Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(3): 954-958
Received: 04-03-2018
Accepted: 08-04-2018

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Effect of popping on physico-chemical and nutritional parameters of amaranth grain

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Abstract
Processing has a major role in altering the physical, functional and chemical properties of raw produce. This study evaluated the parameters associated with popping as well as its effect on the functional properties of Amaranthus hybridus grains cultivated in Uttarakhand, India. Flour characteristics such as water and oil absorption capacity, bulk density, foaming capacity and stability of both the raw and popped forms of grains were analyzed. Popping characteristics such as popping quality, volume, expansion volume, ratio and percent flour recovery were also observed. One-way analysis of variance (ANOVA) was applied to judge the differences. Popping significantly enhanced and improved the flour properties as water and oil absorption capacity, whereas a decrease was observed in bulk density and foam capacity after processing. Moisture, crude ash, crude protein, crude fat, crude fiber showcased significant decrease due to popping whereas carbohydrate as a difference showed significant increase after popping. The properties of raw and popped amaranth flour indicate its suitability for use as a substitute for other flour based food products commonly consumed by Indians, which in turns provides wide scope of its utilization in food industry.

Keywords: popping, flour characteristics, nutritional properties

Introduction
Cereals processing is one of the former and the most essential component of all food technologies. It makes up a large and indispensable area of the food production chain as a result of its diversity (Kumari and Sangeetha, 2017) [15]. Understanding of functional and nutritional characteristics of processed flours is necessary to use theses flours as a base material for numerous food products. Presently amaranth is considered to be an alternative crop and researchers all over the world have focused on improving agronomic features of the crop as well as techniques used for processing the pseudo-cereal (Singh *et al.* 2014) [31]. As a gluten-free pseudo-cereal, amaranth is highly recommended for people with celiac disease (Kupper, 2005) [16]. Amaranth seeds can be popped on exposure to high temperature. Popping is believed to occur when the internal pressure caused by the evaporation of water exceeds the tensile strength of the seed coat (Tovar *et al.* 1994) [37]. Due to relatively high starch content, small starch granule size (1 to 3 μm), and low amylose concentration (1%), further investigation of functional properties of native and modified amaranth starch is of great interest (Resio and Suarez, 2001; Bello-P´erez *et al.* 2006) [30, 7].
Since food processing is one of the intrinsic factors that determine functional characteristics, starch digestibility of any raw material, so in case of amaranth seeds also these features are likely to be affected by the type of processing technique applied. The aim of the present work was to examine the physico-chemical and nutritional properties of amaranth flour in raw and popped forms to check for the variation brought about by the processing technique applied and identify the potential application in end use product.

Material and Methods
The experiment was conducted in Department of Foods and Nutrition, College of Home Science, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, District-Udham Singh agar, Uttarakhand, India during 2017-2018. Amaranth seeds were procured from the local market of Pantnagar.

Preparation of raw amaranth grain flour
Raw amaranth grains were cleaned, washed, dried and ground to form flour.

Preparation of popped amaranth grain flour
Amaranth grains were cleaned, washed, dried at 50 °C for 4 hours and then popped in a

closed pan at 190 °C for 15 seconds. Seeds were sifted by using a 20 mesh size sieve to remove un-popped seeds. Popped seeds were then milled to form flour. Popping was carried out by using the modified form of method described by Njoki *et al.* in 2014 [25].

Popping parameters of amaranth grains

Popping Per cent

The number of completely popped grains in two gram sample was recorded and expressed as per cent popping.

Popping Per cent = (Number of popped kernels ÷ Number of total kernels) x 100.

Popping volume

The volume of whole popped products from two gram sample was measured in graduated tube of 10 ml capacity and was expressed as popping volume.

Popping per cent and popping volume was obtained by methods as described by Srivastava and Batra in 1998 [34].

Expansion volume

Expansion volume and flake size was calculated according to the method given by Pordesimo *et al.* (1990) [29].

Expansion volume= [{Total popped volume} ÷ {Original weight of popped kernels}]

Expansion Ratio

The apparent bulk volume of the popped seeds was measured using a 20 mL graduated cylinder as described by Konishi *et al.* 1998 [14] and expressed as the expansion ratio.

