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Impact of popping on the nutritional value and Anti-nutrients in millets

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Abstract
Malnutrition in India is a major problem especially among the rural population. Millets being rich in several nutrients can be an answer to this problem as an economically viable and nutritively highly valued resource. However, the consumption of millets is very less, this may be due to their non-availability as convenient foods. Therefore, an attempt was made in the present study to subject the millet to thermal processing of popping which may help in improving the bioavailability of some nutrients and may prevent the growth of microorganism by lowering the water activity. In the present study three millet grains (viz,) Finger millet (*Eleusine coracana),* Pearl millet (*Pennisetum),* Little millet (*Panicum sumatrense),* were popped by subjecting them to high heat in a traditional popping setup, the popped millets were analyzed for the physical properties (popping yield, expansion volume), nutritional components (fat, protein, carbohydrate, fiber, calcium, phosphorous, iron) and anti-nutrients (oxalates, tannins, phytic acid) using standard AOAC methods. From the results it was observed that there is a significant increase in the macro nutrients and decrease in anti-nutrients in the popped millets compared to native millets.

Keywords: millets, popping, nutrients, anti- nutrients

1. Introduction

Millets belong to the group of cereal crops which are usually small seeded species widely grown around the world for food and fodder. The word 'mil' implies that thousands of grains can be held in a handful. Millets have been classified as major and minor millets based on their grain size. Sorghum and pearl millet come under the category of major millets and the minor millets comprise of Foxtail Millet, Finger Millet, Barnyard Millet, Little Millet, Kodo Millet and Proso Millet. According to FAO statistics (2001), the world production of millets has been 26.7 million metric tonnes from an area of 33.6 million hectare. Africa and India have been the major contributors at global production level. The characteristics of millets are unique as they are sustainable to adverse agro climatic conditions like geographic areas with low soil fertility, rainfall; its resistance to pest and disease and shorter growing season when compared with other major cereal crops and can be considered as crop of food security (Ushakumari *et al*., 2004) [34]. These crops have considerably good potential in broadening the genetic diversity in the food basket and ensuring improved food and nutrition security (Mal *et al*., 2010) [20]. Nutritionally millets can be called as store-houses of nutrition and is miles ahead of rice and wheat in terms of their mineral content. Depending on the species, the proximate composition varies (Bavec and Bavec, 2006) [6]. The calcium content in finger millet is thirty times more than rice while every other millet has at least twice the amount of calcium compared to rice, while the iron content in foxtail and little millet is more compared to rice (Millet Network of India). Finger millet is significantly rich in tannin content, which contributes to its poor protein digestibility (Ramachandra *et al*., 1977) [28]. Along with nutrition, millets offer health benefits in daily diet and help in the management of disorders like diabetes mellitus, obesity, hyperlipidemia, etc. (Veena *et al*., 2013) [35]. Millets have an alkaline pH and are the only grains that keep their alkaline properties even after being cooked. An added advantage with, millet is a gluten free grain and thus, is ideal for people with wheat/gluten intolerance (Baltensperger and Cai, 2004) [5].

Primary processing of millets before consumption involves the partial separation and/or modification of the three major constituents of the cereal grain - the germ, the starch-containing endosperm and the protective pericarp. Traditional methods of processing are still widely practiced, particularly in those parts of the semi-arid tropics where millets are grown primarily for human consumption. Most traditional processing techniques are manual which are laborious, monotonous and is carried out by hand. Traditional techniques that are commonly used include decorticating (usually by pounding followed by winnowing or sometimes sifting), malting, fermentation, roasting, flaking, parboiling, puffing, popping and grinding which also have shown significant impact on the anti – nutrients.

In spite of being nutritionally rich the millet consumption is limited. Non-availability of processed millets in the form of ready to use form and relative difficulty in processing of millet grains as compared to other major cereals are some of the important factors which seem to be affecting their lack of consumption and popularization mainly among the urban masses. Hence a study was undertaken to evaluate the nutritional and anti- nutritional components in millet grains which were subjected to popping process.

2 Materials and Methods

2.1. Sample procurement

Little Millet intact with husk was procured from local farmer from Chitradurga district, Karnataka, India. Pearl Millet and Finger Millet were procured from local market of Mysuru, Karnataka, India.

2.2. Sample preparation

Popping was carried out by sand roasting methods. The procured millets were cleaned and tempered with eight percent of butter milk and kept overnight and was roasted in iron pan at 250^{O}c ± 10^{O}c for 3-4 min, s and then popped millets were separated from the sand using a perforated metal sheet or a wire mesh sieve. The popped millets are then cooled to room temperature before using for further analysis.

