J Food Sci Technol (February 2016) 53(2):1151–1163
DOI 10.1007/s13197-015-2121-8

ORIGINAL ARTICLE

Antioxidant, functional and rheological properties of optimized composite flour, consisting wheat and amaranth seed, brewers' spent grain and apple pomace

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Revised: 4 October 2015 / Accepted: 17 November 2015

Abstract Consumer's interest in functional food has continued to increase due to its potential health benefits. This study therefore is aimed at developing a functional wheat based flour comprising, amaranth *(Amaranthus hypochondriacus)* seed, brewers' spent grain and apple pomace. The statistical analyses were carried out using response surface methodology (RSM). For the experimental design, the composite flour components were the variables while the proximate and mineral compositions were the responses. After the statistical optimisation process, the best three blends were chosen for further analyses; determination of antioxidant, functional and rheological properties. From the results, the best blends were Runs 11, 13 and 19, with percentages composition of wheat, amaranth seed, brewers, spent grain and apple pomace of 65 %, 30 %, 2 %, 3 %; 60.43 %, 29.68 %, 4.1 %, 5.79 % and 81.94 %, 6.75 %, 3.39 %, 7.92 % respectively. The ANOVA, R^2 and R^2 adjusted values for the proximate and mineral compositions showed that the composite flours were statistically satisfactory. The results also indicated that the antioxidant, functional and rheological properties of the three best blends showed good and acceptable nutritional and rheological properties. Composite flours with acceptable and excellent nutritional composition, functional properties and rheological behaviour can be obtained from composite blends consisting wheat, amaranth seed, brewers, spent grain and apple pomace flours.

Keywords ANOVA · Composite flour · Functional · Proximate · Responses surface methodology · Rheology

Highlights • Composite flour consisting wheat, amaranth seed, BSG and apple pomace was developed
• Optimization of the proximate and mineral compositions were carried out
• Three best blends from the optimization process were selected for further processing
• Antioxidant, functional, rheological properties of the best blends were determined
• Overall best blend based on the antioxidant, functional, rheological properties was chosen

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Introduction

Development of functional food in the production of bakery products is growing (Awolu et al. 2015). The role of diet in the prevention of human ailments such as cancer, cardiovascular diseases and obesity has become more evident and many consumers are increasingly seeking functional foods to improve their diets (Omoba et al. 2013). Natural raw materials rich in dietary fibre (DF) and high in antioxidant capacity serve as functional ingredients for the food industry (Lunn and Buttriss 2007). In fact, the use of cheap and nutritionally rich raw materials which may otherwise go as wastes is being encouraged (Singh et al. 2012). Some of these wastes are orange pomace, apple pomace and brewers' spent grains which have gain prominence in development of functional foods. Such wastes, however, usually have composition rich in sugars, minerals and proteins, which qualify them as potential raw materials for other industrial processes (Mussatto et al. 2012).

Pomace is the solid remains of any fruit, such as apples, grapes, and olives, after pressing for juice or oil, which contains the skin, pulp feeding. Due to its high contents of protein and fibre (around 20 and 70 % dry basis, respectively) of pomace, it can also serve as an attractive adjunct in human nutrition. The antioxidant property of pomace can function as a natural substitute for synthetic antioxidants. Cakes prepared with apple pomace had higher dietary fibre and phenolic contents (Kennedy et al. 1999). Attempts have been made to use apple pomace as a dietary fibre in some baked food products (Masoodi et al. 2002). Apple pomace is the major by-product of the apple juice industry, representing 25 %, whereas approximately 75 % of the fruit weight is extracted as juice.

Brewer's spent grain (BSG) is a by-product of the brewing industry, representing around 85 % of the total by-products generated (Forssell et al. 2008). It consists primarily of grain husks, pericarp and endosperm. It has predominantly been used for animal feed but there is a strong argument for its use for human consumption, as it is rich in dietary fibre and protein (Peter 2007). It is a lignocellulosic material containing about 17 % cellulose, 28 % non-cellulosic polysaccharides, chiefly arabinoxylans, and 28 % lignin.

Wheat is the third most produced cereal in the world after maize and rice (Van den Broeck et al. 2010). It is a very important food crop for the daily intake of proteins, vitamins, minerals and fibers in a growing part of the world population (Cummins and Roberts-Thomson 2009).

Amaranth [*Amaranthus hypochondriacus, A. cruentus* (Grain type) & *A. tricolor* (Vegetable type)] is cultivated for both its seeds which are used as a grain and its leaves which are used as a vegetable or green. It contains high content of lysine, which is the limiting amino acid in cereals such as maize, wheat and rice (O'Brien and Price 2008). The grain is milled for flour or popped like popcorn. Amaranth has the potential to improve nutrition, boost food security, foster rural development and support sustainable land care (National Research Council (NRC) 2006).

Response Surface Methodology (RSM) is used to create response-surface models for the prediction of changes in response variables as a function of changes in input variables (Montgomery 2009). The response variable is the measured quantity of the output of a trial whose value is assumed to be affected by changing the levels of input variables (Shad et al. 2013). Response surface methodology had been utilized in statistical optimization of nutritional properties of composite flours production (Awolu et al. 2015; Omoba et al. 2013). Response surface 3D plots provide a good way for visualizing the parameters interactions between the variables and the responses (Awolu et al. 2015; Omoba et al. 2013; Awolu et al. 2013).

This study therefore is aimed at optimizing the production of functional composite flour from wheat, amaranth seed, brewers' spent grain and apple pomace flours; assess its nutritional quality characteristic, antioxidant properties and hence, its rheological properties in order to determine its suitability as flour.

