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Physical, textural, and sensory characteristics of wheat and amaranth flour blend cookies

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Abstract: This study examined the effects of whole amaranth substitutions at various proportions and evaluated the cookies baking behavior. Six types of formulations of cookies were prepared with whole amaranth flour ranging from 20, 40, 60, 80, and 100%. These cookies were evaluated for physical (thickness, diameter, spread ratio, and bake loss), textural, and organoleptic attributes. The diameter and spread ratios were found to be higher in whole amaranth flour cookies 52.20 mm and 6.46, respectively, as compared to other blends (20–80%) of cookies from 51.37 to 51.92 mm and 6.13 to 6.36, respectively. Textural measurement showed that hardness of cookies decreased with the addition of amaranth flour. Whole amaranth flour cookies required least snap force (72.4 N) compared to control (whole-wheat flour) cookies (145 N). Sensory data indicated that the amaranth cookies with up to 60% were acceptable, while additional amaranth flour resulted in a decreased mean score for overall acceptability.

Subjects: Engineering & Technology; Food Engineering; Food Science & Technology

Keywords: amaranth flour; wheat flour; cookies; spread ratio; hardness

1. Introduction

Amaranthus plants (*Amaranthaceae*) are spread all over the world, and it can be grown under a broad range of climatic conditions to infest or to produce useful feed and food products (Rastrelli, Pizza, Saturnino, Schettino, & Dini, 1995). In India, Amaranths are chiefly grown in Himalayas from Kashmir to Bhutan, and also in South Indian hills. Amaranth is not a "true cereal" such as wheat, corn, or barley, but it is rather considered a "pseudocereal" like buckwheat (*Fagopyrum esculentum*)

ABOUT THE AUTHORS

The authors are involved in the research activities mainly based upon amaranth processing, characterization, and utilization. The group of authors is also working on the impact of germination on pseudocereal nutritional status and other aspects. The flour prepared from raw and germinated amaranth is characterized for their physicochemical and functional properties. The flour from raw and germinated amaranth grains was used for the development of the products like cookies and pasta. The use of amaranth flour in the fabrication of gluten-free products is a novel approach to provide with a healthy alternative, to traditional gluten containing products, to the large population of consumers suffering from celiac disease and gluten sensitivity.

PUBLIC INTEREST STATEMENT

Grain amaranth has several attractive features like gluten-free ingredient, high-quality protein, and the presence of abundant quantities of fiber and minerals such as calcium and iron. This study can help industries to develop gluten-free food products and also help researchers for further research on pseudocereals.

and quinoa (*Chenopodium quinoa*). Grain amaranth has several attractive features like gluten-free ingredient, high-quality protein, and the presence of abundant quantities of fiber and minerals such as calcium and iron (Ballabio et al., 2011; Moreno, Comino, & Sousa, 2014). Moreover, these grains are also a source of many bioactive compounds with health-promoting effects such as phytosterols, polyphenols, saponins, and squalene (Alvarez-Jubete, Arendt, & Gallagher, 2010). In addition to nutritional characteristics, amaranth plants have agronomic features identifying it as an alternative crop where cereals and vegetables cannot be grown (dry soils, high altitudes, and high temperatures) (Omamt, Hammes, & Robbertse, 2006). In Asia, the Indian diet finds in amaranth grain a culinary acceptable high protein, high fiber, alternative to wheat, and easy to incorporate into the traditional cuisine (Dixit, Azar, Gardner, & Palaniappan, 2011). Along with nutritional benefits, many health benefits are attributed to amaranth seeds, such as decreasing plasma cholesterol levels, stimulating the immune system, antitumor activity, reducing blood glucose levels, and improving conditions of hypertension and anemia (Caselato-Sousa & Amaya-Farfán, 2012).

Cookies hold an important place in snacks due to its taste, crispness, and eating convenience. These are popular among all age groups especially in children. Generally, cookies are prepared from wheat flour, which are deficient in some essential amino acids like lysine and tryptophan, (Kent, 1975) whereas amaranth grains are rich in lysine and tryptophan (Mlakar, Turinek, Jakop, Bavec, & Bavec, 2010). To increase its nutritive value, cookies are prepared with fortified or composite flour. Composite flour has an economic value in developing countries because it reduces the burden on imported wheat flour and encourages use of locally grown crops as flour (Hasmadi et al., 2014; Hugo, Rooney, & Taylor, 2000). A number of studies have shown the improved nutritive values of cookies by incorporating navy bean, sesame seed (Hoojjat & Zabik, 1984), corn fiber (Artz, Warren, Mohring, & Villota, 1990), soy protein and fiber (Shrestha & Noomhorm, 2002), chickpea, lentil (Zucco, Borsuk, & Arntfield, 2011), barley (Gupta, Bawa, & Abu-Ghannam, 2011), soybean, maize (Mishra, Puranik, Akhtar, & Rai, 2012), and barley (Sharma & Gujral, 2014).

