



Effects of Processing (Germination and Popping) on the Nutritional and Anti-nutritional Properties of Finger Millet (*Eleusine coracana*)

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Abstract

This study is aimed to analyze nutrient and anti-nutrient content of finger millet and add value to it through household processing techniques such as germination and popping. Total ash content for WRFMF (Whole Raw Finger Millet Flour), GFMF (Germinated Finger Millet Flour) and PFMF (Popped Finger Millet Flour) were 2.8 ± 0.17 , 2.7 ± 0.10 and 2.88 ± 0.08 (g/100g). Finger millets are good source of protein and in the same line protein content was 6.3 ± 0.20 in WRFMF, 8.8 ± 0.30 in GFMF, 7.1 ± 0.3 g/100g in PFMF. Mineral analysis of processed forms of finger millet revealed that calcium and iron content increased significantly during germination. While during popping of finger millet, calcium content decreased and iron content increased significantly. Phosphorus content decreased in GFMF and increased in PFMF significantly. Statistical analysis for significance was observed at $P < 0.05$. Tannin contents of WRFMF, GFMF and PFMF were found as 870.8 ± 1.05 , 360.5 ± 0.10 , 610.2 ± 2.1 mg/100g respectively. Phytic acid content for WRFMF was 851.4 ± 1.6 mg/100g, in germination it was 238.5 ± 1.3 mg/100g (GMFM) and while in popping it was 333.1 ± 1.07 mg/100g (PFMF). Oxalic acid content and trypsin inhibitor activity decreased after germination and popping process significantly. Results showed that germination and popping increased the nutritional profile and decreased anti-nutrients content in finger millet. The current findings are helpful for nourishing and maximize the human health. Reduction of anti-nutrients enhanced the acceptability, digestibility and bioavailability of nutrient. Household food processing strategies like germination and popping can be used for improving the nutritional quality to promote finger millet utilization.



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Introduction

Finger millet (*Eleusine coracana* L.) is also known as *ragi* and *mandua* in India. It is a good source of nutrients especially of calcium, iron, phosphorus, zinc, potassium, other minerals and fibre. It is a very good source of variety of phenolic compounds which may have health benefits⁸. The main polyphenols are phenolic acid and tannins³³ while flavonoids are present in small quantities²⁸. Polyphenols has been known to impart antimicrobial³⁶, anti-diabetic³⁴, antimutagenic properties⁶. Along these, functional property (gelatinization) is also present in finger millet¹⁸. Finger millet has high amount of tannin content ranging from 0.04 to 3.47 % compared to other millets³². Poor iron availability (low ionizable iron) in brown varieties of finger millet is due to high tannin content which act as adverse effects on the nutritional qualities. Phytate content of finger millet was found in the range of 240 to 300 mg/100g and act as anti-nutrient³³. Household processing such as germination, popping etc. are the best approach to enhance the nutritional level of food stuffs. Germination is a biochemical enrichment tool which involves transition of a seed from dormant state to vital active state. It improves nutritive value of seeds and reduces the level of anti-nutrients as well as maximizes the optimum level of absorbable nutrients¹². Anti-nutrients like tannin, phytic acid, oxalic acid content and trypsin inhibitor which caused low utilization of protein, calcium, iron and zinc in millets¹⁰. Popping is a type of starch cookery which is simplest, inexpensive and fastest traditional method. It is a procedure of dry heat application on kernels of seeds until internal moisture expands, for preparation of healthy ready-to-eat snacks products as well as making weaning foods. As value added health products, home processed (popping) ready-to-eat snacks has great potential for market, efficient for convenient food because consumers are changing into more convenient as well as nutritious and less refined and polished grains²⁰. It is also process of reducing anti-nutrients in millets²⁹. The objective of the study is to analysis nutrient and anti-nutrient content of finger millet and to make them value added through household processing techniques.

Materials and Methods

Finger millet seeds were thoroughly cleaned, remove foreign material and dirt. Thereafter, they were sundried and ground into fine flour or powder in a

mixer and stored. One portion of finger millet seeds was soaked overnight. Next day, water was drained and wrapping of seeds in a muslin cloth and hung in a humid atmosphere for germination. After 48 hours germination, seeds were sundried to remove moisture. Germinated seeds were ground in a mixer and stored in air tight container at room temperature for analysis. Another portion of finger millet seeds were popped and after cooling down, ground in mixer into powdered form and stored in air tight container at room temperature for analysis.

