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Full Length Research Paper

Value added product development and quality characterization of amaranth (*Amaranthus caudatus* L.) grown in East Africa

Shimelis Admassu Emire[1] and Martha Arega[2]

[1]Food Engineering Program, Department of Chemical Engineering, Addis Ababa Institute of Technology, Addis Ababa University, Ethiopia
[2] Ministry of Trade and Industry, Agro-Processing Department, Addis Ababa, Ethiopia

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Amaranth has important role in actions against hunger and malnutrition that occur due to low rain fall conditions. The aim of this study was to investigate the development of value added product from blends of amaranth flour with wheat flour and quality characterization of composite flours. A chemical composition, physico-chemical characteristics, farinographic profiles and sensory quality were investigated to characterize blends and value added food products. It was found that protein, fat, ash, iron, zinc, phosphorous and calcium contents in the blends increased significantly with an increase in amaranth substitution. The amaranth flour substitution of 5 to 30% increased water absorption and quality of the dough. It also increased dough development time from 3.5 to 5 minutes, but decreased the dough stability time from 5.6 to 2 min. Gluten content of the blend flours containing 5-10% amaranth were within the recommended range for standard bread production. It was concluded that the flour blends containing up to 10% of amaranth and baked at 220°C for 18min can be used in industrial bread production. The substitution of wheat flour with amaranth one can contribute to improvement of food security and production of various gluten-free value added products.

Keywords: Composite flour, grain amaranth, quality characterization, rheological properties, sensory characteristics, value added product.

INTRODUCTION

Amaranth is easy to grow, nutrient rich and underutilized pseudo cereal that can play an important role in actions against hunger and malnutrition that occur due to low rainfall conditions. Amaranths are broad-leafed non-grass plants that produce significant amounts of edible cereal-like grains. Amaranth (family *Amaranthaceae*) is an under-exploited plant with an exceptional nutritive value. A grain amaranth is very versatile as a food ingredient and can diversify farming enterprise; as it can be expected to prevent food depletion and to feed the world (Saunders and Becker 1984). Amaranth grows rapidly and has a high tolerance to arid conditions and poor soils where traditional cereals cannot be grown. Amaranth has been touted as a miracle grain, a super grain, and the grain of the future (Samuel, 1991; Evgeny, 2001). The main species are *Amaranthus caudatus* (L.), *Amaranthus cruentus* (L.) and *Amaranthus hypochondriacus*(L.). *Amaranthus caudatus* (L.) has long been grown as a food crop in Ecuador, Peru, Bolivia and Argentina. *Amaranthus caudatus* (L.)has also been grown in East Africa (Ethiopia, Kenya, Eritrea, Uganda) as grain and vegetable crops (Teutonico and Knorr, 1985; Willinams and Brenner, 1995). The seeds, although barely bigger than a *tef* seed (0.9-1.0 mm in diameter), occur in massive numbers to a plant and are pale-white, golden, pink, red or dark-brown colored (Melaku and Kelbessa, 2005).

Amaranth with an excellent seed quality and the greatest potential for use as a food ingredient is now grown as a grain crop in such widely scattered regions as the mountains of Ethiopia, the hills of South India, the Nepal Himalaya, and the plains of Mongolia (Agong,

*Corresponding Author E-mail: shimelisemire@yahoo.com

2006). Amaranth seeds with their phenomenal nutritional profile provide several important nutrients that are often difficult to incorporate into a restrictive diet. The seeds contain large amounts of dietary fiber, iron, and calcium. They also have high amounts of lysine, methionine and cysteine, combined with a fine balance of amino acids, making them an excellent source of high quality, balanced protein, which is more complete than the protein found in most grains. In addition to its outstanding nutritional value, amaranth is also very low in sodium and contains no saturated fat (Garuda, 2004).

Amaranths are being used in breakfast food, bakery products, gluten-free foods and extruded foods. For making a leavened food, they must be blended with wheat (Elizabeth, 2010). Amaranth meal, or flour, is especially suitable for where it can be used as a sole, or predominant, cereal ingredient. Grains are toasted and popped, ground into flour, or boiled for gruel. The flour is used in Latin America and in the Himalayas to produce a variety of flat breads (tortillas and chapattis). The leaves can be used as a tasty leafy vegetable meal, often preferred to spinach by some people (Teutonico and Knorr, 1985).

Amaranth has various health benefits and medicinal properties including those which are very useful in preventing a retarded growth in children, increase the flow of breast milk, valuable in preventing a premature old age, important in all bleeding tendencies, beneficial in treatment of leucorrhoea, considered highly beneficial in treatment of gonorrhea and benefits patients with cardiovascular disease (Getahun, 1976; Home remedies, 2008). In South America grain amaranths are traditionally used in medicine, folk festivals, and as dye sources. In Ethiopia the root is used as a laxative, and the seed for expelling tapeworms and for treating eye diseases, amoebic dysentery, and breast complaints. In India the plant is taken as a diuretic and is applied to sores (Agong, 2006).

In East African countries and Peru *Amaranthus caudatus* leaves are boiled and consumed as vegetable like those of other amaranth species. Seeds are used as food in Konso (South Western part of Ethiopia) while young branches of a stalk are eaten in South Omo by the Ari people (Bink and Belay, 2006). The seeds are also used for preparation of local beverage known as '*Chaqa'* in Konso. In Ethiopia cooked seeds are added into porridge, and ground seeds are mixed with *tef* to prepare pancake-like bread (*injera*). The plant is very common and semi-domesticated on farm fields in Konso and South Omo. Some farmers have started to cultivate and intercrop the species on their farm fields near their homestead. The Konso people calls amaranth *passa*. The name varies from place to place in Ethiopia. It is also called *lishalisho*, *Aluma* and *Ferenjitef* in Amharic; *Iyaso* and *Jolili* in Oromifa; *Zapina* in Arigna and *Gegabsa* in Wolayita (Getahun, 1976). In Guraferda, Jimma, the people use amaranth to make alcoholic drink named *borde*, unleavened bread called '*kita*' or prepare a thin porridge '*atmit*' for babies and mothers who recently gave birth.

