, while the value for the control bread was 12.1 g·kg^{-1}.

Mineral contents of the samples are summarized in Tab. 3. Increasing the WG level in cake formulation also increased ($p < 0.05$) Ca, Fe, K, Mg, P and Zn contents of the cake samples. High replacement level of RS (15%) caused a significant ($p < 0.05$) decrease in Mg and P contents.

Ca contents of the cakes was between 381.6 mg·kg^{-1} and 412.9 mg·kg^{-1}, the highest value being obtained with 20% WG usage (without RS) due to a higher Ca content of WG (486 mg·kg^{-1}) than wheat flour (187 mg·kg^{-1}, data not shown). Ca is the most abundant mineral in the body, and 99% of Ca is found within the bones and teeth. Ca is very important for biological functions such as cell adhesiveness, mitosis, blood coagulation, structural support, muscle contraction and glandular secretion [45–46]. Cu contents of the cake samples increased up to 1.4 mg·kg^{-1} with a high WG (20%) replacement level. A significant ($p < 0.05$) increase was also obtained in Fe content of cakes with WG replacement. The increment ratio reached up to 1.6 times at a high WG (20%) replacement level. Fe is another important mineral in human health due to the fact that Fe deficiency is one of the widespread nutritional disorder in the world. The World Health Organization (WHO) has estimated that nearly 3.7 billion people are iron-deficient, with two billion of these so severely deficient that they can be described

Tab. 3. Mineral content of cake samples.

	Wheat germ [%]	Resistant starch [%]			
		0	5	10	15
Ca [mg·kg^{-1}]	0	388.9 ± 2.0 ^{Ca}	384.1 ± 2.0 ^{Cab}	383.4 ± 1.8 ^{Cb}	381.6 ± 1.3 ^{Cb}
	10	395.5 ± 1.8 ^{Ba}	394.6 ± 2.1 ^{Ba}	392.8 ± 1.8 ^{Ba}	391.4 ± 1.4 ^{Ba}
	20	412.9 ± 2.5 ^{Aa}	411.9 ± 2.4 ^{Aa}	410.6 ± 1.3 ^{Aa}	410.5 ± 2.0 ^{Aa}
Cu [mg·kg^{-1}]	0	0.9 ± 0.2 ^{Ba}	0.9 ± 0.0 ^{Ba}	0.8 ± 0.1 ^{Ba}	0.8 ± 0.1 ^{Ba}
	10	1.2 ± 0.1 ^{ABa}	1.2 ± 0.1 ^{ABa}	1.2 ± 0.1 ^{ABa}	1.1 ± 0.1 ^{ABa}
	20	1.4 ± 0.1 ^{Aa}	1.4 ± 0.1 ^{Aa}	1.3 ± 0.1 ^{Aa}	1.3 ± 0.1 ^{Aa}
Fe [mg·kg^{-1}]	0	7.1 ± 0.3 ^{Ca}	6.9 ± 0.3 ^{Ca}	6.7 ± 0.6 ^{Ca}	6.7 ± 0.4 ^{Ca}
	10	9.6 ± 0.6 ^{Ba}	9.4 ± 0.4 ^{Ba}	9.3 ± 0.3 ^{Ba}	9.0 ± 0.4 ^{Ba}
	20	11.3 ± 0.4 ^{Aa}	11.0 ± 0.4 ^{Aa}	10.8 ± 0.4 ^{Aa}	10.7 ± 0.3 ^{Aa}
K [mg·kg^{-1}]	0	1212.0 ± 25.5 ^{Ca}	1186.6 ± 30.5 ^{Cab}	1152.8 ± 26.5 ^{Cab}	1124.0 ± 22.6 ^{Cb}
	10	1497.0 ± 24.0 ^{Ba}	1473.9 ± 22.8 ^{Bab}	1442.0 ± 25.5 ^{Bab}	1413.0 ± 24.0 ^{Bb}
	20	1692.1 ± 45.4 ^{Aa}	1671.2 ± 27.2 ^{Aa}	1650.7 ± 26.4 ^{Aa}	1622.8 ± 29.4 ^{Aa}
Mg [mg·kg^{-1}]	0	82.8 ± 2.5 ^{Ca}	68.1 ± 1.6 ^{Cb}	53.7 ± 2.4 ^{Cc}	41.1 ± 2.5 ^{Cd}
	10	207.1 ± 2.3 ^{Ba}	191.9 ± 1.9 ^{Bb}	181.2 ± 1.6 ^{Bc}	171.2 ± 2.3 ^{Bd}
	20	312.5 ± 2.8 ^{Aa}	302.1 ± 2.7 ^{Ab}	291.2 ± 2.4 ^{Ac}	278.9 ± 1.8 ^{Ad}
P [mg·kg^{-1}]	0	2251.1 ± 29.8 ^{Ca}	2218.0 ± 31.1 ^{Cab}	2185.4 ± 20.6 ^{Cab}	2153.2 ± 25.7 ^{Cb}
	10	2590.0 ± 28.3 ^{Ba}	2553.2 ± 25.7 ^{Bab}	2513.6 ± 23.2 ^{Bb}	2486.5 ± 26.1 ^{Bb}
	20	2750.0 ± 26.9 ^{Aa}	2713.0 ± 29.7 ^{Aab}	2675.2 ± 20.1 ^{Abc}	2634.0 ± 21.2 ^{Ac}
Zn [mg·kg^{-1}]	0	5.0 ± 0.3 ^{Ca}	4.8 ± 0.3 ^{Ca}	4.7 ± 0.3 ^{Ca}	4.6 ± 0.3 ^{Ca}
	10	9.3 ± 0.4 ^{Ba}	9.3 ± 0.3 ^{Ba}	9.2 ± 0.1 ^{Ba}	9.2 ± 0.3 ^{Ba}
	20	12.9 ± 0.3 ^{Aa}	12.9 ± 0.4 ^{Aa}	12.8 ± 0.4 ^{Aa}	12.7 ± 0.3 ^{Aa}

