

Effect of Processing on the Characteristics Changes in Barnyard and Foxtail Millet

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Abstract

Introduction: Millet grains, before consumption and for preparing food, are usually processed by commonly used traditional processing techniques to improve their edible, nutritional and sensory properties.

Background: The processing techniques aim to increase the physicochemical accessibility of micronutrients, decrease the content of anti-nutrients or increase the content of compounds that improve bioavailability.

Objectives: Thus, an attempt was made in the present study with the objectives to study the effects of boiling, pressure cooking, roasting and germination on functional, nutritional, anti-nutritional and pasting properties of barnyard millet and foxtail millet.

Materials and Methods: Physical properties of unprocessed millets, chemical, functional, anti-nutritional and pasting properties of both unprocessed and processed millets were analysed using standard techniques.

Results and Conclusion: Physical characteristics such as thousand grain weight, thousand grain volumes, hydration capacity and index, swelling capacity and index and cooking quality of the selected two unprocessed millets were considerably differed from each other. There was a significant variation with respect to functional, nutritional, anti-nutritional and pasting properties of selected two millets in response to different processing methods. Among them, germination reduces the anti-nutritional factors while roasting significantly increases the nutritional compounds. The improved functional and pasting properties of the selected two millets were observed in the germinated and roasted millet flours.

Keywords: Barnyard millet; Foxtail millet; Functional properties; Nutritional properties; Anti nutritional parameters and pasting properties

Introduction

Millet is a collective term referring to a number of small-seeded annual grasses that are cultivated as grain crops, primarily on marginal lands in dry areas in temperate, subtropical and tropical regions. The most important species are barnyard millet and foxtail millet. Foxtail millet is important in parts of Asia (mainly China) and Europe. The other species barnyard millet is locally important food grains restricted to smaller regions or individual countries. The various species differ in their physical characteristics, quality attributes, soil and climatic requirements and growth duration [1].

Cereal grains are the most important source of the world's food and have a significant role in the human diet throughout the world. Millets are also rich sources of phytochemicals and micronutrients [2]. As a food source it is non-glutinous and non-acid forming, so is soothing and easy to digest. It is considered to be one of the least allergenic grains. It is high in quality protein, contains high fibre, B-complex vitamins and also the vitamins A and E [3]. Millets may serve as a natural source of antioxidants in food applicants and as a nutraceutical and functional food ingredient in health promotion and disease risk reduction. Millets are also rich sources of non-nutritional components like phenols, tannins, phytate and flavonoids. These compounds serves as an antioxidant and millets could also be used as source of extremely beneficial phytochemicals in the pharmaceutical and food industry [4]. Therefore, millet grains are now receiving specific attention from the developing countries in terms of utilization as food as well as from some

developed countries in terms of its good potential in the manufacturing of bioethanol and biofilms [5].

Millet grains, before consumption and for preparing food, are usually processed by commonly used traditional processing techniques to improve their edible, nutritional and sensory properties [6]. The processing techniques aim to increase the physicochemical accessibility of micronutrients, decrease the content of antinutrients or increase the content of compounds that improve bioavailability [7]. Thus, an attempt was made in the present study with the objectives to study the effects of wet heat treatment (boiling and pressure cooking), dry heat treatment (roasting) and germination on physicochemical, functional, anti-nutritional and pasting properties of barnyard millet, and foxtail millet.

Materials and Methods

The selected two millets namely barnyard millet and foxtail millet were procured from local market of Vellore district, Tamil Nadu, India. The millets were cleaned properly and stored in sealed containers.

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Physical characterization of selected two unprocessed millet grains

Physical characteristics such as thousand grain weights, thousand grain volumes, hydration capacity and index, swelling capacity and index, cooking quantity/characteristics were analyzed for the selected two unprocessed millet grains using standard procedures in triplicates.

Processing of selected two millet grains in to flours

Food processing is the transformation of raw ingredients, by physical or chemical means into food, or of food into other forms. It is widely accepted that simple and inexpensive traditional processing techniques are effective methods of achieving desirable changes in the composition of grains. The processing methods such as boiling, germination, pressure cooking and roasting were implemented with raw sample to test the effect of processing on functional, chemical, anti-nutritional and pasting characteristics of millet grains.

Functional properties of raw and processed millet flours

The functional properties such as bulk density, swelling power, solubility, solid loss, water absorption capacity and oil absorption capacity were analyzed using standard procedure in triplicates. Bulk density of each sample was determined by the method described by Ige et al. [8]. Swelling power, solubility and solid loss of the raw and processed millet flours was determined using the modified method of Shin et al. [9]. The water and oil absorption capacity were determined using the method described by Lin et al. [10].