Expansion ratio= {(The volume of popped seeds) ÷ (The volume of raw seeds)}.

Functional properties of flours

Both raw and popped forms of flours were assessed for following properties.

Water absorption capacity

Water absorption capacity was determined by modifying the method of Adele and Odedeji, 2010 [2].

Oil absorption capacity

Fat absorption was measured by a modification of the method used by Lin *et al.* (1974) [20].

Bulk density

Bulk density of the samples was determined by the method of Wang and Kinsella (1976) [39].

Foam capacity

It was determined by the method given by Lawhon *et al.* (1972) [19].

Foam stability

The foam stability was expressed in volume per cent as suggested by Ahmed and Schmidt (1976) [3].

Nutritional properties of flours

Both raw and popped forms of flours were assessed for following properties.

Moisture, Ash, Crude fiber, Crude fat and crude protein

The Nutritional parameters (Moisture, Ash, Crude fiber, Crude fat and crude protein) was estimated using AOAC 2000 Methods

Carbohydrate

Per cent Carbohydrate =100-[moisture (%) + ash (%) + crude fat (%) + crude fibre (%) + crude protein (%)]

Physiological energy

Physiological energy was calculated by the formula given by Mudambi and Rao, 1989 [22] Physiological energy value (Kcal/100g) = 4 x crude protein (%) + 4 x carbohydrate (%) + 9 x crude fat (%)

Results

Popping characteristics

Table 1 depicts the popping percent to be 76.2, which is quite appreciable as obtained by using non- mechanical techniques. According to Chávez-Servín *et al*. 2017 [8] the popping per cent of amaranth grain cultivated in green houses and open fields were 84 and 82 per cent respectively. Various researchers have reported a wide range of popping per cent, Murty *et al.* (1983) [23] and Thorat *et al.* (1988) [36] noted that popping per cent was affected by grain moisture and grain hardness. Popping and expansion volume was observed to be 9.24 and 4.62 ml respectively as showcased in table 1. Lara and Ruales in 2002 [18] quoted that the expansion volume of amaranth seeds when popped by using A West Bend Poppery ranged from 4.9 to 5.3 ml which is comparable to the results quoted above. Expansion ratio was found to be 4.36 whereas it was observed to range from 5.5 to 6.9 in a study by Inoue *et al.* 2009 [10]. The researchers in the study used a specialized experimental apparatus for popping the seeds. Percent flour recovery was 74.3%.

Table 1

1	Popping Percent (%)	76.2±1.5%
2	Popping Volume (ml)	9.24±0.24
3	Expansion Volume (ml)	4.62±0.12
4	Expansion Ratio	4.36±0.11
5	Percent Flour Recovery (%)	74.3±0.2%

Functional properties

The water absorption capacity of raw amaranth grain flour was determined to be 205.42% i.e. 2.05 (g/g) which is more than 1.60 (g/g) reported by Tanimola *et al.* in 2016 [35] and 132% quoted by Sindhu and Khatkar, 2016 [32]. Water absorption capacity is the ability of the flour to associate with water under a condition where water is limiting, which is mainly dependent on proteins at room temperature (Otegbayo *et al.* 2013) [26], and to a lesser extent on starch and cellulose. In the present study a significant increase of 183.9% was observed in the water absorption capacity due to popping technique. Lara *et al.* 2004 [17] also reported significant increase in water absorption capacity after undergoing popping process. According to the study water absorption capacity was recorded to be 2.16 (g/g) in raw form which significantly enhanced to 6.93 (g/g) in popped amaranth flour. Oil absorption capacity of flour is influenced by the interactions between the non-polar amino acid side chains and hydrocarbon chains of lipid that also determine mouth feel and flavor retention of products. In this study oil absorption capacity of raw amaranth flour was found to be 138% that was comparable with the results of Pachelo de Delahaye, 1987 [27] and Sindhu and Khatkar, 2016 [32] that was reported to be 150% and 144% respectively. In the current work significant increase of 7.25% was observed in oil absorption capacity. Singh *et al.* 2004 conducted a study on foxtail millet and reported that oil absorption capacity of popped millet was higher than that of decorticated millet. Higher oil absorption capacity of popped flour could be attributed to its porous nature which allowed oil to percolate through it more easily unlike for the native flour (Narayana and Rao, 1982) [24].