Easy-to-grow nutrient rich foods such as amaranth can help improve food security and reduce malnutrition among communities that heavily depend on subsistence agriculture specifically in the African context. In this regard, production of value-added food product from under-utilized raw material is the way to reward the valuable nutrients to the society by changing the amaranth into value added food products. The current study has significant contribution towards encouragement of amaranth cultivation via creating a value-chain on production of amaranth-based value-added products which, in turn can contribute to food security and improvement of nutritional quality. Although distribution of amaranth species used as cereal grains and product development with ancient grain has been reported for several countries, no such investigation has been conducted in East African countries. Owning to the scarcity of information on amaranth-containing composite flours and their rheological properties; the present study provides useful information on practical application for the formulation of value added products.

The purpose of the present work was therefore to develop value added food product from blends of amaranth-wheat flour and characterize amaranth flour and blends. Quality characterization includes nutrients composition, rheological properties (i.e. farinographic qualities), gluten content and sensory quality.

MATERIALS AND METHODS

Source of materials, collection, sample preparation and storage

The grains of *Amaranthus caudatus* with pale-white color were purchased from Jimma, Bench- Maji Zone of Ethiopia in a local market in Guraferda. The wheat flour was obtained from the Kality Food Share Company, Addis Ababa. The grains were cleaned to remove stones, dust, light materials, and broken, undersized and immature grains. Experimental materials were ground to flour using a cyclone mill (Tecator AB, Haganas, Sweden) to pass a 0.5mm mesh screen. The milled samples were then packed in polyethylene bags and stored at 4^oC until analysis. The flour blend formulations were prepared by substituting 5, 10, 15, 20 and 30% of the wheat flour with the amaranth flour according to the method described by Naofumi et al. (1999).

Development of value added food product

Amaranth-wheat based breads were processed, with various blend formulations following the commercial bread processing technology applied at the Kality Food Share Company located in Addis Ababa. The breads were baked in an electric oven (G.P.A Orlandi, Italy) at different times (18min, 21min and 24min) and temperatures (210, 220 and 230^{o}C). These values of the time and the temperature were chosen based on the baking practice applied by the company adopted by Patel et al.(2005). The breads were cooled and then used in various analyses.

Methods of analysis

Physicochemical, minerals and rheological properties

A falling number was measured according to the ICC (2000) Standard No.107/1 using the Perten Falling Number Instrument (Perten model 1500, Sweden). A colour intensity of the flour and the bread was measured using the Kent Innes Colour Grade equipment (SATAKE Colorimeter, Belgium). The flour was tested for gluten using the ICC (2000) Standard No. 137/1. A dough raising capacity (DRC) was measured according to the ICC (2000) standard method.

About 100 g of flour, 1.5g yeast, 2.5g sugar and 53ml water was mixed in a test tube and an initial height of the dough was measured. The dough was placed in the oven set at 40^{o}C and allowed to rise for 75min. The final height was measured and the dough raising capacity was calculated (as percent) from the following formula:

$$DRC = \frac{Height\ of\ dough\ final - Height\ of\ dough\ initial}{Height\ of\ dough\ initial} \times 100\%$$

Equation (1)

Where DRC- Dough raising capacity in %

Minerals concentration (calcium, iron and zinc) were determined using an atomic absorption spectrophotometer (Varian Spectra A10/20 Plus, Varian Australia Pty., Ltd.) following the method of Osborne and Vooget (1978). Total phosphorus was measured colorimetrically by the method of Fiske and Subbarrow (1925). A farinograph (physical dough-testing machine) was used to measure the rheological properties (mixing characteristics of dough during processing, baking performance) of flour for selecting the suitable flours for different bakery products. A farinographic performance (rheological properties) was measured according to ICC Standard No.115/1 (1998) by the Brabender Farinograph-E Version 2.5.12 equipment and results were obtained as graphic output (farinograms).

Proximate chemical composition

Proximate chemical composition analysis of the flour and bread included measurement of moisture, total ash, crude protein(N x 6.25), crude fiber and crude fat content, and was performed according to the AOAC (2000) official methods 925.09,923.03,979.09,962.09 and 4.5.01; respectively. Total carbohydrates excluding crude fiber were calculated by difference.

The energy values in kJ of the flour and bread were calculated by multiplying the percentage of crude protein, crude fat and carbohydrates by the energy values for gross nutrients conversion factors 16.76, 37.71 and 15.71; respectively. The energy value for 1g of the three groups of nutrients which provide the body energy were calculated by using the specific values of water factors for protein, fat and total carbohydrates; as recommended by Birch et al.(1980).

Determination of antinutrients

Tannins were assayed according to the Vanillin-HCl Method of Price et al.(1978) and phytic acid in amaranth was measured using the method of Haug and Lantzsch (1983).

Sensory quality evaluation

Nine trained panelists participated in bread sensory analysis to conduct acceptability test for breads' crust color and texture, crumb color and texture, taste and flavor using five points hedonic scale. The tests were conducted in a test laboratory of the Kality Food Share Company where the company conducts panel tests for various added value products.

Statistical analysis

Data were summarized and analyzed using SAS (version 9.1, SAS Institute, Cary, NC) statistical software. Data obtained were subjected to generalized linear model procedure; and the means were separated using analysis of variance (ANOVA) and Tukey's studentized range test (95% confidence interval) to determine whether there were significant differences between the samples. Results were expressed as mean ± standard deviation (SD) of three separate determinations.

RESULTS AND DISCUSSION

Proximate chemical composition of amaranth and wheat flours

The flour analysis showed that the amaranth had 7.49% fat and 14.19% protein which were better than the wheat flour that had 1.33% and 9.41% fat and protein contents; respectively (Table 1). The amaranth contained less

Table 1. Proximate chemical composition of amaranth and wheat whole grain

Grain type	Fat (%)	Protein (%)	Ash (%)	Crude fiber (%)	Phytate (mg/100g)	Tannin (mg/100g)	Moisture (%)	CHO (%)	Energy value (kJ/100g)
Wheat	1.33 ±0.02	9.41 ±0.06	0.57 ±0.01	11.52 ±0.05	41.85 ±0.14	BDL	13.63 ±0.06	24.94 ±0.12	599.67 ±0.24
Amaranth	7.49 ±0.03	14.19 ±0.08	2.39 ±0.02	5.81 ±0.03	237.75 ±0.09	1.49 ±0.01	9.60 ±0.04	33.67 ±0.14	1049.23 ±0.32

All values are means ± SD at P< 0.05; CHO-Total carbohydrates excluding crude fiber

BDL-Below detectable limit.