Nutrient analysis of raw and processed millet flours

Proximate composition such as pH, moisture, ash, total titrable acidity, crude protein, crude fibre, carbohydrate, fat, energy, amylose content, total starch and mineral composition like sodium, potassium, calcium, iron and phosphorus were determined for the selected two raw and processed millet flours using standard procedures.

Anti nutritional parameters of raw and processed millet flours

Anti-nutrients are natural or synthetic compounds that when present in foods reduce the availability of the nutrients. The anti-nutritional parameters such as tannin, total phenolics and trypsin inhibitor were determined using standard procedures as described by Sadasivam and Manickam [11].

Pasting properties of raw and processed millet flours

Pasting properties of the selected two raw and processed millet flours were analyzed using Rapid Visco Analyzer (RVA) as described by Tester and Morrison [12]. Parameters recorded were pasting temperature, peak viscosity, trough viscosity (minimum viscosity at 95°C), final viscosity (viscosity at 50°C), breakdown viscosity (peak-trough viscosity), and setback viscosity (final-trough viscosity). The pasting properties of each sample were determined from 3g of flour (dry basis) in 25ml of distilled water by using a Rapid Visco Analyzer (RVA) model 3D (Newport Scientific Pty. Ltd., Australia). The sample was heated from 50 to 95°C at the rate of 12°C/min with constant stirring at 160 rpm and held at 95°C for 2.5minutes (break down), then cooled at 50°C at the rate of 13°C/min (set back) and held for 2 minutes. The total cycle was 12.5 minutes. Pasting temperature was recorded as the temperature at which an increase in viscosity was first observed. The values reported included pasting temperature (°C), Peak viscosity (cP), final viscosity (cP), trough (lowest viscosity, cP), break down

(difference between peak viscosity and trough, cP), set back from peak (the difference between final viscosity and peak viscosity, cP) and set back from trough (the difference between final viscosity and trough, cP).

Statistical analysis

The final data was compiled and analyzed using suitable statistical methods. The results were represented as descriptive statistics such as mean, standard deviation and one way ANOVA. p-values < 0.05 were considered significant. Analysis of variance (ANOVA) was used to test the differences among different processed millet flours. The data reported in tables are an average of triplicate observations subjected to one-way analysis of variance (ANOVA).

Results and Discussion

Physical characteristics of selected two unprocessed millet grains

The physical characteristics such as thousand grain weight, thousand grain volume, hydration capacity and index, swelling capacity and index and cooking quantity/characteristics of selected two unprocessed millets grains were presented in Table 1. The thousand grain weight of barnyard millet and foxtail millet were 3.69 g and 2.64 g respectively. The thousand grain volume of barnyard millet was 4.01 ml and 2.96 ml for foxtail millet. Grain volumes change significantly and most often, regularly at varying moisture contents.

The hydration capacity of the barnyard millet and foxtail millet were 2.93 g/1000 seeds and 2.01 g/1000 seeds with the hydration index of 78.39% and 76.9% respectively. The barnyard millet grain was found to have swelling capacity of 0.23 ml/1000 seeds with an index of 5.83% and foxtail millet grain was observed to have swelling capacity of 0.21 ml/1000 seeds with an index of 6.72%. The presence of high protein, lipid, fiber and larger amount of amylose-lipid complex in flour could inhibit the swelling of starch granules [13].

Cooking quality of the grain is an important criterion to assess the consumer acceptability [14]. The barnyard millet and foxtail millet grains required 12 minutes to get cooked. The increase in the weight of barnyard millet and foxtail millet grains after cooking were 175.6% and 197.6% respectively. The increase in the volume of barnyard millet and foxtail millet grains after cooking were 41.2% and 75.5% respectively.

Functional properties of selected two raw and processed millet flours

The functional properties such as bulk density, swelling power, solubility, solid loss, water absorption capacity and oil absorption capacity of the selected two raw and processed millet flours were discussed below.