Materials and methods

Raw materials and reagents

Brewers' spent grain (BSG) was obtained from International Breweries PLC Ilesha, Nigeria; while fresh wholesome Apples (*Malus domestica*), Wheat (*Triticum aestivum)* flour and Amaranth seed (*Amaranthus hypochondriacus*) were purchased from Oja Oba, Akure, Nigeria. All chemicals used were of analytical grade.

Samples preparation

Production of apple pomace flour

Apple pomace flour was produced using method of Singh et al. (2012). Fresh wholesome apples (25 Kg) were cleaned, sliced, decored and dipped in 2000 ppm Potassium metabisulphite (KMS) solution. The apple pieces were crushed in the fruit crusher and juice removed through the juice opening. The remaining pulp was put in a muslin cloth and pressed in a Carver press at 15 m tons of pressure for 90 mins. The apple pomace obtained was then oven-dried at 60 °C until 10–12 % moisture content was obtained. The dried apple pomace was ground, packed in airtight polythene bags for further processing.

Production of brewers' spent grain flour

The spent grains were treated to remove residual sugar and alcohol. Brewer's spent grain (100 g) was made into a suspension by dissolving in 400 ml of water and fermented with yeast (0.8 g) for 1 h to convert its residual sugar to alcohol. The fermented suspension was subjected to distillation to remove residual alcohol. The pH of the distilled suspension was adjusted to about 6.0 to 7.0 by adding 5 % (w/v) sodium hydroxide solution and dried to a moisture content of 5.0 % (Ajanaku et al. 2011). The dried grains was then milled with an attrition mill and sieved to a fine consistency which was then packed in airtight polythene bags (Benfarhner 2012) for further processing.

Production of amaranth seed flour

Amaranth seed (1 Kg) were cleaned to remove stones, dust, light materials, and broken, undersized and immature grains.

It was thereafter rinsed with water to get rid of the saponin on the seed coat, oven dried, milled using hammer mill and sieved using 0.5 mm mesh screen to give a fine flour consistency. The milled samples were then packed in polyethylene bags and stored at 4 °C until analysis (modified method of Emire and Arega 2012).

Experimental design for composite flour

Optimal Mixture model of response surface methodology (RSM) (Design expert 8.0) was used for the experimental design. This is shown in Table 1.

Proximate analysis of composite flour

This was carried out using Association of Official Analytical Chemists (AOAC 2000) methods in order to determine the percentages of moisture contents, protein, crude fibre, fat and carbohydrate in the flour blends.

Mineral content

Determination of Calcium, Magnesium, Zinc, and Iron were carried out using Atomic Absorption Spectrophotometer (AOAC 2000) while Potassium was determined by flame photometry method (AOAC 2000).

Functional properties of composite flour

Bulk density Bulk density was estimated as described by Maninder et al. (2007). A 50 ml measuring cylinder was filled with 50 g of the flour sample. The bottom of the cylinder was continuously tapped on the laboratory bench until there was no further reduction of the sample volume. The weight of the flour samples was taken and the bulk density was calculated as weight per unit volume of sample (g/ml) using the Eq. (1)

$$Bulk\ density = \frac{weight\ of\ sample\ (g)}{volume\ of\ sample\ (ml)} \quad (1)$$

Swelling index This was determined as the ratio of the swollen volume to the ordinary volume of a unit weight of the flour. The method of Abbey and Ibeh (1988) was used. One gram of the sample was weighed into a clean dry measuring cylinder. The volume occupied by the sample was recorded before 5 ml of distilled water was added to the sample. This was left to stand undisturbed for an hour, after which the volume was observed and recorded again. The index of swelling ability of the sample was calculated as indicated in Eq. (2)

$$Swelling\ index = \frac{volume\ occupied\ by\ sample\ after\ swelling}{volume\ of\ sample\ (ml) volumeoccupied\ by\ sample\ before\ swelling} \quad (2)$$

Water and oil absorption capacity Water and oil absorption capacities of flours were measured using centrifugation method (AOAC 2000) as indicated in Eqs. (3) and (4).

$$WAC = \frac{Weight\ of\ water\ absorbed\ (g)\ \times density\ of\ water}{Sample\ weight\ (g)} \quad (3)$$

Table 1 Experimental Design using Optimal Mixture Model of RSM for the Composite Flour

	Symbol	Coded levels	
		−1	+1
Wheat flour (%)	A	60.426	90.000
Amaranth seed flour (%)	B	5.000	30.000
Brewers' spent grain flour (%)	C	2.000	6.000
Apple pomace flour (%)	D	3.000	8.000

$$OAC = \frac{Weight\ of\ oil\ absorbed\ (g)\ \times density\ of\ water}{Sample\ weight\ (g)} \quad (4)$$

Water and oil absorption capacity were expressed as grams of water or oil bound per gram of the sample on a dry basis.

Determination of anti-oxidant activity The DPPH assay method is based on the reduction of DPPH, a stable free radical. The free radical DPPH with an odd electron gives a maximum absorption at 517 nm (purple colour). DPPH (1, 1-Diphenyl −2-picrylhydrazyl) (4.3 mg) was dissolved in 3.3 ml methanol; it was protected from light by covering the test tubes with aluminium foil. About 150 μl DPPH solution was added to 3 ml methanol and absorbance was taken immediately at 517 nm for control reading. Various concentrations of composite flour (50 μl) as well as standard compound (Ascorbic acid) were taken and the volumes were made up uniformly to 150 μl using methanol. Each of the samples was further diluted with methanol up to 3 ml and to each 150 μl DPPH was added. Absorbance was taken after 15 min. at 517 nm using methanol as blank on UV-visible spectrometer Shimadzu, UV-1601, Japan. The DPPH free radical scavenging activity was calculated using Eq. (5)

$$\%\, scavenging = \frac{(Absorbance\ of\ control - Absorbance\ of\ test\ sample)}{Absorbance\ of\ control} \times 100 \tag{5}$$

Determination of rheological properties

Pasting properties (AACC 2000)

Pasting properties were determined using the rapid visco analyser (RVA). The composite flour sample (3.5 g) was weighed and dispensed into the test canister. Distilled water (25.0 ml) was thereafter dispensed into the canister (14 % moisture basis). The visco analyser was switched on and the pasting performance of the flour was automatically recorded on the graduated sheet of the instrument.