VValues with the same small letter within row are not significantly different from each other ($p < 0.05$). Values with the same capital letter within column are not significantly different from each other ($p < 0.05$). Results are expressed on dry-weight basis.

as anemic [47]. K and Mg contents of the cakes increased with WG replacement, but a slight decrease was observed with the increasing RS usage in Mg content. Higher K and Mg contents of WG (11 750 mg·kg^{-1} and 3081 mg·kg^{-1}) compared to wheat flour (1 080 mg·kg^{-1} and 450 mg·kg^{-1}) affected K and Mg contents in the final product.

P content of the cake samples was between 2153.2 mg·kg^{-1} and 2750.0 mg·kg^{-1}. Like other minerals, P content of the cakes increased ($p < 0.05$) with WG replacement. Zn content of the cake samples was between 4.6 mg·kg^{-1} and 12.9 mg·kg^{-1}. While RS replacement level had no significant ($p > 0.05$) effect on Zn content of the cakes, WG addition increased the Zn content because WG has the highest Zn content among the milling fractions of wheat grain (endosperm, bran and germ) [48]. In this study, Zn content of WG (98 mg·kg^{-1}) was found 12.1-times higher than wheat flour (8.1 mg·kg^{-1}). Zn has many biological functions, and Zn deficiency decreases serum testosterone level, hyperammonemia, neurosensory disorders and decreased lean body mass [49]. Arshad et al. [12] reported that supplementation of cookies with defatted WG (at a level of 25%) increased Ca, Fe and K from 501, 18.5 and 1050 mg·kg^{-1} to 531, 32.2 and 3060 mg·kg^{-1}, respectively. Abd El-Hady [50] and Bilgiçli et al. [40] also reported an increase in the mineral content of biscuit and tarhana when WG was used in the formulations at 5–25% and 10–50% levels, respectively.