Table 2. Mineral composition and physicochemical characteristics of amaranth and wheat flours

Grain type	Fe (mg/100g)	Zn (mg/100g)	Ca (mg/100g)	P (mg/100g)	Falling No. (s)	Wet gluten (%)	Color	DRC (%)
Wheat	2.28 ±0.01	0.94 ±0.02	18.99 ±0.07	28.00 ±0.09	239.33 ±0.22	28.77 ±0.07	2.73 ±0.02	72.95 ±0.14
Amaranth	13.73 ±0.03	4.23 ±0.05	76.18 ±0.12	565.00 ±0.32	61.67 ±0.13	0.00	18.39 ±0.02	Nil

All values are means ± SD at P< 0.05 DRC: Dough raising capacity

crude fiber than the wheat flour. However, Breen (1991) and Vitali et al (2010) showed that amaranth has higher fiber content than wheat. Rita & Dietrich (2006) reported that amaranth has twice as much fiber as corn and oats, and three times as much as wheat. According to the results obtained, wholegrain amaranth flour has a considerably higher ash (2.39%) content than wheat (0.57%) flour tested, and thus amaranth substitution has the potential to improve the nutritive value of leavened products, besides other favorable nutritional claims. The reason for differences could be related to the type of amaranth used in the studies. Unlike the findings of other studies, the phytate content of amaranth was higher than that of wheat. Amaranth flour had a very minimal amount of tannin which is consistent with data obtained by Lorenz and Wright (1984). Calorific value for amaranth was higher compared to wheat grain (599.67 kJ/100g). In general, the proximate chemical composition analysis results indicate the potential of amaranth flour to substitute wheat flour in production of bread.

Mineral composition and physico-chemical properties of amaranth and wheat flours

Amaranth flour contained 13.73 mg iron/100g, 4.23 mg zinc/100g and 76.18 mg calcium/100g (Table 2). These exceeded the iron, zinc and calcium contents of wheat by 11.45, 3.74, 57.19 mg/100g; respectively. The most abundant mineral among the investigated elements was calcium. Bressani et al. (1987), Rathod & Udipi (1991) reported that amaranth is an excellent source of calcium, iron, and magnesium. The contents of investigated minerals (Ca, Mg, Fe) were consistent with the data obtained by (Vitali et al, 2010) in similar types of samples of amaranths. The mineral contents in the amaranth

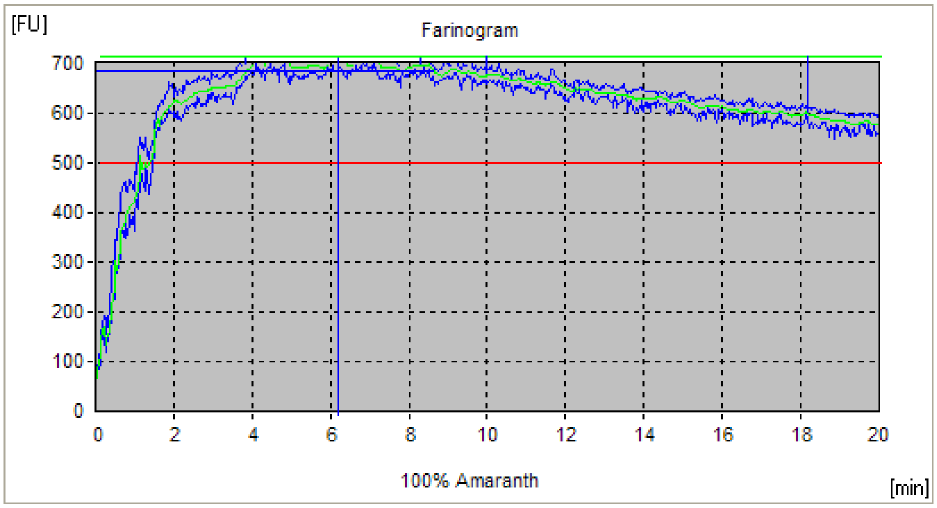

Figure 1. farinogram of amaranth flour

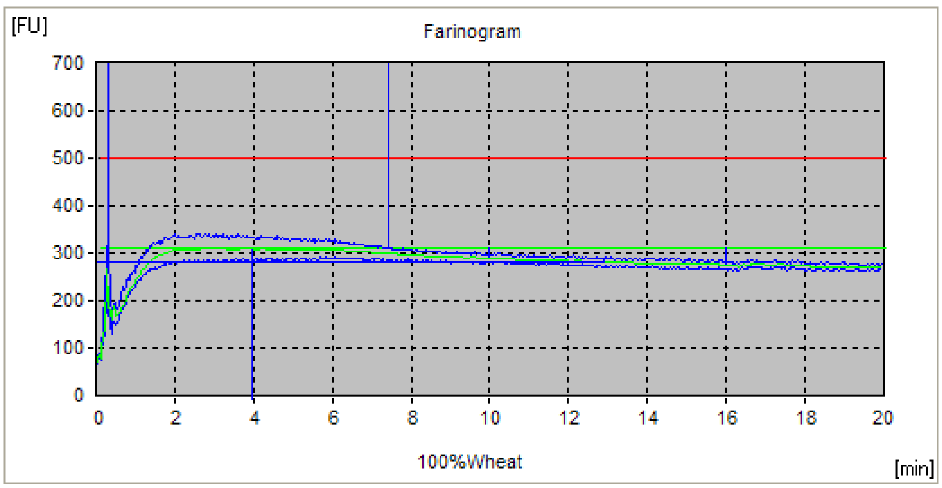

Figure 2. farinogram of wheat flour

seeds obtained in this study were higher that those found in the wheat seeds.

However, the physical properties of amaranth such as falling number and gluten contents were very low as compared to those for the wheat flour. Additionally, dough raising capacity was nil due to the absence of a wet gluten in the amaranth flour. The results on physicochemical properties of the amaranth flour clearly revealed that production of high quality baked products such as bread and biscuit from amaranth flour alone is theoretical impossible. However, incorporation of amaranth in to wheat flour has the potential to enrich the final product, especially in bread and infant food preparations.