Proximate Analysis

Moisture content was determined by the method of AOAC₂. Ash founded when sample is burned to high temperature (600°C) for 4-5 hours in muffle furnace²⁶. Fat is estimated as crude ether extract of the dry material explained by Raghuramulu, *et al.*, (2003)²⁶. Crude fibre is estimated by subjecting the foodstuff acted upon by a dilute mineral acid and alkali²⁶. Protein was estimated by Kjeldahl method²⁵. Protein based on organic nitrogen when digested with sulphuric acid is converted into ammonium sulphate in the presence of catalyst. By making the solution alkaline, liberated ammonia is distilled into a known volume of standard acid, which is titrated. Protein (g/100g) is calculated by using % Nitrogen x 6.38. Total carbohydrate was calculated by difference, i.e. by subtracting from 100 the sum of the values (per 100 g) for moisture, protein, fat, ash and crude fibre²⁶.

Mineral Analysis

Calcium is precipitated as oxalates. The precipitate is titrated with standard KMnO_4 in the presence of diluted HCL following redox reaction in which KMnO_4 act as a self indicator³¹. One ml of 0.01 KMnO_4 is equivalent to 0.2004 mg of Ca. Phosphorus is founded as suitable aliquot of the solution is taken and treated with molybdic acid to produce phosphomolybdic acid, which is reduced by the addition of 1 amino, 2 naphthol, 4-sulfonic acid (ANSA) and measured the blue color³¹. Concentration of phosphorous (mg/100ml) was calculated using a standard graph plotted by using standard solution of dihydrogen sodium phosphate. Iron is estimated spectrophotometrically making use of the fact that ferric iron gives a blood red color with potassium thiocyanate²⁶.

Vitamin Analysis

Vitamin C calculated (L-ascorbic acid) gets oxidized to its dehydro form. Therefore, vitamin C in 6% metaphosphoric acid is stabilized and titrates with 2, 6, dichlorophenol indophenol solution. Oxidized form of this dye has a red color in acidic medium and blue color in alkaline medium²⁵.

Antinutrient Analysis

Tannins

Tannin content of sample is estimated using modified Vanillin-HCL in methanol. The vanillin reagent reacts with any phenol that has a phloroglucinol nucleus and produces a colored product, which is measured at 500 nm in a spectrophotometer²³.

Tannins (mg/100)=

$$\frac{\text{Optical density of test x conc. of standard x 1000}}{\text{Optical density of standard x volume of extract x weight of sample}}$$

Phytic Acid

This method is based on the determination of pink color complex precipitate as ferric ions complexed with phytate at pH1-2 can't react with thiocyanate ion and the phytate phosphorus content calculated from this value assuming a constant 4 Fe: 6P molecular ratios in the precipitate⁷. Graph of standard was plotted and results were expressed as mg phytic acid/100 g dry wt.

Oxalic acid

Oxalic acid is precipitated as oxalate and is titrated with standard KMnO_4 ²⁵.

$$\text{Oxalic acid (mg/100ml)} = \frac{S - B}{X} \times 0.45 \times 100$$

S = volume (ml) KMnO_4 used for sample titration;
B = volume (ml) KMnO_4 used for a blank titration;
X = volume (ml) of a aliquot of sample.

Trypsin Inhibitor

Trypsin enzymatic activity is assayed using casein as substrate. Inhibition of this activity is measured in the extract¹⁴. Absorbance was plotted against the volume of extract. One trypsin unit (TU) is defined as an increase of 0.01 absorbance units at 20 minutes per 10 ml of the reaction mixture. Trypsin inhibitor

is defined as the number of trypsin units inhibited (TIU).

Statistical Analysis of Data

The statistical method used for the analysis of data for the present study is mean, standard deviation³⁵ and Student's t-test described by Steel and Torrie³⁵. Three times of samples analyses were done and determined means of values. The significant difference was obtained at 5% probability level ($P < 0.05$).