Physical properties of cake samples

Some physical properties of cake samples are given in Tab. 4. Weight of the cake samples did not change significantly ($p > 0.05$) with increasing WG or RS replacement levels. The volume index is an indicator of cake volume [51]. In the present study, volume index values varied between 116.8 mm and 142.5 mm, and the high levels of WG or RS decreased the volume index values significantly ($p < 0.05$). However, 5% RS level, with 10% WG or without WG, gave the highest volume index value. In the study conducted by Karaoğlu et al. [52], native and modified starches (pregelatinized, thinned with acid, cross-linked, dextrinized) obtained from wheat and corn were used in cake formulation up to a level of 30%, and the results showed that the volume index values of cakes did not change significantly ($p > 0.05$) at starch levels of up to 20%. It was also reported that the addition of 10% of pregelatinized starch had a positive effect on the quality of cakes. The decrease in the volume index at high replacement levels of WG and RS could be due to dilution of gluten and deterioration of the gluten network in cake dough. It was reported that the loaf volume of bread decreased significantly as the addition level of different commercial RS increased up to 10% or 20% ($p < 0.05$) [23]. In another study, it was found that muffin volume and height decreased significantly at addition levels of RS of above 15 (by weight of total formulation) [27]. WG addition levels of 10–20% decreased the symmetry index at all addition levels of RS. Uniformity index values of cake samples were not affected by WG or RS replacement. Increasing symmetry index value indicated that the cakes were higher in the center than on sides, decreasing values showed that the cakes had flat surface and negative values showed that the cake volume decreased at the end of the baking process [53, 54]. For good cake quality, uniformity index should be close to zero [53]. Firmness of the cakes was adversely affected by increasing levels of WG or RS. In a study by Öztürk et al. [23], a significant increase in bread firmness was observed at RS levels above 10%. In another study, RS was used to replace the shortening in yellow layer cake formulation at levels of up to 50%. Here the cake volume decreased and firmness increased at higher replacement levels of shortening (37.5% and 50%). However, when RS replaced 15% of flour, without reducing shortening, no significant difference was observed in cake weight, volume and softness [24].

Colour values of cake crumb and crust

Crumb and crust colour values of cake samples are summarized in Tab. 5. Crumb and crust L^* (light/dark) values decreased, a^*(green/red) and b^* (blue/yellow) values increased with WG addition. High replacement levels of RS increased the L^* values of crust and crumb of cakes. b^* values of crumb and a^* values of crust also decreased at 15% addition level of RS. L^*, a^* and b^* values were 78.15, 1.32 and 28.36 for WG; 97.93, 0.01 and 1.47 for RS, respectively (data not shown). Natural colour characteristics of WG and RS had a significant effect on final product colour values. On the other hand, rich amino acid and saccharide contents of WG may promote Maillard reaction, which may increase darkness and redness of the product. It was reported that muffins containing increasing amounts of RS rich ingredients were whiter than the control muffin [25]. Laguna et al. [32] found that the colour of control biscuits without RS-rich ingredients were significantly darker and yellowish than biscuits with RS-rich ingredients. This can be attributed to diluting effect of RS on pigmented elements in the formulation [25].

Tab. 4. Physical properties of cake samples.

	Wheat germ [%]	Resistant starch [%]			
		0	5	10	15
Weight [g]	0	116.8 ± 0.85^{Aa}	117.0 ± 1.41^{Aa}	116.8 ± 0.99^{Aa}	116.9 ± 0.71^{Aa}
	10	117.8 ± 1.13^{Aa}	117.5 ± 1.13^{Aa}	116.8 ± 1.13^{Aa}	116.6 ± 1.13^{Aa}
	20	117.0 ± 1.41^{Aa}	117.5 ± 0.71^{Aa}	116.7 ± 0.99^{Aa}	117.3 ± 1.84^{Aa}
Volume index [mm]	0	135.2 ± 0.85^{Ab}	142.5 ± 0.71^{Aa}	133.9 ± 0.71^{Ab}	129.8 ± 0.57^{Ac}
	10	130.4 ± 0.57^{Bb}	133.1 ± 0.57^{Ba}	124.8 ± 0.99^{Bc}	119.7 ± 0.99^{Bd}
	20	128.2 ± 0.57^{Ca}	128.7 ± 0.99^{Ca}	119.8 ± 0.71^{Cb}	116.8 ± 0.57^{Cc}
Symmetry index [mm]	0	5.6 ± 0.14^{Aa}	5.2 ± 0.14^{Aa}	4.4 ± 0.28^{Ab}	3.7 ± 0.28^{Ac}
	10	2.4 ± 0.14^{Ba}	2.1 ± 0.28^{Ba}	2.2 ± 0.42^{Ba}	1.8 ± 0.28^{Ba}
	20	2.6 ± 0.42^{Ba}	2.4 ± 0.28^{Ba}	2.2 ± 0.28^{Ba}	1.9 ± 0.28^{Ba}
Uniformity index [mm]	0	0.9 ± 0.14^{Aa}	1.1 ± 0.14^{Aa}	1.2 ± 0.28^{Aa}	0.9 ± 0.14^{Aa}
	10	1.0 ± 0.28^{Aa}	1.2 ± 0.28^{Aa}	1.1 ± 0.14^{Aa}	1.2 ± 0.28^{Aa}
	20	1.3 ± 0.42^{Aa}	1.3 ± 0.17^{Aa}	1.4 ± 0.28^{Aa}	1.44 ± 0.20^{Aa}
Firmness [g]	0	$1\,860 \pm 7.07^{Cd}$	$1\,902 \pm 8.49^{Cc}$	$1\,985 \pm 7.07^{Cb}$	$2\,059 \pm 7.07^{Ca}$
	10	$2\,079 \pm 8.49^{Bc}$	$2\,152 \pm 9.90^{Bb}$	$2\,262 \pm 9.90^{Ba}$	$2\,278 \pm 8.49^{Ba}$
	20	$2\,231 \pm 9.90^{Ad}$	$2\,284 \pm 5.66^{Ac}$	$2\,315 \pm 8.49^{Ab}$	$2\,373 \pm 7.07^{Aa}$