Farinograph analysis (AACC 2000)

A flour sample of 300 g on a 14 % moisture basis was weighed and placed into the corresponding farinograph mixing bowl. Water from a burette was added to the flour and mixed to form dough. As the dough is mixed the farinograph records a curve on the graph paper. The curve was centred on the 500-Brabender unit (BU) line ±20 BU by adding the appropriate amount of water and is run until the curve leaves the 500- BU line.

Results and discussion

Result of proximate composition of flour blend

The results of the proximate analysis for the composite flour are shown in Fig. (1a, b, c, d, e, f).

Protein content

The protein content values varied from 9.9 to 11.5 g/100 g. The high protein content may be attributed to the presence of amaranth (*Amaranthus hypochondriacus)* seed (Gruss 2009). Protein is an important component that enhances the rheological properties of composite flours.

The result of the ANOVA showed that the model (quadratic) and model terms (linear mixture, AC, BC, CD) were significant ($P \le 0.05$). The 3D plots showing the effect of variables on the protein is shown in Fig. 1a. The 'R'-squared and 'Adj' R-squared values are 0.9087 and 0.8265 respectively. The final equation for the regression analysis is given in Eq. (6)

$$\begin{aligned} Protein\ &= +9.96\,A + 11.72B - 112.25\,C + 11.79D \\ &\quad + 0.085AB + 143.57AC - 10.05AD \\ &\quad + 129.58BC - 5.55BD + 187.30CD \end{aligned} \tag{6}$$

Moisture content

The result of the moisture content of the flour blends ranged from 5.2 to 9.1 g/100 g. The moisture and water activity of a product determine greatly the keeping quality of the foods (Bugusu et al. 2001). The result obtained showed that the moisture content is not too high, hence, promote the shelf life and water activity of the flour.

The result of the ANOVA showed that the model (special cubic) and model terms (linear mixture, AB, AC, AD, BC, CD, ABC, ABD, ACD, BCD) were all significant ($P \le 0.05$). This indicated that the raw materials have positive effect on the moisture. The 3D plots showing the effect of variables on the moisture is shown in Fig. 1b. The 'R'-squared and 'Adj' R-squared values are 0.7781 and 0.9999 respectively. The final equation for the regression analysis is given in Eq. (7).

$$\begin{aligned} Moisture &= +6.93A + 3.69B + 13.59C + 918.74D + 11.02AB \\ &\quad + 22.51AC - 1192.44AD + 38.80BC - 1170.36BD \\ &\quad - 10537.04CD - 257.93ABC + 781.88ABD \\ &\quad + 13012.06ACD + 13650.29BCD \end{aligned} \tag{7}$$

Fat content

The fat content of the flour blends ranged from 0.5 to 1.4 g/100 g.Fat content of flour blends are moderate when compared to 1.64 % for plantain flour (Mepba et al. 2007), 8.145 to 15.755 g/100 g for composite flour blend from rice, cassava and kersting's groundnut flour (Awolu et al. 2015) and 14.1 % for avocado seed flour ((Ifesan et al. 2015).

