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Effect of various thermal treatments on functional properties of *Amaranthus* Grain Flour

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ABSTRACT

For the fast-growing food industry and to address the issue of food security that too with an effective sustainable plant source Grain Amaranth can be a potential ingredient. Hence, this study aimed to assess the functional properties of grain Amaranthus flour. Grains were subjected to various thermal treatments like roasting at 140 ^{0}C for 3 minutes, germinating for 24 hrs and popping at 160 ^{0}C. The results revealed that the Water/Oil Absorption Capacities, foaming abilities, Emulsifying properties and Protein solubility values are recorded high for flours obtained by thermal treatment than untreated one indicating processed flours have better food applicability. Among thermally treated, Popped Amaranthus grain flour registered high values for the above properties except for emulsifying properties. The highest protein solubility was recorded in popped flour (68.78%) followed by germinated (65.87%) and roasted flour (64.86%) whereas raw flour recorded the lowest value (44.39%) indicating that the processed Amaranthus grain flours a good choice for sustainable alternative plant protein. All processed flours formed strong gels at 8% w/v concentration. Processing methods were more effective in improving the functional properties of the Amaranthus grain flour thus, suggesting that these seed flours can be incorporated/substituted/ replaced into different food forms.

***Key words**: Amaranthus grain, Functional properties, Protein solubility, Gelation*

Introduction

It is imperative for ensuring future global food security with a balanced and effective exploration of sustainable plant resources. Grain amaranth (*Amaranthus* spp.) is one such neglected and underutilized species that is a drought-tolerant crop with inherent potential ingredients which are yet to be explored (Akin-Idowu *et al*., 2017). These seeds are excellent sources of protein content (13-19%) with balanced essential amino acids especially rich in lysine a limiting amino acid that is absent in many other grains (Amare *et al*., 2015). The protein of grain amaranth has been claimed to be very near to the levels recommended by FAO/WHO because of the balance in amino acid profile (Murya and Pratibha, 2018).

The mineral content of these grains are comparable with commonly utilized cereal grains such as

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millet, sorghum, rice, wheat and corn (Mustafa *et al.,* 2011). Further, they are rich in good lipids, starches, antioxidants, and bioactive compounds with health-promoting effects (Karamac *et al.,* 2019).

Apart from wheat and other cereals, Amaranthus grain can be a potential food ingredient in the development of different food products for celiac patients (Martinez-Villaluenga *et al.,* 2020). Certainly, the presence of antinutrients in amaranth grains may pose a challenge in its utilization for food security but different thermal treatments can minimize their antinutrient content. To understand their role as an effective ingredient it is vital to characterize and determine the functional properties for proper utilization in food processing applications and in different food systems (Teresa and Pag, 2021). Thus, this research aims to analyze the functional properties of Amaranthus grain flour obtained after different thermal processing methods.

Materials and Methods

Processing methods of Amaranth grain: Procured Amaranth grains were divided into four batches out of which the first batch was cleaned, dried in the hot-air oven at 40 °C for 4 hr, and milled into flour in a pulverizer (Ramesh and Jamuna, 2020). The second batch is subjected to roasting at 140 ^{o}C for 3 minutes with constant stirring, later cooled and milled (Aderibigbe *et al*., 2020). The third batch is subjected to germination using the method of Paredes -Lopez, and Mora- Escobedo, (1989) with slight modification. The seeds were soaked in water for 10 minutes and drained. Then they were spread evenly in a single layer on a dampened muslin cloth and incubated at room temperature for 24 hours. The germinated grains were oven-dried at 60 °C for 6 hours cooled and milled. The fourth batch is roasted at 160 ^{0}C with constant stirring till puffing/popping of all the grains. All the flours obtained after different processing methods were sieved using a standard mesh size of 100.

Functional properties: Water and Oil absorption capacity (WAC/OAC) was analyzed by Onwuka and Onwuka (2005). Swelling Index (SI) by Islam *et al*. (2015), Foaming capacity (FC) and stability (FS) (AOAC, 2006), Emulsion Activity (EA) and Stability (ES) by the method of Elkhalifa and Bernhard *et al.* (2018), Protein solubility (PS) was determined by the method adopted from Singh *et al. (*2017) and Least gelation concentration (LGC) by the method of Sathe and Salunkhe, (1981).