Farinograph quality of amaranth flour and wheat flour

Farinographic analysis output showed that the wheat had higher moisture content, dough stability and a farinographic quality where as the amaranth scored higher in a dough consistency, water absorption, dough development time and degree of softening.

The farinogram of amaranth resembled that of weak gluten flour and this was due to its gluten free nature (Fig.1). The farinogram of the wheat resembled that of strong gluten flour (Fig. 2).

Farinographic qualities of amaranth and wheat flours are illustrated in Figs.1and 2.

Quality characterization of blended flours

Physicochemical characteristics of flours

The investigation of the wheat-amaranth flour blend quality characteristics included the physical characteristics such as falling number, wet gluten, dough

Table 3. Falling number, wet gluten, DRC, color moisture contents for amaranth, wheat and blend flours

Samples	Falling number (s)	Wet gluten (%)	DRC (%)	Color	Moisture content (%)
Wheat	239.33±2.20	28.77±0.30	72.95±2.30	2.73±0.07	13.63±0.05
5%A95%W	218±4.50	28.33±0.14	69.68±0.80	4.46±0.40	13.43±0.52
10%A90%W	214±1.70	28.00±0.10	66.63±1.53	6.22±0.11	12.81±0.20
15%A85%W	215±2.60	26.57±0.14	62.73±1.36	7.27±0.04	12.77±0.16
20%A80%W	213±2.50	24.33±0.15	53.08±1.36	8.85±0.04	12.40±0.17
25%A75%W	204.00±1.70	18.83±0.12	48.99±1.00	10.17±0.07	12.13±0.13
30%A70%W	203.33±2.30	16.37±0.11	39.83±1.51	11.04±0.23	11.93±0.21
Amaranth	61.67±1.30	**Nil**	**Nil**	18.39±0.02	9.60±0.05

All values are means ± SD at *P*<0.05.
Where: A-Amaranth, W-Wheat, DRC: Dough raising capacity

raising capacity and flour color. The falling number was the time (in sec) required to stir and allow a viscometer stirrer fall a measured distance through a hot aqueous flour undergoing liquefaction due to alpha amylase activity. According to Tukey's studentized range tests, each of pure wheat and amaranth flours are significantly (p<0.05) different with other flours in their falling number values. The wheat flour had the highest value of falling number (239s) while amaranth had the lowest (61.67s) (Table 3). This falling number indicated the amount of sprout damage that has occurred in wheat grain. Brain (2005) reported that a falling number value of 350s or higher indicated a low enzyme activity and very sound flour. With an increase in amount of enzyme activity, the falling number decreases. The values below 200s indicate the high level of enzyme activity (German, 2006). As the percentage of amaranth flour increased in the flour mix, the falling number got lowered indicating presence of high amount of enzyme activity in amaranth flour under experimentation. Results obtained in current study are in agreement with the findings of Grobelnik et al. (2009).

A SAS analysis revealed that all experimental flours were significantly (p<0.05) different in their wet gluten content. Wheat flour had the highest gluten content while amaranth flour had none. The gluten content decreased as amount of amaranth increased in the flour mix. This was due to the dilution effect caused by gluten free amaranth flour. However, the gluten contents of the wheat flour, 5% and 10% amaranth flour fell within the average recommended gluten content range (28-35%) which corresponds to a gluten content of hard wheat flour. The blended flour containing15 and 20% amaranth flour had gluten content lower than the average recommended range by 5 and 13%.

Samples containing 20%-100% amaranth flour showed significant difference in dough raising capacity from the rest of the flours. The DRC lowered as the percentage of amaranth increased. Wheat flour and 5% amaranth flour were not significantly different. Also, 10% and 15% flours were not significantly different in their DRC performances. A 100% amaranth had 0% DRC which was due to its gluten free nature.

A statistical analysis revealed that all flours were significantly (p<0.05) different in their appearance with respect to their color. The intensity of color increased as the amaranth percent increased in the flour mix. The wheat flour with color value of 2.73 was much lighter than the amaranth flour color value 18.39. Results showed that none of the flours fall in the recommended bread flour color value which is less than 2.5. All blended flours had moisture content that categorized within the range set by the Ethiopian Standard ES1052:2005. The moisture content decreased as the amount of amaranth increased from 5% to 30%. This could have been associated with a low moisture content of amaranth flour as compared to the wheat flour.

Proximate chemical composition and mineral contents

The blended flour showed an increase in iron, zinc and calcium contents as amount of amaranth substitution in wheat flour increased. This was due to the significant higher mineral contents of amaranth than wheat; as indicated in Tables 2 and 4. Since amaranth is rich in essential minerals; hence its inclusion to wheat enriches the blend with minerals and proximate chemical composition.

Only samples containing 5-15% amaranth were analyzed for proximate composition since the results of gluten, color and falling number analysis indicated that substitution of wheat with amaranth beyond 15% is impossible for the purpose of bread production.

Table 4. Proximate chemical composition and mineral contents of amaranth-wheat composite flours

Composite Flour Samples	Protein (%)	Crude fat (%)	Crude fiber (%)	Phytate (mg/100g)	Tannins (mg/100g)	Ash (%)	Iron (mg/100g)	Zinc (mg/100g)	Calcium (mg/100g)
5%A95%W	10.21 ±0.05	1.78 ±0.00	2.22 ±0.01	47.11 ±0.15	**BDL**	0.58 ±0.00	2.41 ±0.01	1.10 ±0.01	46.44 ±0.01
10%A90%W	10.72 ±0.07	2.00 ±0.01	3.38 ±0.00	56.12 ±0.19	**BDL**	0.68 ±0.00	3.38 ±0.02	1.30 ±0.01	50.13 ±0.00
15%A85%W	10.78 ±0.06	2.34 ±0.02	3.41 ±0.06	65.49 ±0.21	**BDL**	0.89 ±0.01	4.31 ±0.04	1.51 ±0.00	55.18 ±0.04

All values are means ± SD at $P<0.05$
Where: A-Amaranth, W-Wheat; BDL: Below detectable limit.