Result and Discussion

Proximate Analysis

Proximate analysis of all versions of finger millet was done and result shown in Table 1. It was found that the moisture content for WRFMF (Whole Raw Finger Millet Flour), GFMF (Germinated Finger Millet Flour) and PFMF (Popped Finger Millet Flour) were 13.1 ± 0.1 , 16.25 ± 0.25 and 12.2 ± 0.2 (g/100g) respectively. Significant difference was found in moisture content of GFMF, PFMF when compared with WRFMF. It showed that during popping moisture content was decreased significantly but vice-versa was seen during germination. Total ash content for WRFMF, GFMF and PFMF were 2.8 ± 0.17 , 2.7 ± 0.10 and 2.88 ± 0.08 (g/100g). After processing, no significant difference was found in ash content for all versions (GFMF and PFMF) when compared with WRFMF. Fat content for all versions were WRFMF; 1.3 ± 0.2 g/100g, GFMF; 2.0 ± 0.2 g/100g, PFMF; 0.63 ± 0.15 g/100g. It was found that fat content in germination increased while decreased during popping significantly. Germination caused fat content to increase significantly in pearl millet observed by Maneemegalai and Nandakumar, (2011)¹⁷. During popping, fat content was decreased significantly. It may be due to lipolytic enzymes are denatured^{15,27}. Finger millet have reasonable crude fiber helps to make it low energy, mark able protein food stuff rich in fiber. For WRFMF, GFMF and PFMF, the crude fiber contents were 18.9 ± 0.2 , 20.0 ± 0.3 , 15.8 ± 0.4 (g/100g). The crude fiber content increased significantly in germinated samples and decreased significantly in popped samples. Similar results for popped samples of millets were founded in many other studies (Chaudhury, *et al.*, 2011)⁵. Millets are good source of protein and in the same line protein content was 6.3 ± 0.20 g/100g in WRFMF,

8.8±0.30 g/100g in GFMF, 7.1±0.30 g/100g in PFMF. Germination process increased the protein content in maize could be due to the result of mobilization of stored nitrogen to produce nutritious and good quality of protein required for the development of young plant⁹. The effect of popping on protein content of millets was favored by Zeenath, (2007)³⁷. Carbohydrate content for all samples such as WRFMF, GFMF and PFMF was 71.9±1.9, 69.2±2.2, and 75.73±0.98 (g/100g) respectively. Reduction of

carbohydrate content could be due to its utilization as an energy source to begin germination process²¹ and increase in α -amylase activity¹². The α -amylase breaks the complex carbohydrates into simple sugar which were utilized in growing seeds in the first phase of germination²². The mean values of carbohydrate content in popped samples were found to be increased significantly similar as observed by different studies^{3,37}.

Table 1: Proximate analysis of finger millet (g/100g)

Versions	Moisture	Total	Crude	Fat ash	Protein fiber	CHO
WRFMF	13.1±0.1	2.8±0.17	18.9±0.2	1.3±0.2	6.3±0.20	71.9±1.9
GFMF	16.25±0.25 ^s	2.7±0.10 ^{ns}	20.0±0.3 ^s	2.0±0.2 ^s	8.8±0.30 ^s	69.2±2.2 ^s
PFMF	12.2±0.2 ^s	2.88±0.08 ^{ns}	15.8±0.4 ^s	0.63±0.15 ^s	7.1±0.30 ^s	75.73±0.98 ^s

^s Significant (P < 0.05), ns Non-significant (P > 0.05)

WRFMF- whole raw finger millet flour, GFMF- germinated finger millet flour, PFMF- popped finger millet

Mineral Analysis

The mineral content analysis of all versions of finger millet was done and result shown in Table 2. It was observed that the calcium content of WRFMF, GFMF, and PFMF were found as 342.4±1.36, 359.6±2.05 and 338.3±1.00 (mg/100g) respectively. Mineral analysis of processed forms of all versions revealed that calcium content increased and decreased significantly during germination and popping respectively. Due to decreases of oxalic acid during sprouting, correspondingly increases calcium content in finger millet because oxalic acid is known to interfere with calcium absorption²⁴. Iron content for WRFMF, GFMF and PFMF were 3.7±0.06, 4.5±0.05 and 5.1±0.1 mg/100g respectively. Significant different was found in GFMF and PFMF iron content. Similar result for germinated maize founded as an 11.4% increase in iron content¹⁹. Phosphorous contents of all versions i.e. WRFMF, GFMF and PFMF were as 280.1±1.23, 272.2±2.0, 282.1±1.1 (mg/100g). Phosphorus content decreased significantly during germination and increase insignificantly during popping of different versions respectively.