Values with the same small letter within row are not significantly different from each other ($p < 0.05$). Values with the same capital letter within column are not significantly different from each other ($p < 0.05$).

Tab. 5. Crust and crumb colour values of cake samples.

	Wheat germ [%]	Resistant starch [%]			
		0	5	10	15
Crumb colour					
*L**	0	71.29 ± 0.24^{Ac}	71.76 ± 0.28^{Abc}	72.27 ± 0.25^{Ab}	73.95 ± 0.24^{Aa}
	10	70.42 ± 0.23^{Bb}	70.68 ± 0.28^{Bab}	70.95 ± 0.25^{Bab}	71.20 ± 0.28^{Ba}
	20	69.05 ± 0.20^{Cc}	69.99 ± 0.38^{Bb}	70.61 ± 0.27^{Bab}	70.90 ± 0.21^{Ba}
*a**	0	-2.21 ± 0.14^{Ca}	-2.14 ± 0.14^{Ba}	-2.08 ± 0.11^{Ba}	-2.02 ± 0.14^{Ca}
	10	-1.53 ± 0.10^{Bc}	-0.93 ± 0.07^{Ab}	-0.74 ± 0.07^{Aab}	-0.68 ± 0.10^{Ba}
	20	-0.95 ± 0.13^{Ab}	-0.89 ± 0.13^{Ab}	-0.45 ± 0.14^{Aa}	-0.25 ± 0.07^{Aa}
*b**	0	26.74 ± 0.16^{Ba}	26.29 ± 0.14^{Bb}	26.06 ± 0.14^{Bbc}	25.72 ± 0.14^{Bc}
	10	27.89 ± 0.14^{Aa}	27.65 ± 0.20^{Aa}	27.63 ± 0.14^{Aa}	26.94 ± 0.17^{Ab}
	20	28.38 ± 0.17^{Aa}	27.91 ± 0.23^{Aab}	27.54 ± 0.14^{Abc}	27.12 ± 0.17^{Ac}
Crust colour					
*L**	0	53.66 ± 0.23^{Ac}	53.55 ± 0.21^{Ac}	54.92 ± 0.31^{Ab}	56.97 ± 0.31^{Aa}
	10	52.46 ± 0.28^{Bb}	52.95 ± 0.24^{Ab}	53.02 ± 0.34^{Bb}	54.23 ± 0.33^{Ba}
	20	51.62 ± 0.23^{Cb}	51.45 ± 0.23^{Bb}	52.74 ± 0.28^{Ba}	52.94 ± 0.28^{Ca}
*a**	0	13.91 ± 0.07^{Ca}	13.24 ± 0.07^{Bb}	13.31 ± 0.08^{Bb}	13.09 ± 0.13^{Cb}
	10	14.57 ± 0.11^{Ba}	14.67 ± 0.10^{Aa}	14.18 ± 0.08^{Ab}	13.51 ± 0.08^{Bc}
	20	15.15 ± 0.06^{Aa}	14.46 ± 0.06^{Ab}	14.25 ± 0.07^{Ac}	14.23 ± 0.04^{Ac}
*b**	0	25.66 ± 0.16^{Ca}	24.42 ± 0.25^{Cb}	24.12 ± 0.17^{Cb}	23.89 ± 0.27^{Cb}
	10	27.55 ± 0.21^{Ba}	27.82 ± 0.24^{Ba}	27.34 ± 0.28^{Ba}	27.55 ± 0.14^{Ba}
	20	28.91 ± 0.28^{Aa}	29.11 ± 0.28^{Aa}	28.69 ± 0.23^{Aa}	28.45 ± 0.28^{Aa}

Values with the same small letter within row are not significantly different from each other ($p < 0.05$). Values with the same capital letter within column are not significantly different from each other ($p < 0.05$).