In view of the nutritional and agronomic benefits of amaranth, cookies were prepared from the composite flour containing various proportions of the whole amaranth flour. The purpose of this study was to determine the physicochemical and sensory attributes of amaranth flour-substituted cookies.

2. Materials and methods

2.1. Material

Amaranth grains were purchased from a local market in (Sangrur, Punjab) India. Grains were cleaned and stored in airtight container in refrigeration conditions at 4°C till further used. Wheat flour, shortening, sugar, skim milk powder, and salt were purchased from a local market (Sangrur, India).

2.2. Methods

2.2.1. Preparation of amaranth flour

Amaranth grains were washed with water 2–3 times and then dried in hot air oven for 2 h. After drying, the grains were milled in stone mill. To get uniform particle size, the flour was passed through 60-mesh sieve and stored at 4°C in refrigeration conditions till further analysis.

2.2.2. Proximate composition

The chemical composition of the flours, (wheat and amaranth) including the moisture, fat, ash, fiber, and protein content, were determined by the AOAC methods (AOAC, 1995).

2.2.3. Pasting properties

The pasting profiles of the flours blend were studied using a Rapid Visco Analyzer (Newport Scientific Pvt. Ltd, Australia). Flour sample (3 g) was mixed with 25 ml of distilled water in the RVA sample canister to make a total of 28 g of flour suspension. The flour suspension was held at 50°C for 1 min and later heated to 95°C for 3 min. The suspension was held at 95°C for 3 min before it was subsequently cooled to 50°C over a period of 4 min and then held at this temperature for 2 min. RVA parameters i.e. pasting temperature, peak viscosity, trough viscosity, final viscosity, breakdown, set back, and pasting temperature were recorded. All the measurements were replicated thrice. The results were expressed in RVU (RVU, 1 RVU = 12 centipoises).

2.3. Cookie formulation

Cookies were made from wheat to serve as a control. The amaranth flour was mixed with wheat flour at different level (20, 40, 60, 80, and 100%.) to prepare cookies. The cookies were prepared using the following ingredients: flour (100 g), shortening (vegetable ghee, Dalda, India) (40 g), sugar (40 g), skim milk powder (10 g), salt (1.0 g), sodium bicarbonate (1.0 g), and water (12–22 ml). Shortening and sugar were mixed to form a cream, then added to the mixture of flour, sodium bicarbonate, and skim milk powder, and mixed thoroughly to form dough. The dough was kneaded and sheeted to a uniform thickness of 0.25 cm and cut into circular shapes of 5-cm diameter. Baking was carried out at 170°C for 15 min. Cookie samples were cooled and stored in airtight containers.

2.4. Physical analysis

Diameter and thickness were measured with a vernier calliper at two different places in each cookie and the average was calculated for each (one value was considered for each cookie). The spread ratio was calculated using the formula: diameter of cookies divided by height of cookies (Zoulias, Piknis, & Oreopoulou, 2000). The bake loss of cookies was calculated by weighing five cookies before and after baking. The difference in weight was averaged and reported as percent bake loss.

2.4.1. Color analysis

Color measurement of cookies was carried out using a Hunter Colorimeter fitted with optical sensor (Hunter Associates Laboratory Inc., Reston, VA, USA) on the basis of CIE L^*, a^*, b^* color system. L^* values measure black to white (0–100), a^* values measure redness when positive, and b^* values measure yellowness when positive.

2.4.2. Texture analysis

Hardness of the baked cookies was measured using a texture analyzer (TA-XT2i, Stable Micro Systems, UK) in a compression mode with a sharp blade-cutting probe. Pre-test, test, and post-test speeds were 1.5, 2, and 10 mm/s, respectively. Hardness, a maximum peak force, was measured with more than six cookies for each sample. The peak force to snap the cookies was reported as fracture force in N.