S.no	Parameters	Barnyard millet	Foxtail millet
1.	Thousand grain weight (g)	3.69 ± 0.01	2.64 ± 0.005
2.	Thousand grain Volume (ml)	4.01 ± 0.01	2.96 ± 0.05
3.	Hydration Capacity (g/1000 seeds)	2.93 ± 0.05	2.01 ± 0.02
4.	Hydration Index (%)	78.39 ± 0.1	76.9 ± 0.05
5.	Swelling Capacity (ml/1000 seeds)	0.23 ± 0.05	0.21 ± 0.02
6.	Swelling Index (%)	5.83 ± 1.44	6.72 ± 0.02
7.	Gain in weight after cooking (%)	175.6 ± 10.6	197.6 ± 14.0
8.	Gain in volume after cooking (%)	41.2 ± 3.76	75.5 ± 2.07
9.	Cooking time (minutes)	12 minutes	12 minutes

Table 1: Physical characteristics of selected two unprocessed millet grains.

Bulk Density of the raw and processed millet flours

The bulk density of the selected two raw and processed millet flours was presented in Table 2. Bulk density is an important parameter that determines the packaging requirement of a product [15]. In comparison with raw millet flours, the bulk density of the boiled, pressure cooked and roasted samples were significantly increased ($p < 0.05$) whereas the bulk density of the germinated millet flours of selected two millets was decreased. The decreased bulk density of the germinated millet flour indicates low porosity or air spacing in the flour, therefore less auto-oxidation. This is an advantage in respect to spoilage, packing and transportation as goods in relation to weight [16].

Swelling power of the raw and processed millet flours

Swelling and water absorption capacities are important parameters in determining the sample consistency (solid, semi-solid and liquid) and are dependent on the compositional structure of the sample [17]. The swelling power of the selected two raw and processed millet flours was given in Table 3. The swelling power of the selected two processed millet flours at 90°C were consistently reduced when compared with raw samples and does not varied significantly with each other ($p > 0.05$). The swelling behaviour below 16 g/g is considered as highly restricted. This restricted swelling behaviour of the flour samples indicates its stability against shearing action when subjected to heat [18]. Therefore, in the present study, the selected two raw and processed millet flours showed restricted swelling behaviour indicate its resistant power towards heating.

Solubility behaviour of the raw and processed millet flours

Solubility is an indicator of the degree of starch granules dispersion after cooking [19]. Solubility behaviour of the selected two raw and processed millet flours at 90°C was presented in Table 4. Among all the processing techniques of selected two millets, germinated millet flour contained highest solubility behaviour. The solubility could imply to the amount of amylose leaching out from starch granule when swelling, therefore the higher the solubility the higher will be the amylose leaching [20]. Difference in solubility could also be attributed to different chain length distribution in the starch [21].

Solid loss of the raw and processed millet flours

Solid loss of the selected two raw and processed millet flours was shown in the Table 5. The processed barnyard millet flour exhibited loss of solids to an extent of 27.9% in boiled, 26.5% in germinated, 29.1% in pressure cooked, 30.1% in roasted and 30.7% in raw samples. The cooking of processed foxtail millet flour resulted in 27.5% of solid loss in boiled, 27% in germinated, 30.5% in pressure cooked, 28.4% in roasted and 29.3% in raw samples. A significant difference in solid loss was observed between different processed barnyard and foxtail millet flours ($p < 0.05$).

S.no	Processing techniques	Barnyard millet (g/ml)	Foxtail millet (g/ml)
1.	Boiling	0.62 ± 0.005 ^a	0.70 ± 0.005 ^a
2.	Germination	0.44 ± 0.005 ^b	0.43 ± 0.005 ^b
3.	Pressure cooking	0.52 ± 0.03 ^c	0.53 ± 0.01 ^c
4.	Roasting	0.55 ± 0.005 ^c	0.53 ± 0.01 ^c
5.	Raw	0.50 ± 0.005 ^c	0.52 ± 0.005 ^c

The values are expressed as the mean of three replicate samples ± SD. Values in a column with different superscripts differ significantly ($p < 0.05$).

Table 2: Bulk Density of the raw and processed millet flours.

S.no	Processing techniques	Barnyard millet (g/g)	Foxtail millet (g/g)
1.	Boiling	4.73 ± 0.3	4.83 ± 0.45
2.	Germination	4.53 ± 0.35	4.63 ± 0.4
3.	Pressure cooking	4.7 ± 0.17	5.16 ± 0.4
4.	Roasting	4.96 ± 0.15	4.9 ± 0.3
5.	Raw	5.2 ± 0.2	5.23 ± 0.4

The values are expressed as the mean of three replicate samples ± SD. Values in a column do not differ significantly ($p > 0.05$).

Table 3: Swelling power of the raw and processed millet flours.