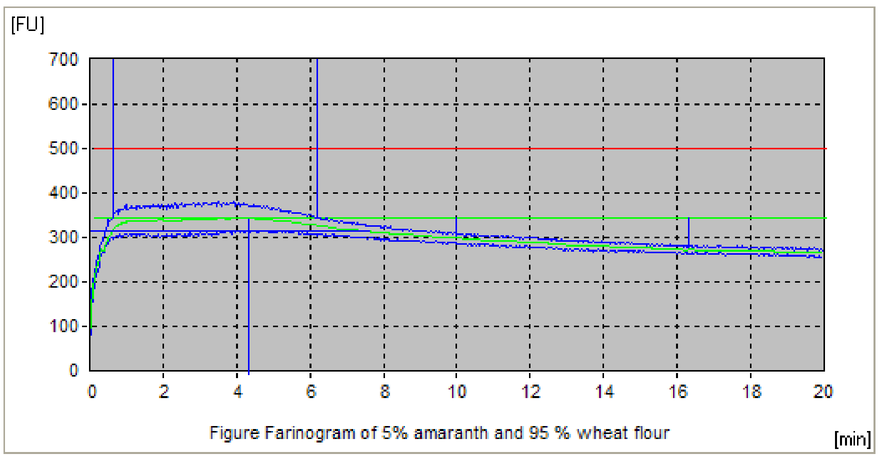

Figure 3. farinogram of 5%amaranth and 95% wheat flour

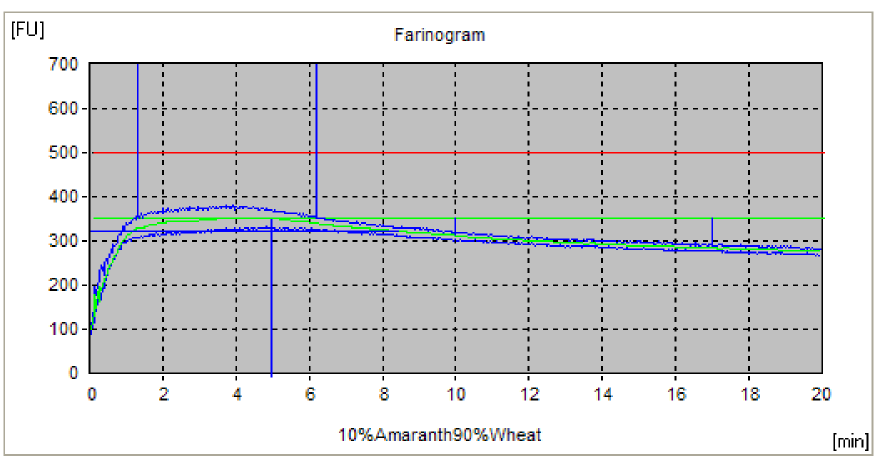

Figure 4. farinogram of 10% amaranth and 90% wheat flour

Farinographic values of blended flours

The investigation of the flour blend characteristics included the farinographic qualities. The results output of Brabender farinogram showed that the farinographic quality number decreased with an increase in a percentage of amaranth flour substitution of wheat flour (Figs.3-8). On the other hand, dough consistency and