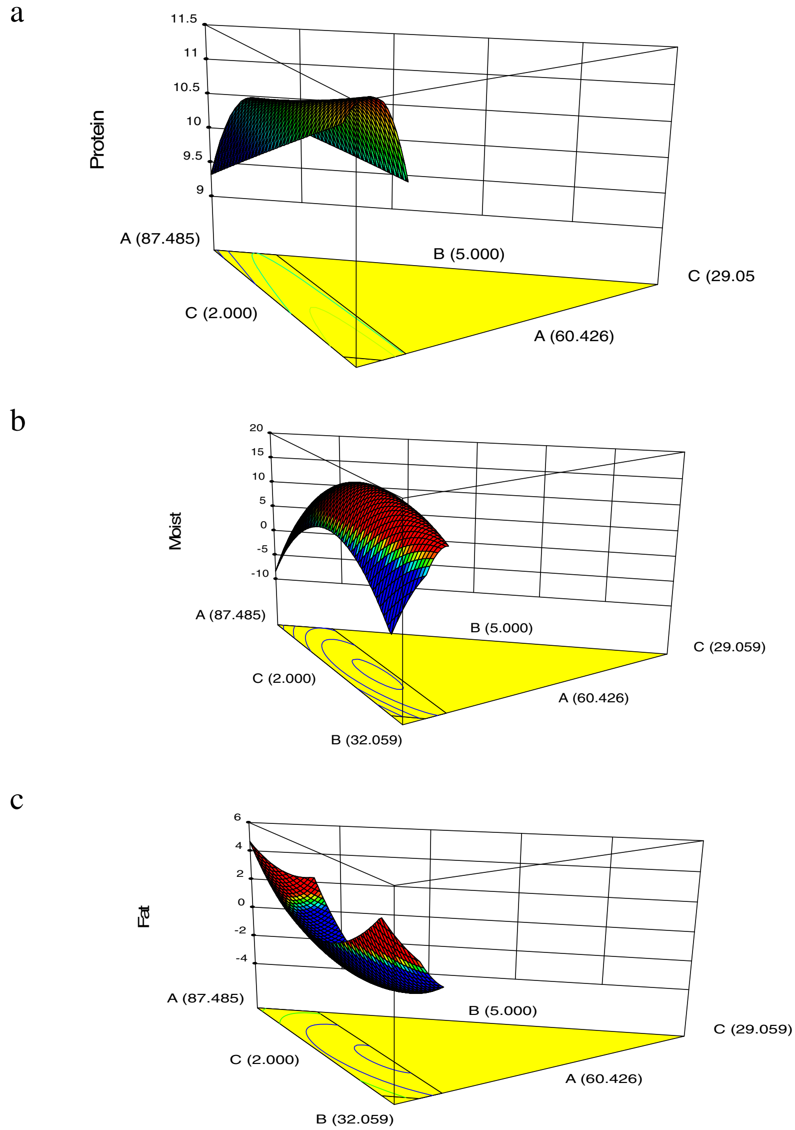

Fig. 1 **a**:3D graphical representation of the effect of composite flour on protein **b**: 3D graphical representation of the effect of composite flour on moisture **c**: 3D graphical representation of the effect of composite flour on fat **d**: 3D graphical representation of the effect of composite flour on fibre **e**:3D graphical representation of the effect of composite flour on ash **f:** 3D graphical representation of the effect of composite flour on carbohydrate

The result of the ANOVA showed that the model (special cubic) and model terms (linear mixture, AB, AC, AD, BC, BD, CD, ABD, ACD, and BCD) were significant ($P \leq 0.05$). The 3D plots showing the effect of variables on the fat content is shown in Fig. 1c. The 'R'-squared and 'Adj' R-squared values are 0.9892 and 0.9658 respectively. The final equation for the regression analysis is given in Eq. (8)

$$
\begin{aligned}
Fat = &+1.31A + 2.25B - 168.57C - 252.35D - 5.4AB + 190.07AC \\
&+ 320.90AD + 188.85BC \quad + 315.22BD + 3715.78CD \\
&+ 7.81AB - 189.90ABD - 4278.82ACD - 4634.86BCD \qquad (8)
\end{aligned}
$$

Crude fibre

The composite flour has relatively high (0.7 to 3.9 g/100 g) crude fibre content. The recommended range is less than 5 g/100 g (Omoba et al. 2013). The high fibre content is advantageous to those with gastro intestinal disorder and cardiovascular diseases as high fibre content has been associated with increased faecal weight, accelerated transit time, increase cholesterol and fat excretion (Aman et al. 1994).

The result of the ANOVA showed that the model (special cubic) and model terms (linear mixture, AD, BD, ABC, ABD) were significant ($P \leq 0.05$). The 3D plots showing the effect of variables on the crude fibre is shown in Fig. 1d. The 'R'-

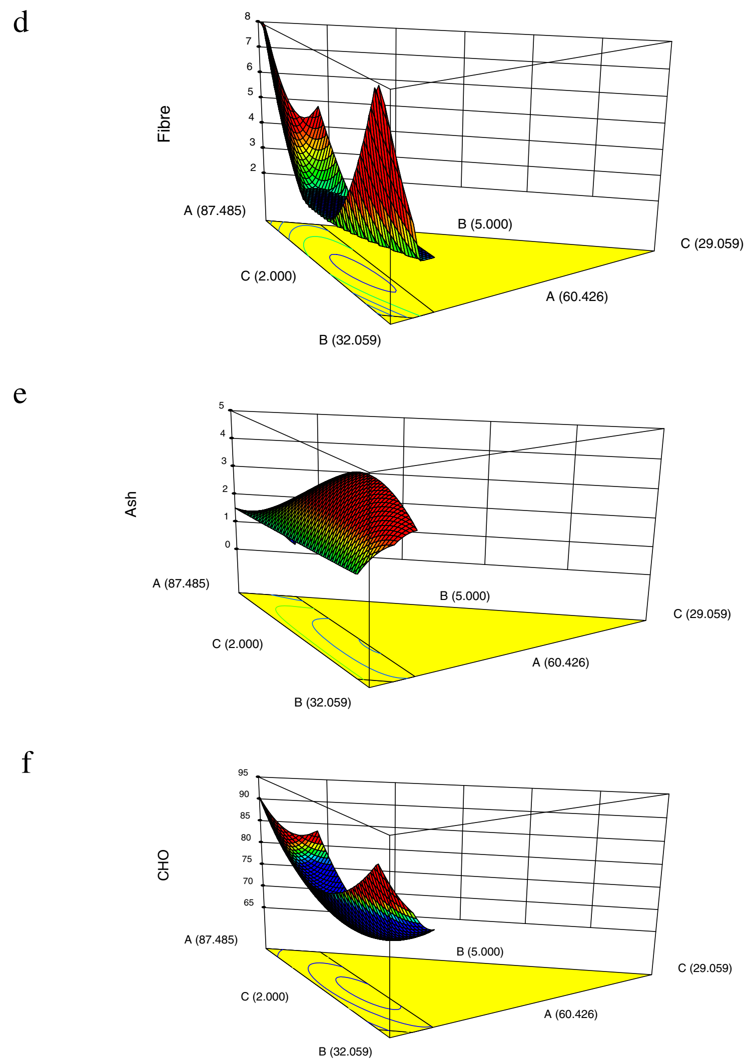

Fig. 1 (continued)

squared and 'Adj' R-squared values are 0.9892 and 0.9658 respectively. The final equation for the regression analysis is given in Eq. (9).