S.no	Processing techniques	Barnyard millet (%)	Foxtail millet (%)
1.	Boiling	6.3 ± 0.41 ^a	6.3 ± 0.55 ^a
2.	Germination	6.8 ± 0.41 ^a	7.1 ± 0.55 ^b
3.	Pressure cooking	6.7 ± 0.60 ^a	5.8 ± 0.60 ^c
4.	Roasting	6.3 ± 0.55 ^a	5.4 ± 0.45 ^d
5.	Raw	6.2 ± 0.26 ^a	6.2 ± 0.55 ^a

The values are expressed as the mean of three replicate samples ± SD. Values with similar superscripts in a column do not differ significantly. Values with different superscripts in a column differ significantly.

Table 4: Solubility behaviour of the raw and processed millet flours.

S.no	Processing techniques	Barnyard millet (%)	Foxtail millet (%)
1.	Boiling	27.9 ± 1.45 ^a	27.5 ± 0.87 ^a
2.	Germination	26.5 ± 1.30 ^b	27 ± 1.76 ^b
3.	Pressure cooking	29.1 ± 1.55 ^c	30.5 ± 1.21 ^c
4.	Roasting	30.1 ± 1.34 ^d	28.4 ± 0.96 ^d
5.	Raw	30.7 ± 0.90 ^e	29.3 ± 0.86 ^e

The values are expressed as the mean of three replicate samples ± SD. Values with different superscripts in a column differ significantly.

Table 5: Solid loss of the raw and processed millet flours.

Water absorption capacity of the raw and processed millet flours

The water absorption capacity of the selected two raw and processed millet flours was presented in the Table 6. Water absorption capacity is important in the development of ready to eat foods, and high absorption capacity may assure product cohesiveness [22]. The variations in water absorption capacity of the selected two processed millets is highly attributed by several factors such as number of hydration positions, physical environment, pH, solvent, presence of lipids and carbohydrates [23]. In the present study, water absorption capacity was significantly increased ($p < 0.05$) in boiled, pressure cooked and roasted samples compared to raw samples, but germinated millet flours of selected two millets have least water absorption capacity. When the lipid content is high in the flour, the water absorption decreases because lipids block the polar sites of the proteins attenuating the absorption of water [24].

Oil absorption capacity of the raw and processed millet flours

Table 7 shows the oil absorption capacity of the selected two raw and processed millet flours. The high oil absorption capacity makes the flours suitable for facilitating enhancement in flavour and mouth feel when used in food preparations [25]. Oil absorption capacity was significantly increased ($p < 0.05$) in boiled, germinated; pressure cooked and roasted millet flours compared to raw samples. Variation in fat absorption may be due to the variation in protein concentration, degree of interaction with water and oil and conformational characteristics [26].

Nutrient analysis of selected two raw and processed millet flours

Proximate composition such as pH, moisture, ash, total titrable acidity, crude protein, crude fibre, carbohydrate, fat, energy, amylose content, total starch and mineral composition like sodium, potassium, calcium, iron and phosphorus analyzed for the selected two raw and processed millet flours were discussed below.

Proximate composition of selected two raw and processed millet flours

The proximate composition of raw and processed barnyard millet flour was tabulated in Table 8. The pH value of the boiled, germinated, pressure cooked, roasted and raw samples were 7, 6.5, 6.8, 6.7 and 7.1 respectively. The total ash content of the raw and processed barnyard millet flour ranged from 2 g to 2.5 g. The ash content of the samples is the reflection of minerals. Hence the barnyard millets are rich in minerals. The highest total titrable acidity was noticed in germinated barnyard millet flour 0.72 g and lowest value was seen in pressure cooked sample 0.32 g. The higher the moisture content the lower the dry matter yield on drying [27]. The raw barnyard millet flour contained high moisture content of 10 g, followed by germinated 9.5 g, boiled 8 g, pressure cooked 7.4 g and roasted 6.2 g [28-31], found that total protein

increased after germination process. In this study, the results showed that roasted barnyard millet flour contained high protein content (12.8 g) when compared to other processed samples.

The fibre content of the raw and processed barnyard millet flour ranged from 5.3 g to 7.2 g, being the highest for pressure cooked flour 7.2 g and lowest for raw flour 5.3 g. It is generally accepted that the consumption of food naturally rich in dietary fibre is beneficial to the maintenance of health [32]. The carbohydrate content of the boiled barnyard millet flour was 72 g, 61 g for germinated, 80 g for pressure cooked, 75 g for roasted and 72 g for raw samples. The carbohydrate content of the germinated barnyard millet flour was comparatively lesser than the other processed samples. This results were in agreement with Mubarak [33], reported that germinated samples showed a significant reduction in the total carbohydrate. The decrease in the carbohydrate during the process of germination is due to the use of carbohydrate for metabolism by the sprouts [34].