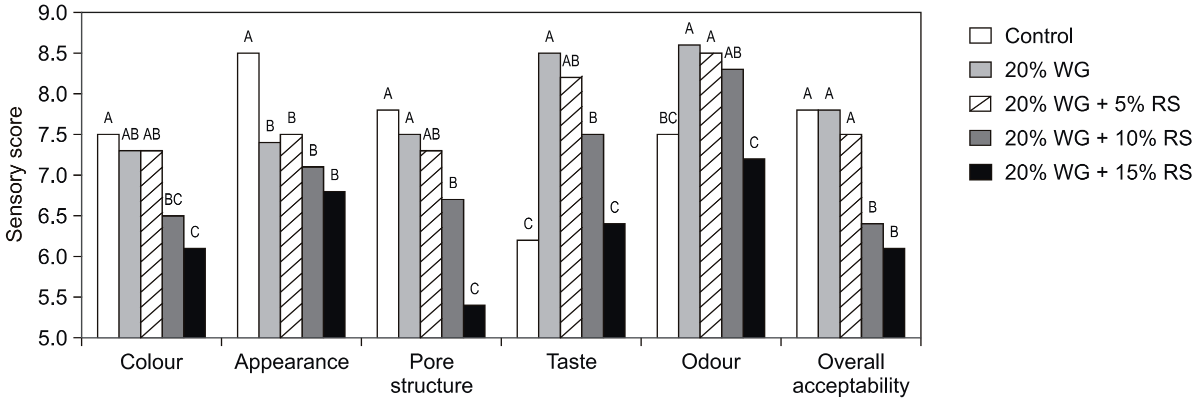

Fig. 1. Sensory scores of cake samples.

Different capital letters above colums indicate significant statistical differences ($p < 0.05$).
WG – wheat germ, RS – resistant starch.

Sensory analysis

Sensory properties of the cake samples are given in Fig. 1. Cake samples containing 20% WG were subjected to sensory analysis due to nutritional superiority. The effect of RS ratio at 20% WG replacement level was compared with control cake samples without WG and RS. Colour values of cakes containing 20% WG and 0–5% RS gave score similar to control, but higher addition levels of RS decreased the colour score. Appearance of the cakes containing WG and/or RS were evaluated at a lower score by the panelists, compared to control. 10–15% addition levels of RS had a negative effect on the pore structure of the cake crumb. Replacement of 20% WG with 0–10% RS improved the taste and odour of the cake compared to control cake due to the unique taste and odour of WG. Higher replacement levels of RS (10–15%) decreased the overall acceptability score compared to control and other cake samples. Gómez et al. [14] reported that adequate quality breads could be obtained by adding up to 5 g extruded WG per 100 g of flour. In another study, acceptable cookies were produced from wheat flour containing up to 15% defatted WG [12]. Baixauli et al. [26] studied the sensory properties of muffins enriched with RS at levels of up to 20% (flour based). Taste, overall acceptance and consumption intention of muffins were not found significantly different, whereas RS addition significantly decreased the appearance and texture acceptance score at levels above 5% ($p < 0.05$).

CONCLUSION

WG is a rich source of protein, lipid, vitamin, mineral, bioactive components and free saccharides. RS has potential health benefits as dietary fibre, on the other hand it has certain adverse effects on the sensory properties of food compared with traditional sources of fibre, such as whole grains, fruits or brans. In the present study, WG was used in cake formulation at levels of up to 20% with (5–15%) and without RS. WG replacement increased ash, protein, lipid, crude fibre, PA and mineral contents of the cakes, while the high replacement levels of RS caused a significant decrease in protein, PA, Mg and P contents of the cakes. Combination of WG and RS at high replacement levels adversely affected volume index and firmness of the samples. The usage of RS at 10–15% levels decreased the overall acceptability scores of cakes. On the other hand, cakes with RS at a level of 5% showed sensory scores similar to the control cake in all parameters with the exception of appearance. It can be concluded that 20% WG with or without 5% RS can be used in cake formulation for nutritional and functional enrichment of cake without adverse effect on sensory quality except for appearance.

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