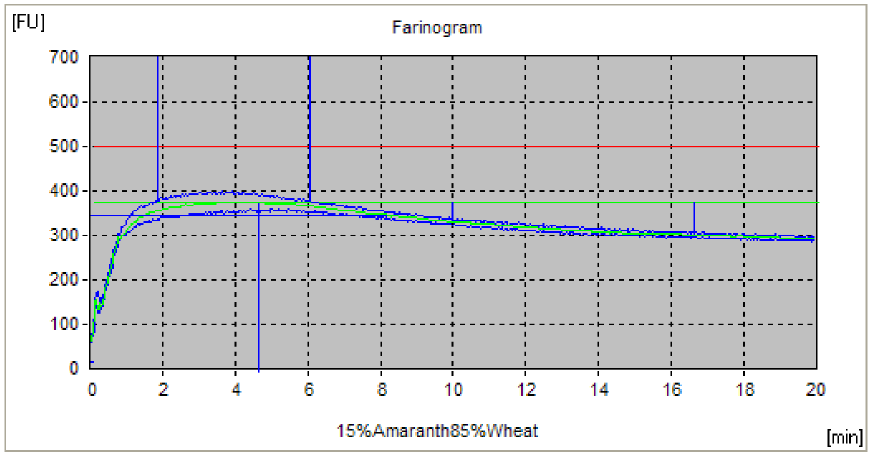

Figure 5. farinogram of 15% amaranth and 85% wheat flour

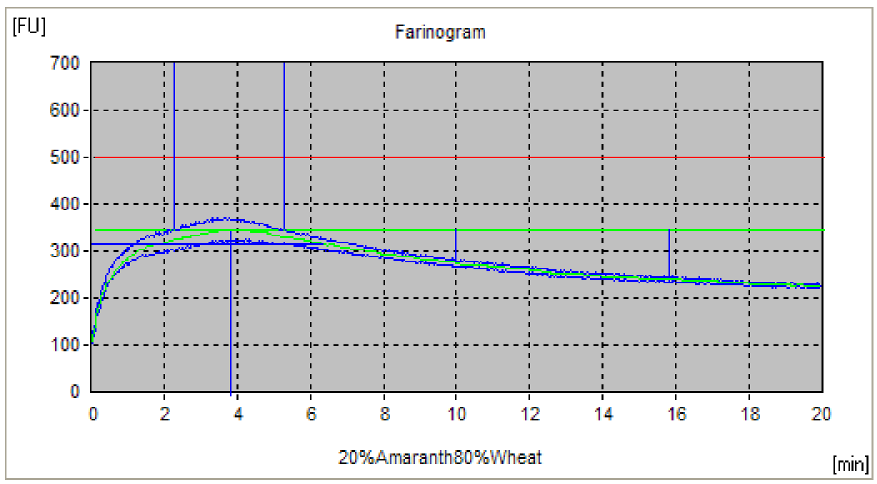

Figure 6. farinogram of 20 % amaranth and 80% wheat flour

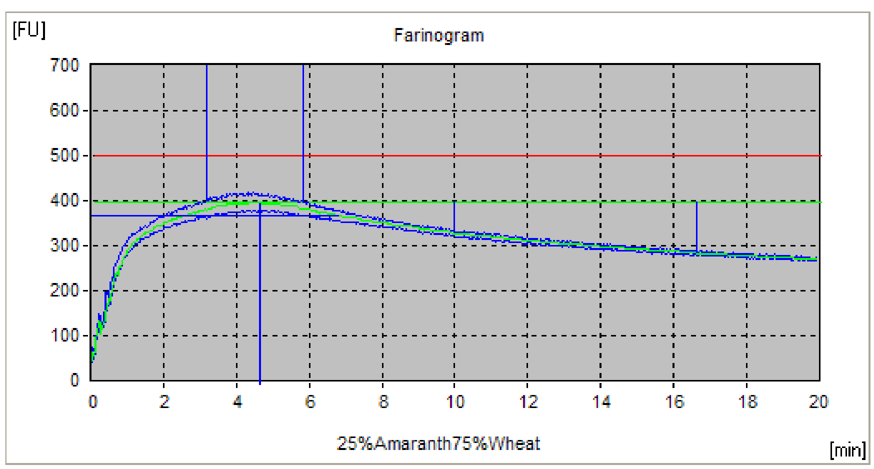

Figure 7. farinogram of 25% amaranth and 75% wheat flour

development time, water absorption and degree of softening increased with amount of amaranth flour substitution. Water absorption increased from 50.9% to 56.7% with an increase in the amaranth substitution.

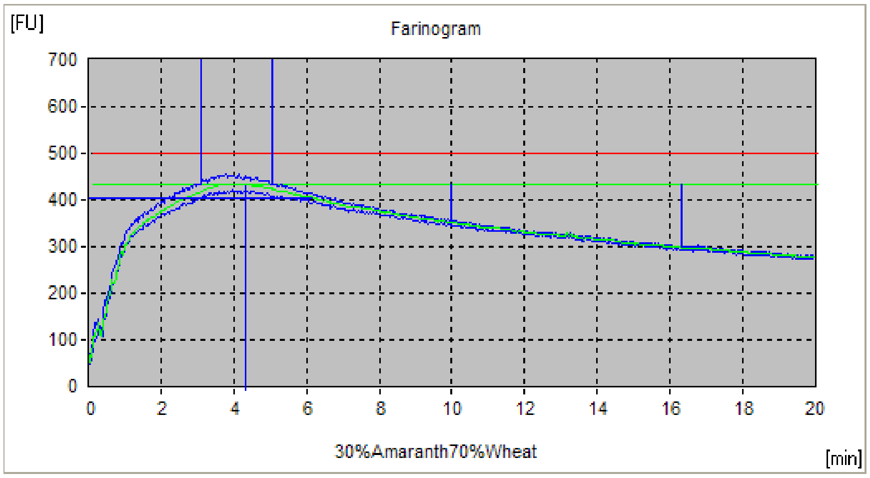

Figure 8. farinogram of 30 % amaranth and 70% wheat flour

Table 5. Bread volume index for breads baked at 210^{0}c and various times

Blend Samples	210°C/18min	210°C/21min	210°C/24min
100% wheat	2.68±.076	3.03±0.057	3.30±.1
5%amaranth95%wheat	3.40±0.01	3.52±0.04	3.83±0.07
10%amaranth90%wheat	3.02±0.02	2.99±0.15	2.91±0.37
15%amaranth85%wheat	2.91±0.12	2.82±0.30	2.74±0.46
20%amaranth80%wheat	2.95±0.02	2.87±0.05	2.81±0.13

All values are means ± SD at *P*<0.05; bread volume index is expressed in cm^3/g

Similar studies conducted by Lorenz and Wright (1984), and Tömösközi et al. (2011) revealed an increase in water absorption of composite flours when amaranth substitution increased. A decrease in dough stability time with an increase in the amaranth substitution was also reported by Lorenz and Wright (1984) and Sindhuja et al. (2005).

Grobelnik et al. (2009) observed an increase in degree of softening with an increase in amaranth substitution, but a decrease in farinographic quality number was found as amaranth substitution increased. In general, the farinographic analysis results were in accordance with those reported in other studies. Thus, the results can be used to make a decision the amount of water required to make dough, to establish the flour blending requirements and to predict processing effects.

In general, based on rheological properties of the dough from amaranth-containing composite flour it can be concluded that the increasing amaranth addition consequently increased dough consistency. Moreover, water absorption by composite flours increased, and the increase in the development time led to a significantly slower blend hydration. The dough stability was generally higher for the composite than for basic flours, and it increased with the amaranth substitution of up to 30%. The amaranth addition to blends also decreased the farinographic quality number.

Quality attributes of amaranth-wheat flour bread

Bread volume index

A bread volume index result showed a significant (p<0.05) difference for all experimental time-temperature combination. The index for bread made from blend of amaranth (5%) and wheat (95%) at various baking temperature (210, 220, 230 °C) and time (18, 21, 24 min) has higher as compared to other samples of blend formulations (Tables 5-7). The index for the bread made with a 5% amaranth substitution and baked at 210°C/24min was 3.83 cm^3/g, which was large as compared with those obtained for other breads.

The 5% amaranth bread scored the highest index and the 20% amaranth bread scored the lowest index among all other breads throughout the experimentation. A

Table 6. Bread volume index for breads baked at 220°c and various times

Blend Samples	220°C/18min	220°C/21min	220°C/24min
100%wheat	3.03±0.05	2.96±0.05	2.73±0.25
5%amaranth95%wheat	3.13±0.11	3.56±0.60	3.36±0.15
10%amaranth90%wheat	3.20±0.51	2.53±0.11	2.86±0.15
15%amaranth85%wheat	2.72±0.07	2.73±0.23	2.46±0.20
20%amaranth80%wheat	2.06±0.12	1.90±0.24	1.64±0.11