Statistical analysis: Statistical analysis: All the data were statistically evaluated by one-way analysis of variance (ANOVA) and the significance of differences between means were determined by Duncan's multiple comparison test at a 5% significance level ($P < 0.05$) by using IBM SPSS statistics software, version 20.0 (IBM, SPSS, Inc., Chicago, IL, USA).

Results and Discussion

Water/Oil Absorption Capacity: These results were tabulated in Table 1. The WAC of raw amaranth grain flour was determined to be 2.01±0.02 (g/g) which is correlated with the findings of Khan and Dutta, (2018). But this value is more compared to the value reported by Tanimola *et al.,* 2016. The highest WAC was recorded by popped flour (4.86±0.02 g/g) followed by roasted flour (4.47±0.01 g/g). This can be attributed to increased porosity and also due to protein denaturation, starch gelatinization, and raw fiber swelling during drying the orientation of residual amino acids change (Timilsena *et al.,* 2016). Lara *et al.* (2004) also reported a significant increase in water absorption capacity after undergoing the popping process. The study of 2 reported similar WAC values in roasted and germinated Amaranthus grain flours when compared with raw flour. WAC and OAC values were significantly different ($p < 0.05$, Duncan test) for all samples in the study.

OAC for the flours ranged from 1.63±0.01 to 2.98±0.01 ml/g respectively. Higher values are recorded for popped flour followed by germinated. This trend might be due to protein denaturation in thermally processed seed flours which exposes hydrophobic groups to bonding to hydrocarbon chains of oil, thereby increasing OAC in samples (Turan *et al.,* 2015). Similar results of OAC increase during germination were reported by Adedeji *et al.* (2014) in maize flours. WAC and OAC results suggest that these flours can be exploited in comminuted meats, extruded products, sausage batters, sausages, meat analogs, bakery products, weaning foods, and bulked and high-consistency foods. These properties could play an important role in food processing since fat acts on flavor retainers and increase food's mouth feel (Reddy *et al.,* 2018).

Swelling Index (SI): The values were significantly different ($p < 0.05$, Duncan test) for all the flours (Table 1). SI of the flours ranged from 2.45±0.04 to

3.14±0.03 g/g. The highest SI value is reported in raw flour when compared to processed Amaranth grain flour. The reduced SI in heat – moisture-treated flours could be because of the disarray of starch molecules, leading to restricted particle hydration. This results in an increase in molecular mobility in starch granules (Huang *et al.,* 2016). These values correlated with the findings of Burgos and Armada, (2015).

Foaming Capacity and Stability (FC and FS): FC and FS ranged from 13.39±0.11 - 15.83±0.07% and 82.13±0.18 – 90.17±0.08% respectively. The highest value for both was recorded in popped flour followed by germinated and roasted flour. There is an inverse relationship between foam capacity and foam stability (Jitngarmkusol *et al.* 2008). The increase in FC and FS in processed flours might be due to the partial unfolding of the structure of the protein which exposes hydrophobic regions of the protein and in turn, enhances the hydrophobic interaction of the protein with air and water interfaces thus, results in improved foaming capacity and stability. Our study results are inconsistent with the study of Singh *et al.,* (2017b) in brown rice flour and Kirthy Reddy *et al.,* (2018) study in Jamun seed flour. FC and FS values were significantly different ($p < 0.05$, Duncan test) for all flours (Table 1).

Large air bubbles are surrounded by a thin and low flexible protein film formed in the flours with high foaming ability. The low foam stability is due to the easy collapse of air bubbles might be easier to collapse. This foaming property is very important for food products such as whipped cream, cake, ice cream, and other bakery products (de Souza *et al.,* 2020).

Emulsifying Activity and Stability (EA and ES): EA and ES increased drastically in the processed amaranth grain flours compared with the raw flour, which ranged from 18.56±0.05– 57.81±0.11% and 29.75±0.06 – 72.14±0.09% respectively. The increase in these properties during the process of germination is because of exposing the hydrophobic sites of amino acids due to hydrolysis and partial unfolding of polypeptides and the same was reported by Olawoye and Gbadamos, (2020) in amaranthus grain flour.

Emulsifying properties of plant proteins are directly correlated with protein solubility. It is clearly understood that the protein concentrates with good emulsifying properties can be used as binders, emulsifiers, surface-active agents, and valuable plant protein-based ingredients for the melioration of textural properties of foods (Preethi *et al*., 2021). These values were significantly different ($p < 0.05$, Duncan test) for all flours (Table 1).