$$Fibre = +1.57A + 3.24B - 46.17C - 582.69D - 10.78AB + 41.28AC + 738.50AD + 33.53BC + 739.85BD + 5307.44CD + 206.33ABC - 346.10ABD - 6123.89ACD - 6634.53BCD \quad (9)$$

Ash content

The ash content of the flour blends ranged between 0.70 and 2.79 g/100 g. This will be an advantage in the preparation of weaning food formulation. The result of the ANOVA showed that the model (special cubic), linear mixture, AC, BC, CD, ABD, ACD, and BCD were significant ($P \leq 0.05$). The 3D plots showing the effect of variables on the crude fibre is shown in Fig. 1e. The 'R'-squared and 'Adj' R-squared values are 0.9856 and 0.9544 respectively. The final equation for the regression analysis is given in Eq. (10)

$$Ash = +1.06 + 2.15B + 93.86C - 4.5D - 2.09AB - 120.67AC + 12.18AD - 118.68BC + 2.34BD - 1574.40CD + 107.04ABC + 23.36ABD + 1916.13ACD + 2178.18BC \quad (10)$$

Carbohydrate

High percentage of carbohydrate content in all the flour blends (76.241–81.004 %) suggested that the blends are good source of energy. The result of the ANOVA showed that the model (special cubic) and model terms (linear mixture, AB, AD, BC, BD, CD, ABC, ABD, ACD, and BCD) were significant ($P \leq 0.05$). The 3D plots showing the effect of variables on the carbohydrate is shown in Fig. 1f. The 'R'-squared and 'Adj' R-squared values are 0.9962 and 0.9881 respectively. The final equation for the regression analysis is given in Eq. (11)

$$\begin{aligned} CHO = & +79.01A + 77.14\,B - 89.93\,C - 817.09D + 6.22AB \\ & + 102.17AC + 1128.42AD + 200.98BC + 1182.86BD \\ & + 10637.28CD + 48.70ABC - 913.17ABD - 11619.99ACD \\ & - 13951.03BCD \end{aligned} \tag{11}$$

Results of mineral analysis of composite flour

The iron content of composite flours ranged from 0.7200 to 2.57 mg/100 g; zinc (0.210–0.810 mg/100 g); potassium (30.000–73.600 mg/100 g); magnesium (7.150–10.090 mg/100 g) and calcium (4.000 to 12.900 mg/100 g). The result when compared with the work of Omoba et al. (2013) showed that the zinc, magnesium and iron contents were slightly higher while calcium and potassium were similar. In general, the mineral contents were high and desirable. The composite flour would be important in contributing to the overall daily dietary intake of essential elements especially the micronutrients.

The result of the ANOVA for calcium content showed that the model (special cubic) and model terms (linear mixture AC, AD, BC, BD, ABC, ABD, ACD, and BCD) were significant ($P \leq 0.05$). This signifies that the flour components had positive effect on calcium. The 3D plots showing the effect of variables on the calcium is shown in Fig. 2a. The 'R'-squared and 'Adj' R-squared values are 0.9990 and 0.9881 respectively. The final equation for the regression analysis is given in Eq. (12).

$$\begin{aligned} Ca = & +4.59\,A + 11.78B \\ & + 196.85C - 291.06D - 0.51AB - 276.84AC \\ & + 346.66AD - 262.93BC \\ & + 348.93BD - 1655.27\,CD \\ & + 53.44\,ABC - 182.38ABD + 3484.36ACD \\ & + 2813.52BCD \end{aligned} \tag{12}$$

The result of the ANOVA for potassium showed that the model (special cubic) and model terms (linear mixture, AB, AC, AD, BC, BD, CD, ABC, ABD, ACD, and BCD) were significant ($P \leq 0.05$), suggesting the composite flour components as good sources of potassium. The 3D plots showing the effect of variables on the potassium is shown in Fig. 2b. The 'R'-squared and 'Adj' R-squared values are 0.9997 and 0.9990 respectively. The final equation for the regression analysis is given in Eq. (13).

$$\begin{aligned} K = & 42.34A + 77.51B - 1789.27\,C - 7344.25D - 72.43AB \\ & + 1607.29AC + 9316.96AD + 1904.06BC \\ & + 9233.98BD + 74728.48CD + 388.38ABC \\ & - 5034.14ABD - 81175.83ACD - 91471.43BCD \end{aligned} \tag{13}$$

The result of the ANOVA for iron showed that the model (special cubic) and model terms (linear mixture, AB, AC, AD, BC, BD, CD, ACD, and BCD) were significant ($P \leq 0.05$), indicating the flour components to be good sources of iron. The 3D plots showing the effect of variables on the iron is shown in Fig. 2c. The 'R'-squared and 'Adj' R-squared values are 0.9988 and 0.9963 respectively. The final equation for the regression analysis is given in Eq. (14).

$$\begin{aligned} Fe = & +1.10A + 2.04B + 96.93C - 54.52D \\ & + 2.47AB - 130.99AC + 65.20AD - 115.56BC \\ & + 65.45BD - 728.68CD \\ & + 7.12ABC - 30.25ABD + 1176.91ACD \\ & + 1018.99BCD \end{aligned} \tag{14}$$

The result of the ANOVA for magnesium showed that the model (special cubic) and model terms (linear mixture, AB, AD, BD, CD, ABC, ABD, ACD and BDC) are significant ($P \leq 0.05$). The 3D plots showing the effect of variables on magnesium is shown in Fig. 2d. The 'R'-squared and 'Adj' R-squared values are 0.9991 and 0.9971 respectively. The final equation for the regression analysis is given in Eq. (15).

$$\begin{aligned} Mg = & +7.79A + 10.63B + 9.55\,C - 214.48\,D - 3.91AB - 21.52AC \\ & + 270.97AD - 18.70BC + 265.10BD + 1124.97CD \\ & + 17.81ABC - 75.98ABD - 960.29ACD - 1167.99BCD \end{aligned} \tag{15}$$