All values are means ± SD at $P<0.05$; bread volume index is expressed in cm^3/g

Table 7. Bread volume index for breads baked at 230°c and various times

Blend Samples	230°C/18min	230°C/21min	230°C/24min
100%wheat	3.23±0.05	3.36±0.05	3.26±0.05
5%amaranth95%wheat	2.86±0.11	3.46±0.15	3.20±0.17
10%amaranth90%wheat	3.16±0.05	3.23±0.05	3.03±0.23
15%amaranth85%wheat	3.03±0.05	3.13±0.11	3.33±0.11
20%amaranth80%wheat	2.76±0.20	2.86±0.15	2.63±0.25

All values are means ± SD at $P<0.05$; bread volume index is expressed in cm^3/g

Table 8. Proximate composition of breads baked at 220°c and different baking time

Parameters	5%amaranth 95%wheat			10%amaranth 90%wheat			15%amaranth 85%wheat		
	Baking time			Baking time			Baking time		
	18min	21min	24min	18min	21min	24min	18min	21min	24min
Fat (%)	1.07	0.61	0.79	0.59	0.75	1.23	0.86	0.75	0.99
Protein (%)	6.82	6.83	7.06	8.44	8.2	8.74	7.92	8.2	8.1
Fiber (%)	1.95	1.43	1.37	1.41	1.34	0.77	1.29	1.34	2.02
Ash (%)	2.41	2.13	2.28	2.54	2.27	2.47	2.55	2.27	2.67
Zinc(mg/100g)	0.99	1.04	1.02	1.18	1.28	1.29	1.37	1.28	1.4
Calcium (mg/100g)	64.74	129.8	52.86	60	61.73	78.73	69.74	61.73	78.44
Iron(mg/100g)	4.46	5.8	5.19	4.6	4.19	4.24	6.28	4.19	6.7
Tannin(mg/100g)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Phytate (mg/100g)	44.12	40.57	43.12	51.52	48.56	51.27	72.64	48.56	69.96

All values are means ± SD, where BDL-Below detectable limit.

reason for decrease in the index was mainly associated with lowering of gluten contents. The lowering of falling number with increase of amaranth substitution was another factor. A decrease in the index with increase in amaranth substitution was also observed in research findings reported by Naofumi et al. (1999).

Proximate composition of bread

Among eighteen different types of breads made from 5-30% amaranth substituted flours and baked at three time and temperature levels, those baked at 220°C were the most preferred by panelists. Moreover, analysis conducted to characterize the blend flours property revealed that flours containing more than 15% amaranth were not suitable for bread making due to low gluten content of the blend and darker color of blended flours. Due to these facts, proximate analyses were done only for breads prepared from flours containing only 5-15% amaranth and baked at 220°C.

It was established that zinc, calcium and iron contents of bread increased as amount of amaranth substitution increased. Tannin was absent in all breads. Comparable fat, protein and fiber contents were observed in all breads (Table 8). Nutrient composition properties of these breads correlate with the nutrient properties of the corresponding blend flours. Wheat bread had an average of 2-4% protein while 10% amaranth bread contained

Table 9. Bread sensory evaluation using 5-points hedonic scale

Sample	Processing parameters	csc	cst	cbc	cbt	Flavor	Taste
5%A 95%W	210°C/18min	2.40±0.95	2.60±0.86	2.44±0.96	1.80±0.95	1.96±1.02	3.60±1.11
	210°C/21min	4.08±1.28	2.72±1.02	4.40±0.91	2.92±1.03	3.84±1.28	3.96±1.00
	210°C/24min	3.32±1.10	3.44±1.00	3.88±1.09	3.60±1.04	3.84±0.89	4.20±.707
	220°C/18min	4.16±0.89	4.04±0.88	4.32±1.06	4.36±0.99	4.00±1.00	3.56±1.04
	220°C/21min	3.40±0.95	4.08±1.18	4.36±0.99	3.92±1.15	3.84±1.10	3.92±1.03
	220°C/24min	2.04±0.97	1.96±1.02	3.56±1.00	3.68±1.37	3.12±1.13	3.64±1.15
	230°C/18min	2.24±0.72	2.24±0.66	2.00±1.08	2.00±0.86	2.24±0.97	1.80±0.76
	230°C/21min	1.80±0.57	1.64±0.95	1.64±0.90	1.76±0.92	1.84±0.94	2.64±0.63
	230°C/24min	1.92±0.90	2.20±0.91	1.68±0.85	1.60±0.91	2.28±1.02	1.68±0.85
10%A 90%W	210°C/18min	2.12±0.66	2.16±0.89	1.56±0.91	1.88±0.92	1.92±1.22	1.72±1.02
	210°C/21min	1.44±0.65	1.28±0.61	1.32±0.69	1.44±0.65	1.44±0.76	1.48±0.77
	210°C/24min	1.16±0.47	1.32±0.62	1.32±0.62	1.16±0.37	1.44±0.76	1.40±0.70
	220°C/18min	3.80±1.09	3.88±1.02	3.92±1.08	4.16±1.06	4.28±0.93	4.24±0.75
	220°C/21min	3.32±1.31	3.32±1.14	3.36±1.31	3.68±1.28	4.36±0.95	3.28±1.27
	220°C/24min	2.88±1.13	2.88±1.09	2.68±1.14	2.96±1.06	3.72±1.06	3.08±0.81
	230°C/18min	3.16±0.98	3.80±1.25	3.24±1.01	3.28±0.84	3.48±0.87	3.80±1.11
	230°C/21min	3.80±1.08	3.44±1.19	3.72±1.02	3.72±1.17	3.60±1.04	3.12±0.88
	230°C/24min	3.20±0.86	3.08±1.03	2.56±1.26	3.16±1.31	3.20±1.11	3.20±0.91
15%A 85%W	210°C/18min	2.08±0.90	2.36±1.03	1.72±0.79	2.60±1.29	3.60±1.08	3.32±1.03
	210°C/21min	1.88±1.09	1.56±0.87	1.44±0.76	1.64±0.63	1.60±0.86	1.68±0.85
	210°C/24min	1.88±1.09	1.52±0.71	1.64±0.75	3.08±1.11	2.48±1.26	2.08±0.86
	220°C/18min	1.52±0.71	1.28±0.61	1.36±0.63	2.08±1.03	1.72±0.84	1.80±0.76
	220°C/21min	1.32±0.62	1.20±0.57	1.04±0.20	1.48±0.65	1.72±0.89	1.40±0.70
	220°C/24min	1.40±0.57	1.40±0.81	1.36±0.81	1.36±0.81	1.72±0.93	1.68±0.90
	230°C/18min	1.36±0.75	1.28±0.67	1.28±0.73	1.28±0.84	1.60±0.91	1.68±0.85
	230°C/21min	1.34±0.77	1.28±0.67	1.20±0.53	1.22±0.58	1.40±0.83	1.52±0.86
	230°C/24min	1.04±0.20	1.24±0.52	1.08±0.27	1.16±0.47	1.32±0.74	1.44±0.71

twice more. The bread prepared from 10% amaranth with 90% wheat and baked at 220°C for 18 min contained 8.44% of crude protein composition which was the highest as compared to other blend formulation, baking time and temperature combinations (Table 8).