Protein Solubility (PS): The most critical functional property of protein is protein solubility because of other functional properties. The solubility of the processed Amaranthus Viridis seed four increased as the pH increased from the isoelectric point as explained by Olawoye and Gbadamos, (2020). These values were significantly different ($p < 0.05$, Duncan test) for all flours (Table 1). PS at pH 10 showed higher values for Processed flours than raw flours where the highest PS of 68.78±0.11% was recorded in popped flour followed by germinated (65.87±0.10%) and roasted flour (64.86±0.04%). This scenario may be due to the accumulation of the highest protein content with processing and inactivation of antinutritional factors present in raw grains. This trend of our result is in incompliance with the results quoted by Shevkani *et al.* (2014). So that these results suggest that these grains can be used in food processing applications as a sustainable

Table 1. Functional Properties of raw and processed Amaranthus Grain flours

Parameters	Raw	Roasted	Germinated	Popped
Water Absorption Capacity (WAC) (g/g)	$2.01±0.02^{d}$	$4.47±0.01^{b}$	$2.68±0.05^{c}$	$4.86±0.02^{a}$
Oil Absorption Capacity (OAC) (ml/g)	$1.63±0.01^{d}$	$2.46±0.02^{c}$	$2.83±0.06^{b}$	$2.98±0.01^{a}$
Swelling Index (SI)	$3.14±0.03^{a}$	$2.58±0.06^{c}$	$2.45±0.04^{b}$	$2.76±0.04^{b}$
Foaming Capacity (FC) %	$13.39±0.11^{d}$	$14.12±0.12^{c}$	$15.36±0.08^{b}$	$15.83±0.07^{a}$
Foaming Stability (FS) %	$82.13±0.18^{d}$	$86.14±0.21^{c}$	$87.89±0.19^{b}$	$90.17±0.08^{a}$
Emulsifying Activity (EA) %	$18.56±0.05^{d}$	$23.15±0.06^{c}$	$57.81±0.11^{a}$	$54.78±0.09^{b}$
Emulsifying Stability (ES) %	$29.75±0.06^{d}$	$36.79±0.08^{c}$	$72.14±0.09^{a}$	$67.19±0.10^{b}$
Protein Solubility (PS) %	$44.39±0.08^{d}$	$64.86±0.05^{c}$	$65.87±0.10^{b}$	$68.78±0.11^{a}$

Note: Values are expressed as mean ± S.Ed (n = 6). The values in the same row with different superscript letters are significantly different ($p < 0.05$) as per Duncan's multiple comparison test.

protein substitute (Jia *et al.,* 2021).

Least Gelation Concentration (LGC): The results of LGC were tabulated in Table 2. Strong gels were found at 8% concentration in the processed flours whereas strong gel was observed at 12% in case of raw flour. Our results were correlated to the LGC values in study by Saha *et al.,* (2021) in Camachile powder. The increasing concentration of proteins in the flour facilitates the gelation properties which may be due to the enhanced interaction among the binding forces (Lawal *et al.,* 2005). Similar results were presented by Tripathi *et al.* (2019) in raw amaranth grain flour. This result of LGC shows that these flours can be beneficial in food applications such as puddings and for the development of new food products like soup, sauce, pudding, cake, and biscuits (Maduwage *et al.,* 2019).

Table 2. Gelling Concentrations of raw and processed Amaranthus Grain flours

Gelling Concentrations (%)	Raw	Roasted	Germinated	Popped
2	-	-	-	-
4	-	-	-	-
6	-	+	+	+
8	+	++	++	++
10	+	++	++	++
12	++	++	++	++
14	++	++	++	++

Note: (-) Not gelled, (+) weak gels and (++) strong gels

Conclusion

This study consludes that pesudo -cereal amaranth seed flours have remarkable functional properties as a pseudo-cereal. Both raw and processed flours showed their suitability for use as a substitute and replacement in different food forms for various food applicability like emulsifier, binding agent, bulk agent, thickening agent, surface active agent, foaming agent etc. Protein solubility values exhibited that this grain flour is very desirable as sustianable plant protein and can be an alternative choice for meat.

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Conflict of interest: None

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