Among the fat content of barnyard millet flour, the roasted and raw flour contained less fat content of 1.9 g and 1.8 g respectively. This results confirms with the report of Aremu, et al. [35] stated that kersting groundnut and cranberry bean upon roasting were found to greatly reduce crude fat content. The energy value of raw and processed flour varied from 302.1 kcals to 380.2 kcals. The lowest energy value was observed in germinated flour (302.1 kcals) and the highest energy value was observed in pressure cooked flour (380.2 kcals) due to its high carbohydrate and fat content. The total starch content of raw and processed barnyard millet flour ranged from 7.8 g to 17.2 g, being the highest in boiled 17.2 g and lowest in germinated flour 7.8 g. Germination of proso millet grains decreased the dry weight and the total starch content [36]. All the processing methods were exhibited increased amylose content of barnyard millet flour compared to raw flour. The boiled sample contained high amylose content of 15.22%, followed by pressure cooked 12%, germinated 10.8%, roasted 9.6% and raw sample of 8%.

Grains are the store houses of many chemical components including nutrients, phytochemicals, and non-nutritive plant protective functional constituents. The nutritional content of the raw and processed foxtail millet flour was tabulated in Table 9. The pH value of boiled, germinated, pressure cooked, roasted and raw foxtail millet flour was 6.7, 7.2, 6.5, 6.2 and 7.0 respectively. The ash content of the raw and processed foxtail millet flour ranged from 2.1 g to 4.2 g. This indicates the high mineral content of foxtail millet flour. Ash is the inorganic residue remaining after the water and organic matter have been removed by heating in the presence of oxidizing agents which provides a measure of the total amount of minerals within a food. Regarding the total titrable acidity, the highest value was found in germinated sample (0.55 g), followed by 0.54 g in raw, 0.45 g in roasted, 0.34 g in boiled and 0.32 g in pressure cooked samples. The moisture content of boiled (6.46 g), germinated (11.56 g), pressure cooked (7.3 g) and roasted foxtail millet flour (7.56 g) was comparatively lesser than the raw millet flour (15 g). This indicates the less susceptibility to microbial infection. The high protein content was seen in germinated flour (12.6 g) were in agreement with the report of Srichuwong et al. [37] stated that process of germination greatly attributed protein increase to protein synthesis due to inclusion of microbial cells in to the flour.

The crude fibre content ranged from 4.9 g to 6.1 g. processing of foxtail millet flour showed an increase in the fibre content compared to raw flour. Germination can increase dietary fibre content than other processing and increase mineral bioavailability [38,39]. The

S.no	Processing techniques	Barnyard millet (g/g)	Foxtail millet (g/g)
1.	Boiling	2.40 ± 0.02 ^a	1.86 ± 0.04 ^a
2.	Germination	1.12 ± 0.01 ^b	0.95 ± 0.02 ^b
3.	Pressure cooking	2.31 ± 0.02 ^c	2.06 ± 0.04 ^c
4.	Roasting	1.59 ± 0.01 ^d	1.39 ± 0.06 ^d
5.	Raw	1.24 ± 0.04 ^e	1.18 ± 0.05 ^e

The values are expressed as the mean of three replicate samples ± SD. Values with different superscripts in a column differ significantly.

Table 6: Water absorption capacity of the raw and processed millet flours.

S.no	Processing techniques	Barnyard millet (g/g)	Foxtail millet (g/g)
1.	Boiling	1.14 ± 0.03 ^a	1.17 ± 0.04 ^a
2.	Germination	1.12 ± 0.03 ^b	1.26 ± 0.02 ^b
3.	Pressure cooking	1.39 ± 0.05 ^c	1.15 ± 0.03 ^c
4.	Roasting	1.16 ± 0.05 ^d	1.12 ± 0.03 ^d
5.	Raw	1.10 ± 0.01 ^e	1.06 ± 0.02 ^e

The values are expressed as the mean of three replicate samples ± SD. Values with different superscripts in a column differ significantly.

Table 7: Oil absorption capacity of the raw and processed millet flours.