The result of the ANOVA for Zinc showed that only the model (special cubic) and model terms (linear

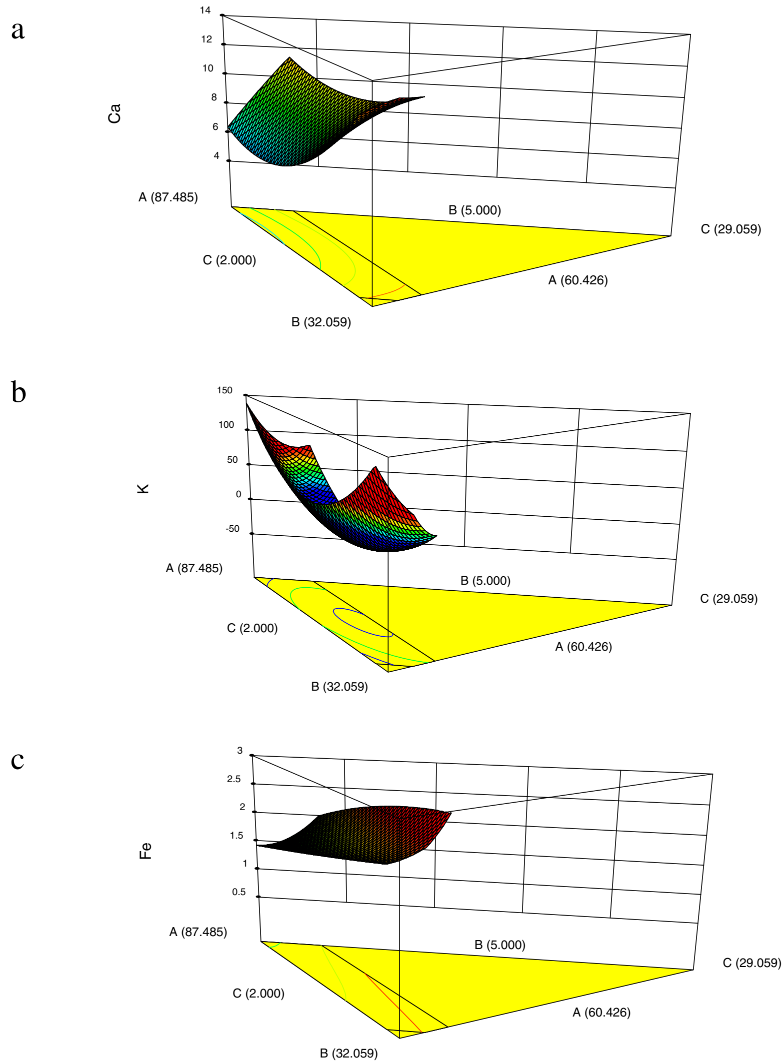

Fig. 2 **a**: 3D graphical representation of the effect of composite flour on calcium **b**: 3D graphical representation of the effect of composite flour on potassium **c**: 3D graphical representation of the effect of composite flour on iron **d**: 3D surface graphical representation of the effect of composite flour on Magnesium **e**: 3D graphical representation of the effect of composite flour on zinc

mixture) are significant ($P\leq0.05$). The implication is that the composite flour components are not good sources of zinc. The 3D plots showing the effect of variables on the potassium is shown in Fig. 2e. The 'R'-squared and 'Adj' R-squared values are 0.9997 and 0.9990 respectively. The final equation for the regression analysis is given in Eq. (16).

$$\begin{aligned} Zn = &+0.36A + 0.60B + 17.15C - 14.18D \\ &+ 0.52AB - 25.48AC + 16.19AD - 20.71BC \\ &+ 16.92\,BD - 214.68\,CD - 0.032\,ABC - 9.83ABD \\ &+ 378.94\,ACD + 314.32\,BCD \end{aligned} \tag{16}$$

Optimized blends based on the proximate and mineral analyses

The results of the best three blends based on the proximate and mineral analyses are shown in Tables (2) and (3).

Functional properties of optimized flour blend

The results of the functional properties for runs 11 and 19 are presented in Table (4). The WAC of the flours (Run 19) and (Run 11) were 1.80±0.00 and 1.60± 0.05 g/g respectively. A low WAC has been explained to be as a result of high protein and fat content in flours (Compaoré et al. 2011). In contrast, high carbohydrate contents in flours increases its WAC due to its

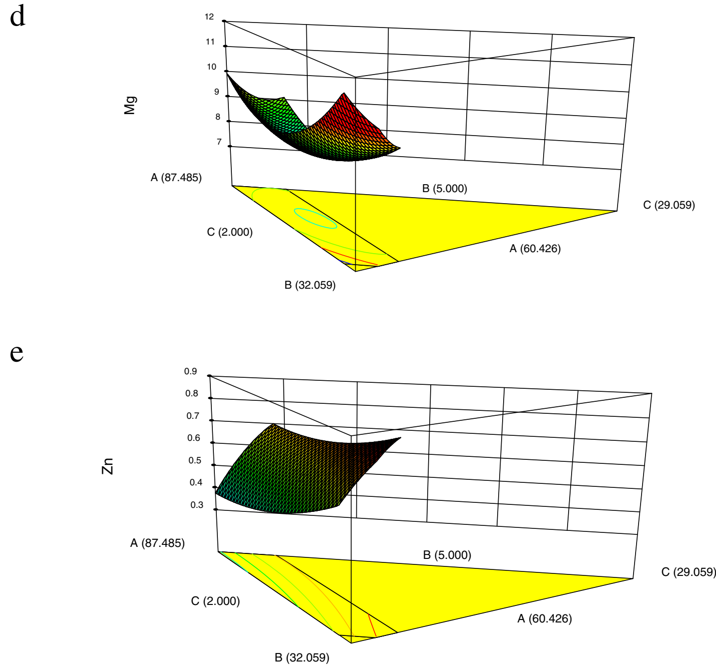

Fig. 2 (continued)

hydrophilic constituents which enable it to bind more water (Mbaeyi 2005).