2.3. Physical properties

2.3.1. Popping Yield

Popped and un-popped kernels were separated using sieve. The popped yield was calculated as

$$Popped\ Yield = \frac{Weight\ of\ Popped\ kernels\ X100}{Weight\ of\ original\ sample}$$

2.3.2. Expansion Volume

A 100 ml graduated cylinder was filled with popped material and weighed. The unprocessed kernel volume (in ml) of equal weight (in g) for given sample was determined. The average of three measurements was recorded and expansion volume was calculated as

$$Expansion\ vol = \frac{100\ ml\ popped\ kernel}{Weight\ of\ eq.\ wt\ of\ unpopped\ kernel}$$

2.4 Nutrient analysis

2.4.1. Principal nutrients

The sample was homogenized into fine powder using mixer grinder and were used for analysis of nutrient and anti-nutrient parameters.

Nutrient analysis was carried out following 'Official Methods of Analysis of AOAC International' (AOAC, 2012). Moisture content was determined gravimetrically after uniformly drying the test portion in preheated oven (AOAC 934.01). Ash content was determined gravimetrically after reducing the test portion into inorganic matter in Muffle furnace (AOAC 942.05). Total fat content was determined in the petroleum ether extract of the of raw and popped millet flour samples using classic SoxPlus apparatus (AOAC 963.15) after moisture removal. Total nitrogen content was determined by titrimetry in Kjeldahl instrument and multiplied with a conversion factor of 6.25 to obtain the protein content (Jones, 1941) [13]. Insoluble dietary fiber (IDF) and soluble dietary fiber (SDF) were quantified after enzymatic digestion of test portion by Hellendoorns method Bach & Munck, (1984) [4]. The carbohydrate content was calculated by the difference method.

2.4.2. Minerals

Raw and popped millet flour was weighed (1g) in duplicate in silica crucibles for ashing. The ash of the samples were digested by adding 5ml of HCl and 1 ml of distilled water were added and the sample digested in hot plate at 200°C for 10 min. The clear residue thus obtained was diluted with double distilled water and minerals were analyzed using UV colorimeter at suitable detection wavelengths: iron (540.nm), phosphorous (650.nm) (AOAC 965.17). Calcium was analyzed using titrimetry method Francis (1911) [9]

2.4.3. Determination of Anti-nutrients

Estimation of Tannin was carried out by Vanillin Hydrochloride Method Ann., E, (2002), oxalate was estimated using potassium permanganate titration method and phytic acid was estimated by spectrophotometric method Ali *et al*. (1986) [1].

2.5. Statistical analysis

Each nutrient was analyzed in triplicate and expressed per 100g of sample. The results were subjected to two-way analysis of variance (ANOVA) and was derived using International Business Machine Statistical Package for Social Sciences (IBM SPSS Inc. Ver. 23.0).

3 Results and Discussion

3.1 Physical properties

Popping yield: Moisture content plays a significant role in popping as the right amount of moisture is required to increase enough pressure inside the grain so that it can burst open. When the moisture content is low, there is insufficient generation of steam in the endosperm which is required for complete expansion while high moisture content can lead to cracks in the outer seed coat due to swelling which then prevent pressure build-up. Similarly, the temperature of the particulate medium is necessary to change the moisture present inside the grain into superheated steam. Low temperature does not generate sufficient heat inside the grain to convert the moisture into superheated steam and too high temperature can impart a burnt flavor to the grain or, at times, burn the grain.

From the results presented in (Table-1) it is observed that at 220℃ and at moisture percentage ranging from 10.5-12.1 the popping yield was low. A very low popping yield (2.3%) was observed in little millet followed by pearl millet (6.5%) and finger millet (12.3%). When the temperature was increased to 250℃ and moisture percentage ranging from 15.2-16.3 the popping yield had significantly increased, a highest yield of 57.7% which was observed in finger millet followed by pearl millet 50.45% and little millet 48.84%. These results indicated that increase in moisture helps in enhancing the popping yield upto certain limit. Thus, indicating the role of moisture and temperature for better popping yield.

The results obtained in the present study are in agreement with earlier reports of Priyanka (2013) [24] who observed that little millet showed highest popping yield when the moisture levels were between 14% -18% and it was also observed that at temperatures below 220°C the percentage of popped grains was very low with increase in temperature to 250℃ the popping yield increased. Srinivas and Desikachar (1973) [33] reported the highest popping yield in rice to be at 14.0% moisture levels, Malleshi and Desikachar (1981) [19] reported highest popping yield in foxtail millet at 19.0% moisture levels which confirms that moisture, and temperature had significant influence on the popping yield.