S.no	Parameters	Boiling	Germination	Pressure cooking	Roasting	Raw
1.	pH	7.00	6.5	6.8	6.7	7.1
2.	Ash (g)	2.5	2.0	2.4	2.2	2.3
3.	Total titrable Acidity (g)	0.48	0.72	0.32	0.36	0.46
4.	Moisture (g)	8	9.5	7.4	6.2	10
5.	Crude Protein (g)	7.4	8.9	8.3	12.8	11.2
6.	Crude Fibre (g)	6.4	5.7	7.2	7.0	5.3
7.	Carbohydrates (g)	72	61	80	75	72
8.	Fat (g)	3.4	2.5	3.0	1.9	1.8
9.	Energy (Kcals)	348.2	302.1	380.2	368.3	349
10.	Total Starch (g)	17.2	7.8	13.59	10.32	12.6
11.	Amylose content (%)	15.22	10.8	12	9.6	8

Table 8: Proximate composition of the raw and processed barnyard millet flour (per 100 gms).

carbohydrate content of processed foxtail millet flour was significantly reduced when compared to raw millet flour except germinated sample which exhibits higher content of carbohydrates (72 g). Fat content was increased in roasted sample (3.2 g), followed by raw (2.9 g), pressure cooked (2.8 g), germinated (2.6 g) and boiled sample (1.9 g). The calorific value of foxtail millet flour exhibited 302.7 kcals in boiled, 361.8 kcals in germinated, 332 kcals in pressure cooked, 294.4 kcals in roasted and 333.3 kcals in raw samples. The high calorific value of germinated flour was due to its high protein and high carbohydrate content. The total starch content of the processed foxtail millet flour was drastically reduced compared to raw flour. It has been observed as 13.6 g of starch in boiled, 11.9 g in germinated, 8.62 g in pressure cooked, 7.85 g in roasted and 18.5 g in raw kodo millet flour. The pressure cooked sample contained high level of amylose (12.4%), followed by germinated (10.8%), boiled (6.8%), roasted (4.4%) and raw flour (4%).

Mineral composition of selected two raw and processed millet flours

The mineral composition of raw and processed barnyard millet flour were shown in the Table 10. The sodium content of the raw and processed barnyard millet flour ranged from 13 mg to 20 mg, being the highest for pressure cooked flour (20 mg) and lowest for boiled barnyard millet flour (13 mg). The potassium content of processed barnyard millet flour was significantly reduced compared to raw flour. Boiled sample has 210 mg of potassium, 215 mg in germinated, 225 mg in pressure cooked, 248 mg in roasted and 298 mg in raw samples. Iron content was decreased when grains were roasted [40]. This statement was in agreement with the current study findings revealed that roasted barnyard millet flour exhibited less iron content (3.28 mg) than other processing techniques. The calcium and phosphorus content of the processed barnyard millet flour were decreased when compared with raw millet flour. Processing techniques were considerably affected the calcium and phosphorus content of the barnyard millet. It has been

S.no	Parameters	Boiling	Germination	Pressure cooking	Roasting	Raw
1.	pH	6.7	7.2	6.5	6.2	7.0
2.	Ash (g)	2.8	4.2	3.4	2.6	2.1
3.	Total titrable Acidity (g)	0.34	0.55	0.32	0.45	0.54
4.	Moisture (g)	6.46	11.56	7.3	7.56	15
5.	Crude Protein (g)	8.4	12.6	7.7	10.4	6.8
6.	Crude Fibre (g)	6.1	5.1	5.9	5.1	4.9
7.	Carbohydrates (g)	63	72	69	56	70
8.	Fat (g)	1.9	2.6	2.8	3.2	2.9
9.	Energy (Kcals)	302.7	361.8	332	294.4	333.3
10.	Total Starch (g)	13.6	11.9	8.62	7.85	18.5
11.	Amylose content (%)	6.8	10.8	12.4	4.4	4

Table 9: Proximate composition of the raw and processed foxtail millet flour (per 100 gms).

S.no	Minerals	Boiling	Germination	Pressure cooking	Roasting	Raw
1.	Sodium (mg)	13	17	20	14	18
2.	Potassium (mg)	210	215	225	248	298
3.	Iron (mg)	3.3	7.59	8.9	3.28	9.0
4.	Calcium (mg)	30	50	32	40	60
5.	Phosphorus (mg)	252	210	227	234	252

Table 10: Mineral composition of the raw and processed barnyard millet flour (per 100 gms).

observed as 30 mg of calcium in boiled, 50 mg in germinated, 32 mg in pressure cooked, 40 mg in roasted and 60 mg in raw millet flour. Whereas phosphorus content of boiled barnyard millet flour was 252 mg, 210 mg in germinated, 227 mg in pressure cooked, 234 mg in roasted and 252 mg in raw flour.