Table 2

Materials	Parameters				
	Water Absorption Capacity (%)	**Fat Absorption Capacity (%)**	**Bulk Density (g/ml)**	**Foam Capacity (%)**	**Foam Stability (%)**
Raw Amaranth Flour	205.42±4.1^{a}	138.26±1.6^{a}	0.67±0.02^{a}	23.59±0.36^{a}	90.02±2.03^{a}
Popped Amaranth Flour	582.34±7.2^{b}	148.54±1.7^{b}	0.36±0.01^{b}	12.67±0.14^{b}	90.87±2.14^{a}
CD at 1%	22.024	6.205	0.059	1.027	-
CD at 5%	13.279	3.742	0.036	0.0619	-
CV	1.487	1.151	3.070	1.507	2.258

All results are mean±standard error of three replicates on as is basis
* CV-coefficient of variation, CD-critical difference
*Different alphabets in superscript in each row show significant difference between values

In the present study bulk density was observed to be 0.67 g/ml in raw form of amaranth flour whereas it significantly decreased to 0.36 g/ml after popping. The decline may be attributed to the loss of moisture and reduced particle size in popped form. An understanding of bulk density is useful in determining the packaging requirement, application in wet processing and material handlings of flours (Adebowale *et al.* 2008) [1]. Tanimola *et al.* in 2016 [35] quoted loose and packed bulk density of raw amaranth flour to be 0.45 and 0.57 (g/cm3) which is comparable to present study. Parde *et al.* in 2003 reported that the standard bulk density of Koto buckwheat increased significantly from 603.90 to 612.9 kgm^{-3} with an increase in moisture content from 14.8 to 15.8%. Significant difference between raw and processed form of flours is observed among all the functional parameters except foam stability at 1 and 5 per cent significance level.

Foaming capacity is related to the proteins' ability to rapidly diffuse to the interface, reorient, and form a viscous film without excessive aggregation or coagulation, whereas foaming stability is influenced by intermolecular cohesiveness and viscosity of this interfacial film as well as a certain degree of elasticity permitting localized contact deformation (Kinsella, 1981) [13]. In the present study foam capacity of raw amaranth seed flour was observed to be 23.59% which is comparable to the results quoted by Shevkani *et al.* 2014 [31]. According to them the foam capacity of raw amaranth flour ranged from 15 to 30% and foam stability ranged from 30 to 90% for different varieties of amaranth seeds. There was an inverse relationship between foam capacity and foam stability. Flours with high foaming ability could form large air bubbles surrounded by thinner and a less flexible protein film. These air bubbles might be easier to collapse and consequently lowered the foam stability (Jitngarmkusol *et al.* 2008) [11]. There was significant difference in the foaming capacity of whole wheat flour (12.16 per cent) and raw amaranth flour (23.59 per cent). Foaming stability of whole wheat flour and amaranth flour was found to be 90.43 per cent and 90.02 per cent respectively. Foam stability is important since success of any whipping agent depends on its ability to maintain the whip as long as possible. Food ingredients with good foaming capacity and stability can be used in bakery products (Akubor *et al.* 2000) [4].