The OAC of the optimized flour blends; Run 19 and Run 11 were 1.56±0.01 and 1.23±0.04 g/g respectively. High OAC indicates the enhanced hydrophobic character of proteins in the flours. Oil absorption capacity is exhibited by the proteins in the flour which physically bind to fat by capillary attraction. These proteins expose more non-polar amino acids to the fat and enhance hydrophobicity as a result of which flours absorb oil. OAC play a significant role in ground meat formulations like sausages and to increase the shelf life of meat products (Akinyede and Amoo 2009). Therefore, Run 19 flour with comparatively higher OAC may be favourable in food formulations where an improvement in oil absorption capacity is required.

The bulk density of a good material is important in relation to its packaging. The bulk density of Run 11 was lower than Run 19.

Swelling capacity is important in manufacturing and maintaining structure of different food products like bakery products during and after processing. The ability of the flours to swell depends on the presence of the flexible protein molecules which may decrease the surface tension of water (Sathe et al. 1982). There is no significance difference ($p \leq 0.05$) between runs 19 and 11.

Radical scavenging capacity

The DPPH radical scavenging capacity of Run 19 is 49.84 % while that of Run 11 is 59.89 %. Natural antioxidants have been found to be effective in enhancing the shelf life of bakery products (Nanditha and Prabhasankar 2009). It has the unique properties of enhancing shelf life of food products without any change in sensory or

Table 2 Proximate Composition of the Optimum Composite Flour

Run	A	B	C	D	Ash	Moisture	Fat	Crude fibre	Protein	CHO
11	65	30	2	3	1.705	5.629	1.395	1.567	11.462	78.241
13	60.426	29.679	4.110	5.785	2.795	6.642	1.085	3.087	11.375	79.191
19	81.943	6.752	3.386	7.920	1.487	7.274	1.133	1.462	10.062	78.579

* Wheat flour (A), Amaranth (B), BSG (C), and Apple pomace (D)

Table 3 Mineral Composition of the Optimum Composite Flour

Run	A	B	C	D	Ca	K	Mg	Zn	Fe
11	65.000	30.000	2.000	3.000	10.600	62.600	9.680	0.630	2.220
13	60.426	29.679	4.110	5.785	12.900	73.600	10.090	0.810	2.570
19	81.943	6.752	3.386	7.920	7.000	50.000	7.790	0.510	1.510

* Wheat flour (A), Amaranth (B), BSG (C), and Apple pomace (D)

nutritional qualities (Rajalakshmi and Narasimhan 1996). The demand for natural antioxidants has increased because of the long-term safety and negative perception of synthetic antioxidants. In addition to improving food quality and stability, natural antioxidants also act as nutraceuticals to scavenge free radical chain reactions in biological systems and therefore provide additional health benefits to their performance as functional foods (Rajalakshmi and Narasimhan 1996).

Rheological properties of optimized blend

Pasting properties

The results of pasting properties of Runs 11 and 19 are shown in Table 5. The peak viscosity of the optimized flour for Runs 19 and 11 were 2864 RVU and 2471 RVU respectively. Peak viscosity indicates the maximum swelling capacity of starch granules. The early onset of initial viscosity is attributed to the detection of the first stage of swelling and is dependent on media viscosity rather than the swelling of the starch granules (Christianson et al. 1981). With continuous heating of the paste, the starch granules rupture, resulting in a reduction in viscosity. Breakdown is a parameter that measures the ease with which the swollen granules can be disintegrated (Singh et al. 2005). The lower breakdown value of Run 11 (845 RVU) compared to Run19 (1240 RVU) may be due to the restricted swelling of the starch granules. An increase in the final viscosity of Run 19 flour blend (3437 RVU) was observed. The lower value of final viscosity in Run 11 (3437 RVU) indicated that the sample has a reduced ability to form a viscous paste compared with the other. In addition, Run 11 flour blend demonstrated a reduced setback (1811 RVU) during cooling. Run 19 was found to be highly retrograded (1827 RVU), which may be explained by the effect of amylose and amylopectin contents. According to Nimsung et al. (2007), starch with low levels of amylose could undergo a reduced retro-gradation process than the starch with high levels of amylase.

Table 4 Functional Properties of Optimum Blends

Functional property	Run 19	Run 11
WAC (g/g)	1.80^{a}±0.0	1.6^{b}±0.05
OAC (g/g)	1.56^{a}±0.01	1.23^{b}±0.04
BD (g/ml)	0.895^{a}±0.01	0.83^{a}±0.0
SC (ml)	14.00^{a}±0.01	13.00^{a}±0.02

* Run 19: 81.44 % wheat, 6.75 % amaranth, 3.39 % BSG and 7.92 % apple pomace; Run 11: 65.00 % wheat, 30.00 % amaranth, 2.00 % BSG and 3.00 % apple pomace

* (*WAC* Water absorption capacity; *OAC* Oil absorption capacity; *SC* Swelling capacity; *BD* Bulk density)

Farinograph

The result of farinograph analysis shown in Fig. 3a and b showed variation in the water absorption of the optimized blends. Run 19 showed a water absorption value of 66.6 % and Run 11 had a water absorption value of 61.80 %. These results were similar to 57 to 62 % obtained by Mutwali (2011) for sudanese wheat cultivars grown in three different locations. Optimum water