Table 2: Mineral and vitamin C estimation of finger millet (mg/100g)

Minerals	WRFMF	GFMF	PFMF
Calcium	342.4±1.36	359.6±2.05 ^s	338.3±1.00 ^s
Iron	3.7±0.06	4.5±0.05 ^s	5.1±0.10 ^s
Phosphorus	280.1±1.23	272.2±2.0 ^s	282.1±1.10 ^{ns}
Vitamin C	0.04±0.01	0.06±0.01 ^s	0

^s Significant (P < 0.05), ns Non-significant (P > 0.05)

WRFMF- whole raw finger millet flour, GFMF- germinated finger millet flour, PFMF- popped finger millet

Vitamin Analysis

Vitamin C analysis of all versions (WRFMF, GFMF and PFMF) revealed that germination process enhance vitamin C content significantly and on popping it not founded; 0.04±0.01 mg/100g -WRFMF, 0.06±0.01 mg/100g- GFMF. Results were shown in Table 2.

Anti-Nutrients Analysis

Table 3 shows the antioxidant content of finger and pearl millet versions. Tannin contents of WRFMF, GFMF and PFMF were found as 870.8±1.05,

360.5±0.10 and 610.2±2.1 mg/100g respectively. Tannin content was significantly decreased during germination as well as popping process. It was founded that reduction of tannin during germination due to leaching¹¹. The reduction of tannin in germination and popping is validated by other studies³⁰. Phytic acid content for WRFMF was 851.4±1.6 mg/100g, in germination it was 238.5±1.3 mg/100g (GFMF) while in popping it was 333.1±1.07 mg/100g (PFMF). Phytic acid content significant decreased due to phytase activity during germination which hydrolyze phytate to phosphate and myoinositol phosphates¹ and increase the availability of phosphorus than phytate, the food than becomes more nutritious. It was observed in other study that phytic acid decreased significantly from 516.57 to 373.82 mg/100g during popping of pearl millet⁴. Whereas, oxalic acid content for all version were WRFMF; 45.8±3.5, GFMF; 29.8±2.06, PFMF; 32.2±1.7 (mg/100g). While, in context of trypsin inhibitor activity resulted of processing in decreasing trends were shown in Table 4. WRFMF, GFMF and PFMF were founded 4188±8.0, 2001±5.1 and 3090±4.5 U/g trypsin inhibitor activity. The apparent decrease in trypsin inhibitor activity during germination may be due to the utilization of trypsin inhibitor as energy source and degradation by peptic and pancreatic hydrolytic enzymes¹⁶. Popping of millets inhibited the trypsin inhibitor activity caused the destruction of protease inhibitors, which destructed in protein digestibility¹³. Results were revealed that anti-nutrients i.e. tannin, phytic acid, oxalic acid and trypsin inhibitor activity content decreased significantly during both processing treatments (germination and popping), but maximum reduction was founded in germination than popping.

Table 3: Anti-nutrient analysis of finger millet (mg/100g)

Versions	Tannin	Phytic acid	Oxalic acid
WRFMF	870.8±1.05	851.4±1.6	45.8±3.5
GFMF	360.5±0.10s	238.5±1.3s	29.8±2.06s
PFMF	610.2±2.10s	333.1±1.07s	32.2±1.7s

^s Significant (P < 0.05), ns Non-significant (P > 0.05)

WRFMF- whole raw finger millet flour, GFMF- germinated finger millet flour, PFMF- popped finger millet

Table 4: Effect of processing on trypsin inhibitor activity (U/g) in finger millet

Versions	Trypsin inhibitor
WRFMF	4188±8.00
GFMF	2001±5.10 ^s
PFMF	3090±4.50 ^s

^s Significant (P < 0.05), ns Non-significant (P > 0.05)

WRFMF- whole raw finger millet flour, GFMF- germinated finger millet flour, PFMF- popped finger millet

Conclusion

Finger millet is rich source of nutrients. In this study it was observed that germination process increased protein content, mineral bioavailability and dietary fibre and reduces anti nutrients like tannin, phytic acid, oxalic acid and trypsin inhibitor activity significantly. It was seen that significant increase was found in protein content of germinated samples and decrease in popping process. Carbohydrate registered a significant decrease in germinated finger millet and an equal significant increase in popped forms respectively. Iron content increased in popping process significantly. It was concluded that food processing methods such as germination and popping, can increased the availability of nutrients and help to fulfill the nutritional needs of poor community. This study was introduced the finger millet as a nutritious food, fulfillment of the nutritional need of global population and founded ways to utilize the finger millet effectively, nutritionally and to alleviate the problems of malnutrition and other health problems.

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