2.4.3. Sensory evaluation

Cookies made from wheat and whole amaranth seed flours were subjected to sensory evaluation as shown in Table 5, using 20 semi-trained panelists drawn within the University community. The cookies were evaluated for taste, aroma, crispiness, color, and overall acceptability. The ratings were on a 9-point hedonic scale ranging from 9 (like extremely) to 1 (dislike extremely). All panelists were regular consumers of cookies. Water at room temperature was provided to rinse the mouth between evaluations. The control was cookies made from 100% wheat flour.

2.4.4. Statistical analysis

Data were assessed by Duncan's multiple range test (Duncan, 1955) using statistical 7(Statistical Soft, TULSA, USA) statistical software packages at $p < 0.05$ was used to determine the level of significance.

3. Results and discussion

3.1. Proximate composition of amaranth and wheat flour

The chemical compositions of wheat and amaranth flour used for cookies preparation are shown in Table 1. Amaranth flour was found to have high crude protein, crude fat, crude fiber, and ash content in comparison with wheat flour.

3.2. Pasting properties

The results of pasting properties of wheat and composite flour (wheat & amaranth flour) were obtained by RVA expressed as RVU (1 RVU = 12 centipoises) (Table 2). The results indicate that the control (wheat) shows maximum values for pasting parameters (peak viscosity, trough viscosity, breakdown, final viscosity, setback, and pasting temperature). The results indicate that the pasting parameters (peak viscosity, trough viscosity, breakdown, final viscosity, setback, and pasting temperature) were decreased with the increase in addition of amaranth flour in the formulation. Similarly, it has been reported that the blending of amaranth flour and wheat flour significantly decreases the pasting parameters (Sindhuja, Sudha, & Rahim, 2005). It may be due to the low viscosity contributed by the amaranth flour.

3.3. Physical properties

The physical characteristics (thickness, diameter, spread ratio, and bake loss) of the six types of cookies are shown in Table 3. Results showed that there was significant difference ($p < 0.05$) between each samples in terms of thickness, diameter, spread ratio, and bake loss. From the results, it was noticed that the diameter of the composite cookies displayed an increasing trend along with the increasing substitution level of amaranth flour. This may be probably due to lower viscosity of amaranth flour than wheat flour, so as a result viscosity of dough reduces as addition of amaranth flour increases and increases the spread rate. Dough with lower viscosity causes cookies to spread at a faster rate (Hoseney & Rogers, 1994). Cookie spread ratio stand for a ratio of diameter to height. Cookies having higher spread ratio are considered most desirable (Finney, Morris, & Yamazaki, 1950; Kissel & Prentice, 1979). Results shows that the spread ratio of the composite cookies displayed an increasing trend along with the increasing substitution level of amaranth flour (Table 3). Singh,

Table 1. Proximate composition of wheat and amaranth flour

Samples	Moisture	Ash	Crude fat	Crude protein	Crude fiber
Wheat flour	11.3 ± 0.06^{a}	1.3 ± 0.04^{b}	1.6 ± 0.05^{b}	10.56 ± 0.03^{b}	1.2 ± 0.04^{b}
Amaranth flour	8.13 ± 0.15^{b}	2.93 ± 0.08^{a}	6.68 ± 0.08^{a}	15.05 ± 0.05^{a}	3.0 ± 0.03^{a}

Notes: Values followed by different superscript letters in a column are significantly ($p < 0.05$) different from each other; Values are means and standard deviations of three determinations ($n = 3$).

Table 2. Pasting profile wheat–amaranth flour blend

Samples	PV (RVU)	TV (RVU)	BD (RVU)	FV (RVU)	SB (RVU)	PT (°C)
Control	115.33 ± 3.0^{a}	69.25 ± 1.23^{a}	46.08 ± 0.9^{a}	146.50 ± 1.2^{a}	77.25 ± 4.12^{a}	86.30 ± 1.09^{a}
A1	99.83 ± 2.86^{b}	68.83 ± 2.05^{b}	31.0 ± 2.41^{b}	129.0 ± 2.37^{b}	60.16 ± 2.54^{b}	84.75 ± 0.56^{b}
A2	80.25 ± 5.71^{c}	65.50 ± 1.86^{c}	28.83 ± 1.7^{c}	90.33 ± 1.59^{c}	41.08 ± 2.11^{c}	79.90 ± 0.16^{c}
A3	79.50 ± 4.30^{d}	62.75 ± 2.13^{d}	22.16 ± 1.1^{d}	86.00 ± 4.12^{d}	30.66 ± 1.97^{d}	79.10 ± 0.54^{d}
A4	78.08 ± 2.25^{e}	55.33 ± 3.05^{e}	16.75 ± 2.0^{e}	84.91 ± 2.86^{e}	22.16 ± 3.22^{e}	78.25 ± 1.21^{e}
A5	77.50 ± 3.39^{f}	49.25 ± 1.16^{f}	14.75 ± 2.14^{f}	75.75 ± 3.69^{f}	10.25 ± 4.62^{f}	76.65 ± 0.23^{f}

Notes: A1 = 20% amaranth flour; A2 = 40% amaranth flour; A3 = 60% amaranth flour; A4 = 80% amaranth flour; A5 = 100% amaranth flour.