Table 11 showed the mineral content of the raw and processed foxtail millet flour. When compared to raw flour, the sodium and potassium content of the processed foxtail millet flour were considerably increased. The sodium and potassium content was ranged from 8 mg to 25 mg and 252 mg to 356 mg respectively. Germinated foxtail millet flour found to have high iron content (5.8mg) followed by pressure cooked 3.8 mg, raw 3.7 mg, boiled 2.59 mg and roasted 2.4 mg. Germination or malting generally improves the nutrient content and digestibility of foods and it could be an appropriate food-based strategy to derive iron and other minerals maximally from food grains [41]. In this study, processing exhibited desirable changes in the calcium and phosphorus content. The calcium content of the raw and processed foxtail millet flour ranged from 31 mg to 60 mg, whereas the phosphorus content varied from 221 mg to 280 mg.

Anti-nutritional parameters of selected two raw and processed millet flours

The anti-nutritional parameters of the selected two raw and processed millet flours were analyzed to determine the effect of processing on anti-nutrients such as tannin, total phenolics and trypsin inhibitor.

Anti-nutritional parameters of raw and processed barnyard millet flour were shown in Figure 1. An increase in the tannin, total phenolics and trypsin inhibitor levels was noticed in processed barnyard millet flour when compared to raw flour. This was in agreement with the study conducted by Seifi et al. [42] also revealed that during processing, an increase in the content of tannin, total phenolics and trypsin inhibitor activity was noticed in little millets compared to the native millets.

The anti-nutritional parameters of raw and processed foxtail millet flour were shown in Figure 2. Among the different processing techniques, the pressure cooked foxtail millet flour showed high level of tannin content (0.41 mg/g). The total phenolics content was found to be high in roasted (68.1 mg/g) and pressure cooked (67.2 mg/g) foxtail millet flour. Longer the cooking time, the greater losses of the total phenolic compound measured. This could be due to the breakdown of phenolics or losses (leached out) during cooking as most of the bioactive compounds are relatively unstable to heat and easily solubilised. The trypsin inhibitor content of processed foxtail millet flour was considerably reduced with that of raw flour. Cooking by boiling, germinating and frying resulted in a significant reduction in the trypsin inhibitor content of tomatoes [43].

Pasting properties of the selected two raw and processed millet flours

Pasting properties are the important factors in determining the application values of flours and starches [44]. Tables 12 and 13 shows the pasting properties of the raw and processed barnyard millet flour and foxtail millet flour respectively. Pasting temperature is an indication of minimum temperature required for cooking the samples [45]. Pasting temperature of the raw and processed barnyard millet flour ranged from 48.25°C to 94.45°C, being the highest for roasted sample (94.45°C) and lowest for boiled sample (48.25°C). Pasting temperature of the raw and processed foxtail millet flour ranged from 48.5°C to 89.6°C being the highest for raw foxtail millet flour (89.6°C)

and lowest for both boiled and pressure cooked foxtail millet flour (48.5°C).

Peak viscosities attained during the heating portion of tests indicates the water binding capacity of starch mixture. This often correlates with the final product qualities [46]. High peak viscosity indicates the high swelling capacity of the starch granules. High peak viscosity of the raw barnyard millet flour (854cP) and roasted foxtail millet flour (1143cP) indicates its high water binding capacity resulting in more swelling of the starch granules. The ranges observed in trough viscosity of the raw and processed barnyard millet flour and foxtail millet flour were 21 to 741cP and 29 to 420cP respectively.

The breakdown is caused by the disintegration of gelatinized starch granules structure during continued stirring and heating, thus, indicating the shear thinning property of starch [47]. The low breakdown viscosity of both boiled and pressure cooked barnyard millet flour and foxtail millet flour (2cP) indicates its stability of the starches under hot conditions. Final viscosity indicates the ability of the starch to form a viscous paste. The high final viscosity of the raw barnyard millet flour (1235cP) and foxtail millet flour (1398cP) indicates its high resistance to shear.

The setback viscosity is an index of retrogradation. The setback viscosity is the increased in viscosity resulting from the rearrangement of amylose molecules that have leached out from the swollen starch granules during cooling and is generally used as a measure of gelling ability or retrogradation tendency of the starch [48]. The lower setback value of boiled barnyard millet flour (9cP) and roasted foxtail millet flour (-107cP) indicated its lowest rate of retrogradation and hence the product made of low set back viscosity flour will have prolonged shelf life period.