Sensory analysis

The mean score for sensory analysis was performed for breads made from four levels of amaranth-wheat blended flour baked at different time temperature levels is indicated in Table 9. The major problem with amaranth bread was that it had a crumb texture which was considered as unattractive by panelists. This was due to the dilution of gluten when more amaranth was added to the flour blend which resulted in compact structure of the crumb. The SAS system mean procedure indicated that 5% amaranth bread scored high for crumb texture while 10% amaranth baked at 210°C for 18min was the best in crust texture. On the other hand, the least score was given for 20% amaranth bread baked at all time temperature conditions.

Table 9. continues

20%A 80%W	210oC/18min	1.04±0.20	1.24±0.52	1.08±0.27	1.12±0.44	1.24±0.72	1.24±0.59
	210°C/21min	1.04±0.20	1.24±0.52	1.08±0.27	1.12±0.44	1.24±0.72	1.24±0.59
	210°C/24min	1.56±0.50	2.36±0.63	1.44±0.50	1.00±0.00	2.92±0.99	2.44±0.50
	220°C/18min	1.28±0.54	1.36±0.81	1.36±0.81	1.36±0.80	1.60±0.91	1.72±0.93
	220°C/21min	1.36±0.75	1.28±0.67	1.28±0.73	1.28±0.84	1.48±0.91	1.44±0.82
	220°C/24min	1.36±0.90	1.24±0.72	1.20±0.50	1.20±0.57	1.40±0.81	1.64±0.90
	230°C/18min	1.32±0.62	1.32±0.62	1.20±0.57	1.24±0.59	1.40±0.86	1.40±0.82
	230°C/21min	1.04±0.20	1.24±0.52	1.08±0.27	1.16±0.47	1.32±0.74	1.36±0.70
	230°C/24min	1.44±0.50	2.41±0.55	1.47±0.50	1.09±0.37	2.82±1.11	2.41±0.60

All values are means ±SD at $P<0.05$; where: A-amaranth, W-wheat, cst-crust texture, csc-crust colour, cbt-crumb texture, cbc- crumb colour

The sensory results showed that as the amaranth substitution increased, the texture score decreased. According to Lorenz (1984) at the substitution levels of 10 and 15% amaranth, the texture of the bread was not silky and attractive. The high color score of the amaranth flour resulted in a darker bread. As panel test results showed that 20% amaranth bread had the least score for both crumb and crust colors while 10% amaranth bread baked at 220°C for 18min was found to be appealing in crumb color (Table 9). The 5% amaranth bread baked at 210°C for 21 min scored the highest. Lorenz (1981) also indicated that the crumb color acquired slightly darker as amaranth substitution increased.

The flavor attribute scores of amaranth breads were in general high. 10% amaranth bread baked at 220°C for 21minutes scored the highest while 20% amaranth bread baked at 230°C for 24 minute scored the least. Breads baked at 230°C scored the least for flavor. At substitution levels 15-20%, the flavor score decreased. This was because the nutty flavor of amaranth was pronounced as the percentage increased. According to Lorenz (1981), the flavor of the breads with amaranth was very pleasant and preferred by the taste panel over the flavor of white bread. The least score was given for breads baked at 230°C. The 20% amaranth breads baked at all time-temperature combinations furthermore scored the least sensory attributes. The 10% amaranth bread baked at 220°C for 18 min scored the highest overall sensory attributes and was accepted by panelists.

CONCLUSION

Results of flour analyses revealed that amaranth flour had better dense nutrient than wheat flour in proximate chemical composition and mineral concentration. Proximate analysis of amaranth-wheat blended flours showed significant nutrient improvement as amount of amaranth in the blend increased. The farinographic quality (rheological properties) results revealed that water absorption increased with increase in amaranth substitution. A decrease in a dough stability time with an increase of amaranth substitution was also observed. Gluten content and falling number values of amaranth were the main challenges for acceptance of amaranth bread production. Due to the gluten free nature of amaranth, the gluten content of amaranth-wheat blend flours' lowered as the percentage of amaranth substitution increased. However, the gluten contents of mixed flours containing 5% and 10% amaranth categorized within the average acceptable gluten content values for bread production.

Considering the results obtained and the characteristics of the basic flour used, the amaranth substitution up to 10% is evident to improve some rheological properties and sensory characteristics of the breads baked at 220°C for 18min. The substitution of wheat by amaranth flour resulted changes in rheological properties of dough and bread sensory quality parameters (crust and crumb texture, volume and color). The substitution of 15% and above causes important quality deterioration in comparison to wheat bread. The use of protein isolate from amaranth to enrich the nutritive value of the added value baked products may be preferred in order to avoid quality deterioration of the end products.

Accordingly, to make use of the nutritionally rich, drought tolerant and inexpensive grain amaranth in the East African countries at industry level is paramount important.

It is recommended to study the application of the amaranth grain for manufacturing of novel fortified baking and functional products, gluten-free, high-quality proteins, starch fractions and granules, non-food allergy and extruded food products. Amaranth grain also considered to have prospects in food coloring, biomedical applications for human health. Utilizing less exploited, but high quality, food sources that are locally available in East Africa can contribute to food security as well as create market opportunity and improve farm gate price via processing export oriented value-added products. The developed countries extract the high priced squalene from shark livers. However, this expensive material is available in amaranth oil, which may find a niche market in products such as lubricants in the computer industry and in cosmetics.

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