Expansion volume: The results presented in (Table-1) have clearly indicated unlike popping yield variation in the moisture content of the grains markedly increased the expansion volume. Significant improvement in expansion volumes of grains occurred as the moisture content was raised from 12.0% to 16.3%. Moisture content of 12% and less, was observed to be inadequate for optimal expansion and maximum expansion was achieved when the grains were tempered at 15.2 -16.3% moisture. Highest expansion volume was observed in little millet (6.2g/ml) followed by pearl millet (5.0 g/ml) and finger millet (4.7g/ml). The increase in expansion volume was 20 %.

Similar results were obtained by Delost- Lewis (1992) [7], that maximum expansion volume of 14.05% was observed when the grains were tempered to 18% moisture and constant pressure of 140 psi in Proso millet. Sabri (2004) reported the highest popping quality, i.e. popping volume, were obtained from grains with a moisture content of 14% in popcorn flakes and as the water content deviates from the optimum, the expansion volume and flake size declined significantly. Hoseney *et al*. (1983) [11] reported the expansion volume increased up to 30% in popcorn containing 13-17% moisture content. Hence it is evident that moisture content in the grain influences the expansion volume of the millets.

3.2. Nutrient analysis

The properties of millets analysed were found to be significantly different in terms of moisture, protein, fat, carbohydrates, ash, and dietary fiber.

Moisture: The moisture content was also found to be significantly different under raw and popped condition (Table-2). The moisture content ranged between 13.0-11.5% in raw condition and 4.8-2.6% in popped condition. Similar results were reported by Rabiaa *et al*. (2006) [26] were the moisture content of sorghum varieties was found to be 8.50-9.13% in raw condition and 3.66-4.83 % in popped condition. Rongrong *et al*. (2018) [31] reported the decrease in the moisture content from 10.41-14.02 to 6.37-8.95 among cereal grains subjected to puffing. Joyce (2013) [14] observed the decrease in moisture content of amaranth seeds on popping from 9.74 to 6.38. The variation in moisture among the millets might be due the variation in temperature in geographical areas while the variation among raw and pooped millets is because the moisture is utilized to build up enough pressure inside the grain so that it bursts open thus losing the moisture from the grain which results in the low moisture content in popped millets was observed by Mubarak (2005) [22].

Protein: The Protein content was also found to be significantly different under raw and puffed condition (Table-2). The variation among raw and popped millets is the slight increase in the protein content. The protein content was found to be in the range of 6.9-10.4 and 9.0-9.7 g/100g in raw and popped condition respectively. Similar findings were reported by Monika *et al*. (2015) the protein content was found to be 9.23 ± 0.11 in raw and 10.91 ± 0.24 popped in condition in maize and 8.36 ± 0.20 in raw and 8.49 ± 0.16 in popped in sorghum. Delosi-Lewis *et al*. (1992) [7] reported increase in protein content of 15.2 on puffing in proso millet. Since the seed coat contains less protein than endosperm MacMasters *et al*. (1971) [17] and it is removed while popping, this might be the reason for increased protein content of popped millet.

Fat: The fat content was also found to be significantly different under raw and puffed condition (Table-2). The fat content ranged between 1.0-7.5 and 1.0-3.4 g/100 g in raw and popped condition respectively. Manisha *et al*. (2011) [18] observed significantly lower fat content (36.2%) in popped millet of yellow variety than its raw counterpart. Rongrong *et al*. (2018) [31] reported the decrease in the fat content on popping in cereal grains. On popping the fat content significantly reduced as in cereals, fat content is found to be more in outer seed coat, hence higher fat content in unprocessed samples MacMasters *et al*. (1971) [17]. As the popped seeds were more with endospermic material, the fat content was lower in popped samples than in raw seeds.

Carbohydrate: The properties of millets tested were found to be significantly different in terms of the carbohydrate content. The carbohydrate content was also found to be significantly different under raw and puffed condition. The carbohydrate content ranged from 71.8-77.9 and 82.3-83.9 g/100 g in raw and popped condition respectively. Carbohydrate content of popped millet was significantly higher than in raw counterparts (Table-2). Monika *et al*. (2015) reported the carbohydrate content to increase from 78.8 to 79.9 in maize and 79.1 to 81.37 g/100g in sorghum on popping. Ritu *et al*. (2018) observed the carbohydrate content varied from 77.18 to 70.73% and 70.77 to 67.90% in the popped and un-popped grains. Increase in carbohydrate content was due to the fact that popped seeds were concentrated more with endosperm which contributes 94% of starch to the kernel MacMasters *et al*. (1971) [17].