PV is peak viscosity; TV is trough viscosity; BD is breakdown; FV is final viscosity is set back; PT is pasting temperature.

Values followed by different superscript letters in a column are significantly ($p < 0.05$) different from each other; Values are means and standard deviations of three determinations ($n = 3$).

Singh, Sharma, and Saxena (2003) documented that the spread ratio of cookies increased as non-wheat protein content increased. Bake loss of cookies was decreased as the proportion of amaranth flour increased in the blend. The reason behind this is that the amaranth flour has high water holding capacity compared to wheat flour due to its high-protein content.

3.4. Color analysis

The color measurements of the composite cookies substituted with different levels of amaranth flour are depicted in Table 4. From the results, it was noticed that the lightness (L^*) of the composite cookies displayed a decreasing trend along with the increasing substitution level of amaranth flour. The reducing values of L^* indicates that the composite cookies are darker in color at higher levels of substitution. On the other hand, a reverse trend was noticed for redness (a^*) and yellowness (b^*) in composite cookies. The increase in a^* and b^* values was noticed as amaranth flour level increased in cookies preparation. Chevallier, Colonna, and Della Valle (2000) suggested that protein content was negatively correlated with lightness of cookie, indicating that the Maillard reaction played the major role in color formation. Maillard browning and caramelization of sugar is considered to produce brown pigments during baking (Laguna, Paula, Ana, Teresa, & Susana, 2011). The cookie color is an important factor for the initial acceptability of food products by consumers.

3.5. Texture analysis

Texture result of the six types of cookies prepared from blend of wheat and whole amaranth flour is shown in Table 4. Hardness differs significantly ($p < 0.05$) in all cookies sample. The decrease in hardness with amaranth flour substitution in cookies could be attributed to the changes in gluten content. The changes in total protein content were not as significant as the change in gluten content for the formation of composite matrix of cookie dough (Chung, Cho, & Lim, 2014). The continuous protein matrix in short-dough cookies, such as sugar-snap cookies, could be achieved mainly by gluten

Table 3. Physical analysis of wheat–amaranth flour blend cookies

Samples	Weight (g)	Thickness (mm)	Diameter (mm)	Spread ratio	Bake loss (g/100 g)
Control	13.17 ± 0.11^f	8.78 ± 0.41^a	51.14 ± 0.04^f	5.82 ± 0.08^f	17.79 ± 0.22^a
A1	13.38 ± 0.21^e	8.49 ± 0.11^b	51.37 ± 0.11^e	6.13 ± 0.05^e	16.36 ± 0.09^b
A2	13.66 ± 0.15^d	8.30 ± 0.08^c	51.50 ± 0.23^d	6.20 ± 0.06^d	14.25 ± 0.31^c
A3	14.00 ± 0.19^c	8.24 ± 0.15^d	51.67 ± 0.09^c	6.29 ± 0.04^c	11.40 ± 0.24^d
A4	14.23 ± 0.22^b	8.16 ± 0.06^e	51.92 ± 0.19^b	6.36 ± 0.05^b	10.64 ± 0.18^e
A5	14.48 ± 0.19^a	8.07 ± 0.11^f	52.20 ± 0.16^a	6.46 ± 0.07^a	10.13 ± 0.20^f

Notes: A1 = 20% amaranth flour; A2 = 40% amaranth flour; A3 = 60% amaranth flour; A4 = 80% amaranth flour; A5 = 100% amaranth flour.

Values followed by different superscript letters in a column are significantly ($p < 0.05$) different from each other; Values are means and standard deviations of three determinations ($n = 6$).