Table 5 Pasting Properties of Optimized Flour Blends

Property	Run 19 (RVU)	Run 11 (RVU)
Peak viscosity	2864	2471
Trough	1624	1626
Breakdown	1240	845
Setback	1827	1811
Final Viscosity	3451	3437

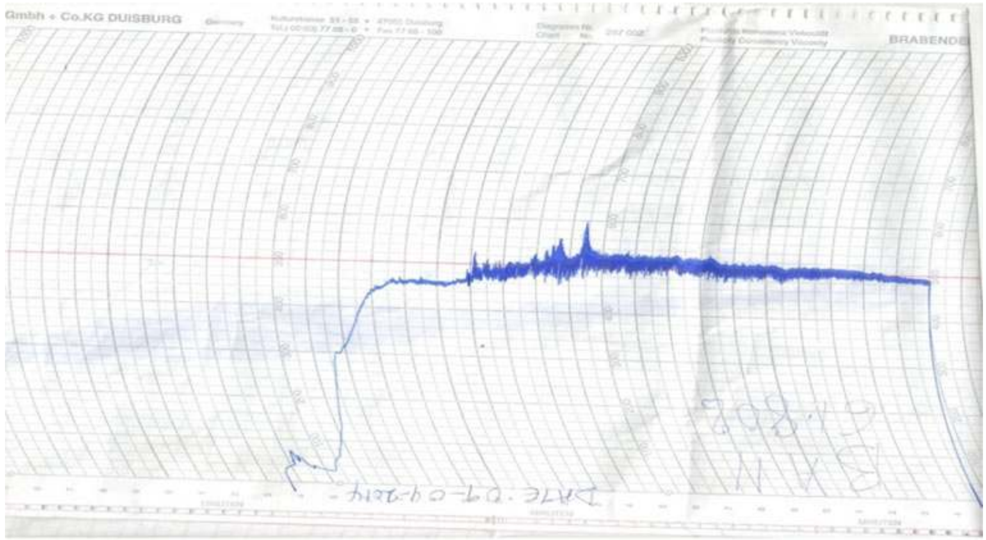

Fig. 3 Farinograph plot of flour blend (Run 11)

absorption for bread making ranged between 50 and 64 % (Mailhot and Patton 1988). In general, high water absorption means good baking performance (Zecevic et al. 2013). It is considered that high protein quantity provides both high water absorption and good baking performance (Bloksma 1990; Basaran and Göçmen 2003) Fig. 4.

Run 19 had the highest Dough Development Time (12 mins) while Run 11 had lowest (10.5 mins). Dough development time depends on the water absorption speed of flour constituents to form a smooth and homogenous appearance. Dough stability time was 12.5 mins for Run 11 and 16.5 mins for Run 19 blend. Malihot and Patton (1998) recommended a minimum dough stability of 7.5 mins for bread making. Strong wheat has a higher water absorption, good extensibility, longer dough development time and stability.

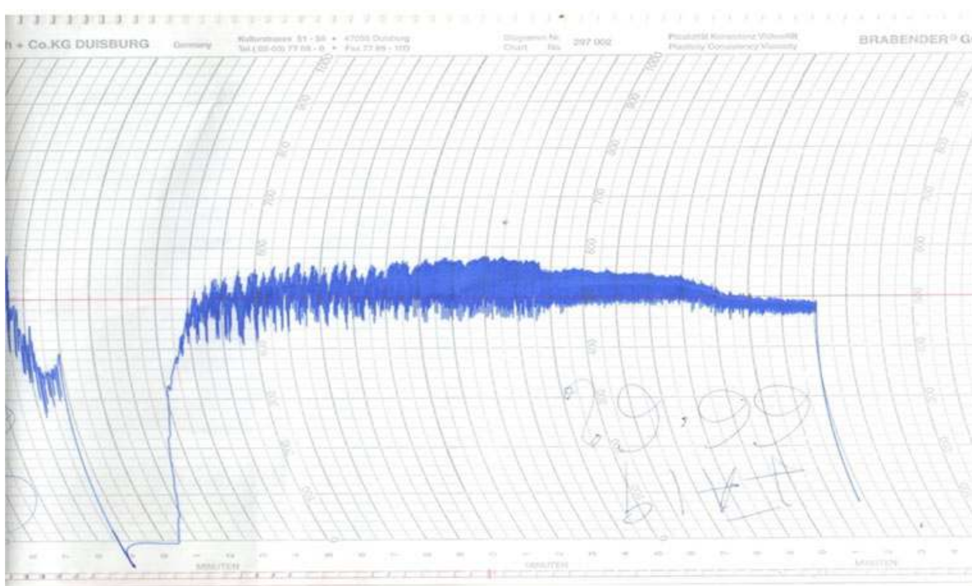

Fig. 4 Farinograph plot of flour blend (Run 19)

Conclusion

Functional wheat based composite flour comprising amaranth, brewers' spent grain and apple pomace were developed. The results of the proximate analysis, minerals analysis and antioxidant properties showed a composite flour with good nutritional and functional properties. The functional and rheological properties showed a good compliant to flour properties. The use of optimal mixture model of response surface methodology assisted in obtaining optimum flour combinations in terms of the quality characteristics, nutritional evaluations and rheological properties. Overall, run 19 (81.44 % wheat, 6.75 % amaranth, 3.39 % BSG and 7.92 % apple pomace) was the best in terms of all the properties considered followed by Run 11 (65.00 % wheat, 30.00 % amaranth, 2.00 % BSG and 3.00 % apple pomace).

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