S.no	Minerals	Boiling	Germination	Pressure cooking	Roasting	Raw
1.	Sodium (mg)	22	25	19	16	8
2.	Potassium (mg)	294	320	275	356	252
3.	Iron (mg)	2.59	5.8	3.8	2.4	3.7
4.	Calcium (mg)	40	50	60	31	40
5.	Phosphorus (mg)	221	265	247	280	238

Table 11: Mineral composition of the raw and processed foxtail millet flour (per 100 gms).

S.no	Parameters	Pasting temperature (°C)	Peak viscosity (cP)	Trough viscosity (cP)	Breakdown viscosity (cP)	Final viscosity (cP)	Setback viscosity (cP)
1.	Boiling	48.25	23	21	2	30	9
2.	Germination	49.55	70	21	49	32	11
3.	Pressure cooking	48.35	31	29	2	44	15
4.	Roasting	94.45	101	93	8	196	103
5.	Raw	90.4	854	741	113	1235	494

Table 12: Pasting properties of the raw and processed barnyard millet flour.

S.No:	Parameters	Pasting temperature (°C)	Peak viscosity (cP)	Trough viscosity (cP)	Breakdown viscosity (cP)	Final viscosity (cP)	Setback viscosity (cP)
1.	Boiling	48.50	41	39	2	59	20
2.	Germination	48.60	116	48	68	90	42
3.	Pressure cooking	48.50	31	29	2	37	8
4.	Roasting	50.2	1143	361	782	254	-107
5.	Raw	89.6	521	420	101	1398	978

Table 13: Pasting properties of the raw and processed foxtail millet flour.

Conclusion

There was a significant variation with respect to functional, nutritional, anti-nutritional and pasting properties of selected two millets in response to different processing methods. Among them, germination reduces the anti-nutritional factors while roasting significantly increases the nutritional compounds. The improved functional and pasting properties were observed in the germinated and roasted millet flours that make them good base ingredients in infant food formulation. Considering the above mentioned benefits, it is recommended that the germinated and roasted millet flours would be of use in food systems where these properties are required.

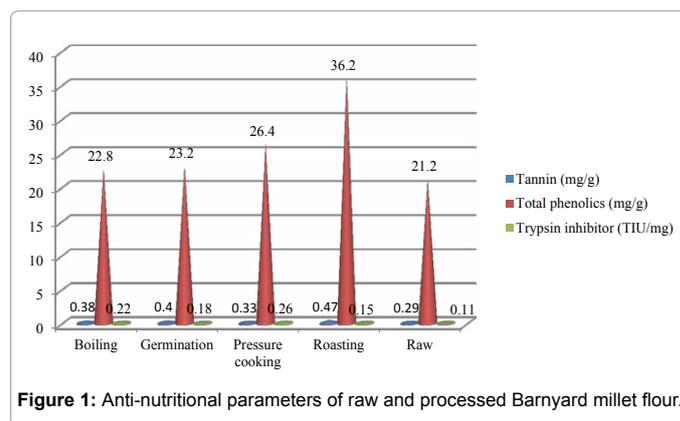


Figure 1: Anti-nutritional parameters of raw and processed Barnyard millet flour.

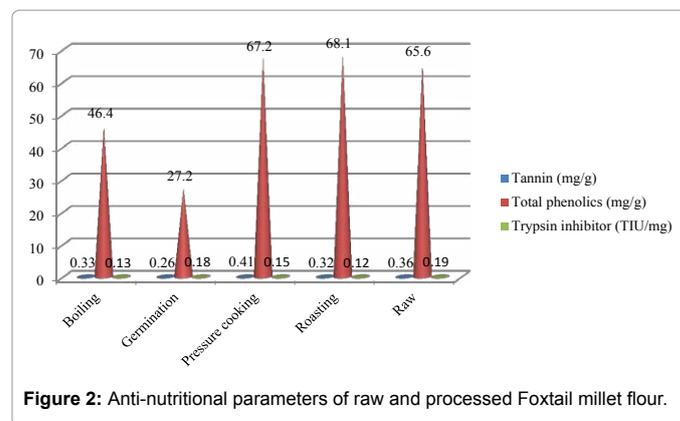


Figure 2: Anti-nutritional parameters of raw and processed Foxtail millet flour.

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