Table 4. Color characteristics and Texture analysis of wheat–amaranth flour blend cookies

Samples	L-value	a-value	b-value	Hardness (N)
Control	63.09 ± 0.21^a	6.31 ± 0.12^f	26.17 ± 0.14^f	145.09 ± 1.02^a
A1	62.57 ± 0.06^b	6.71 ± 0.17^e	26.71 ± 0.06^e	137.77 ± 1.84^b
A2	62.47 ± 0.08^c	7.17 ± 0.24^d	27.45 ± 0.19^d	118.29 ± 1.43^c
A3	61.37 ± 0.17^d	7.84 ± 0.20^c	28.12 ± 0.23^c	102.68 ± 0.89^d
A4	59.59 ± 0.24^e	8.12 ± 0.16^b	28.45 ± 0.07^b	88.58 ± 1.26^e
A5	59.01 ± 0.05^f	8.36 ± 0.08^a	29.36 ± 0.44^a	72.55 ± 1.17^f

Notes: A1 = 20% amaranth flour; A2 = 40% amaranth flour; A3 = 60% amaranth flour; A4 = 80% amaranth flour; A5 = 100% amaranth flour.

Values followed by different superscript letters in a column are significantly ($p < 0.05$) different from each other; Values are means and standard deviations of three determinations ($n = 3$).

Table 5. Effect of replacement of wheat flour with amaranth flour on the sensory characteristics of cookies

Samples	Color and appearance	Aroma	Taste	Texture	Overall acceptability
Control	7.00 ± 1.07^{a}	8.00 ± 1.42^{a}	7.66 ± 1.07^{ab}	7.00 ± 1.25^{a}	7.66 ± 0.36^{a}
A1	7.66 ± 0.57^{a}	8.33 ± 1.06^{a}	8.00 ± 0.48^{a}	7.33 ± 1.54a	7.33 ± 0.52^{ab}
A2	8.00 ± 1.28^{a}	8.00 ± 1.14^{a}	8.00 ± 0.56^{a}	7.66 ± 0.63^{a}	7.66 ± 1.29^{b}
A3	8.00 ± 1.18^{a}	8.00 ± 2.03^{a}	8.33 ± 0.43^{a}	8.00 ± 0.84^{a}	8.00 ± 1.46^{ab}
A4	7.66 ± 1.23^{a}	7.53 ± 1.71^{a}	7.00 ± 1.23^{ac}	7.66 ± 1.06^{a}	6.00 ± 0.68^{bc}
A5	7.66 ± 0.84^{a}	7.50 ± 0.69^{a}	6.00 ± 1.67^{bc}	7.66 ± 0.67^{a}	6.00 ± 0.83^{b}

Notes: A1 = 20% amaranth flour; A2 = 40% amaranth flour; A3 = 60% amaranth flour; A4 = 80% amaranth flour; A5 = 100% amaranth flour.

Values followed by different superscript letters in a column are significantly ($p < 0.05$) different from each other; Values are means and standard deviations of three determinations ($n = 3$).

during baking (Chevallier et al., 2000). Therefore, the reduction of gluten in cookie dough by substituting with amaranth flour resulted in retarding the formation of gluten matrices, which contributed to the substantial decrease in hardness. Sindhuja et al. (2005) also, found the similar result for hardness of amaranth flour cookies. They showed that the force required to break the cookies significantly decreased with the addition of amaranth flour in cookies.

3.6. Sensory evaluation

The sensory scores of wheat–amaranth composite cookies are depicted in Table 5. According to the results presented, there was a significant decrease in taste and overall acceptability of wheat–amaranth composite cookies. No significant change was observed in color, aroma, and texture of cookies prepared from blend containing amaranth flour up to 100% level. In terms of taste, significant increase in mean scores was noted up to 60% addition of amaranth flour into the composite cookies. The sensory score for taste decreased after 60% addition of amaranth flour. This may be due to bitter aftertaste of amaranth flour. The overall acceptability score indicated that the cookies prepared up to 60% amaranth flour had most acceptable sensory attributes. This was contradicting with the result reported by Sindhuja et al. (2005) which revealed that the cookies containing 25% amaranth seed flour was found to be most acceptable by the panelists.

4. Conclusions

This study revealed that the amaranth flour is a good source of protein, fiber, and fat as compared with wheat flour. The physical properties of the amaranth-enriched cookies were affected in a positive way by demonstrating a decrease in bake loss, an increase in diameter, a higher spread ratio, and lesser hardness, leading to softer eating characteristics which are required in cookies. Color characteristics of the cookies were significantly influenced by the addition of amaranth flour. The amaranth-formulated cookies up to 60% were well accepted by their sensory characteristics. So, the use of amaranth flour in cookie was effective for technological and nutritional advantages of cookies.

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Competing interests
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