Table 3

Materials	Parameters						
	Moisture (%)	**Crude Ash (%)**	**Crude Protein (%)**	**Crude Fat (%)**	**Crude Fiber (%)**	**Carbo-hydrate (%)**	**Physio-logical Energy (kcal)**
Raw Amaranth Flour	10.96±0.28^{a}	5.92±0.08^{a}	17.8±0.27^{a}	8.64±0.17^{a}	6.56±0.09^{a}	50.12±0.03^{a}	348.5±0.18^{a}
Popped Amaranth Flour	9.62±0.21^{b}	5.28±0.05^{b}	11.59±0.18^{b}	7.97±0.15^{b}	4.96±0.04^{a}	60.57±0.06^{b}	360.4±0.23^{b}
CD at 1%	0.930	0.251	0.863	0.603	0.262	0.178	0.776
CD at 5%	0.561	0.151	0.520	0.363	0.158	0.108	0.468
CV	2.405	1.191	1.56	1.930	1.175	0.086	0.058

All results are mean± standard error of three replicates on as is basis
* CV-coefficient of variation, CD-critical difference
*Different alphabets in superscript in each row show significant difference between values

Nutritional properties

In the current nutrient estimation the moisture of raw amaranth flour was found to be 10.96 per cent which is comparable with the value provided by USDA, 2018 [38] that is 11.29 per cent. Due to popping the moisture content decreased significantly by 1.34 per cent. In a study by Njoki *et al.* in 2014 [25] the moisture content decreased to 3 per cent as an effect of popping. Dry heat decreased moisture content. In dry heat techniques; heat is transferred by convection to the food's surface, and then penetrates the food by conduction. The surface dehydrates and the food browns from caramelization. Crude ash was found to be 5.92 per cent in the present study which is higher than 3.18 per cent reported by Njoki *et al.* 2014 [25]. The researchers also quoted significant decrease of 0.11 per cent in crude ash due to popping which is comparable to the present study in which the decrease of 0.64 per cent was observed. Crude protein was observed to be 17.8 per cent in the present study which is higher than the value quoted by USDA data base and Kariuki *et al.* 2013 [12] that is 13.56 and 15.8 per cent respectively and is very much similar to 17.2 per cent quoted by Mburu *et al.* 2012 [21]. Amare *et al.* 2016 [5] quoted that popping resulted in a significant decrease in protein content from 14.9 to 14.3 g/100 g. In the present study a decrease of 6.21 per cent was observed in the protein content. The decrease in protein content might be attributed to the partial oxidation of heat labile amino acids. Crude fat was observed to be 8.64 in raw amaranth flour which is slightly higher to the values quoted by USDA, Njoki *et al.* 2014 [25] and Kariuki *et al.* 2013 [12] that were 7.02, 7.09 and 7.5 g/100g respectively. Likewise the present study Njoki *et al.* also quoted significant decrease of 0.22 per cent in fat content after popping. Crude fiber was found to be 6.56 per cent in the present study which is higher than 4.27 per cent as observed by Njoki *et al.* 2014 [25]. The researchers also noticed a decrease of 0.91 per cent in crude fiber content due to popping whereas in the present study a significant decrease of

1.6 per cent was observed. Carbohydrate content by difference was found to be 50.12 per cent which is significantly lower than the values quoted by USDA, Njoki *et al.* 2014 [25], Kariuki *et al.* 2013 [12] and Mburu *et al.* 2012 [21] that were 65.25, 66.28, 66.0 and 59.2 respectively. In the present study the value of carbohydrate increased significantly after popping that can be due to significant decrease of other proximate nutrients. Energy was reported to be 348.5 kcal in the present study which is comparable with 371 kcal given by USDA, 2018 [38].

Conclusion

This investigation concluded that amaranth seeds possess remarkable functional properties as a pseudo-cereal which is enhanced by using the technique of popping. There is significant decrease in amount of protein but decrease in fiber content and improvement in functional properties makes the flour of popped amaranth suitable to be used as a source of energy and carbohydrate in pre-mixes and therapeutic food for children. The properties of amaranth grain flour showed its suitability for use as a substitute for other pastes commonly consumed by people as a staple food or in different forms. Hence, a variety of innovative bakery food products as well as pre-mixes can be developed by using popped amaranth flour to suit the consumer needs.

Acknowledgement

Authors express sincere thanks to Department of Foods and Nutrition, G.B.P. Uni. of Ag. And Tech. Pantnagar and University Grants Commission, Govt. of India for providing financial assistance in the form of MANF fellowship (JRF & SRF).

Conflict of interest

The authors have not declared any conflict of interest.

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