Dietary fiber: The properties of millets tested were found to be significantly different in terms of the dietary fiber content (Table-2). The dietary fiber content was also found to be high in raw condition when compared with popped condition. The dietary fiber content ranged from 1.0-7.5 and 1.0-3.4 g/100g in raw and popped condition respectively. Llopart and Drago (2016) reported decrease in fiber content among 28 hybrids of red and white sorghum on popping. Manisha *et al*. (2011) [18] observed the fiber content of popped millet in yellow and purple varieties of foxtail millet to be significantly lower than in raw millet (54.4% and 67.0%, respectively). The fiber content of popped millet were significantly lower than in raw millet (Table-2) In millet seeds there are two sources of fiber i.e. hull or pericarp and the cell wall structural components. During popping, the endosperm puffs out and localized rupture of the cell wall occurs in the expanded endosperm. In this process, the seed coat gets removed to some extent, which could be the reason for lower fiber content in popped sample compared to that of raw samples Hulse *et al*. (1980).

Ash: There was slight difference under raw and popped condition in ash content. The ash content was observed to be 2.4-1.2 and 0.92-1.7 g/100g in raw and popped condition respectively. Delosi-Lewis *et al*. (1992) [7] observed decrease in the ash content from 3.23 to 2.5(g/100g) on processing than in raw condition and stated that this may be due the high pressure the grain is subjected during the popping. Rabiaa *et al*. (2006) [26] reported similar values of ash content in sorghum varieties 1.5-2.16 % to 1.4-2.3% in raw and popped condition respectively. Manisha *et al*. (2011) [18] reported the total ash content of popped millet was found to be significantly lower than in raw counterpart in case of yellow variety (20.8%) Similarly, there was significant decrease in total ash content of popped samples of purple variety on dry matter basis (37.5%). Lopart and Drago (2016) observed the decrease in the ash content by 1.15 times in popped condition among the 28 hybrids of sorghum.

Iron, calcium, and phosphorous

The iron, calcium and phosphorus content was found to be significantly different under raw and popped condition (Table-2). The iron content ranged from 2.1-8.7 and 8.0-10.0 mg/100g in raw and popped condition respectively. Murakami *et al*. (2014) reported increase in iron content in popped condition from 10,700 ± 112 to 11,400 ± 84 µg/100g. Rabiaa *et al*. (2006) [26] reported similar values of iron content in sorghum varieties 3.43- 4.5mg/100 g to 3.6- 3.79 mg/100 g in raw and popped condition respectively. Llopart and Drago (2016) observed the increase in the iron content by 1.3 and 1.6 times after popping for WS and RS, respectively in popped condition among the 28 hybrids of sorghum. The calcium content ranged from 15.1-291.9 and 8.7-187.0 mg/100g in raw and popped condition respectively. Krishnan *et al*. (2012) [29] reported popping the millet, slightly decreased (7 g/100 g) the total calcium content. The phosphorous content ranged from 223.0-279.3 and 129.6-186.5 mg/100g in raw and popped condition respectively. The decrease in calcium and phosphorous content in popped millets was because of the removal of seed coat during popping, which contributes towards the reduction in the total mineral content in the samples.

3.3. Anti-nutrients

It was observed that raw millets had high antinutrient content than in popped millet (Table-3). The anti-nutritional factors get reduced during popping as these components are located mainly in outer layers (bran) of cereal grains and seed coats Sankara Rao and Deosthale (1983) [32] which is effected during popping. Among all the three anti-nutrients the tannins,phytic acid content was found to be significantly high in finger and little millet than in pearl millet. There was significant difference in the antinutrient content in raw and popped condition (Table-3). The oxalate content ranged from 439-968 and 419-571.33 mg/100g, tannins 359-895 and 140.33-539.33 mg/100g and phytic acid 0.04-0.16 and 0.03-0.15 in raw and popped condition respectively. Joyce (2013) [14] reported around 66.4% total oxalates were lost when grain amaranth were subjected to popping. Yanez *et al*. (1994) reported heat causes the reduction in tannins of popped amaranth grains.

Table 1: Physical properties of Popped millets

Popping Yeild									Expansion Volume					
Finger Millet			Pearl Millet			Little Millet			Finger Millet		Pearl Millet		Little Millet	
T (^{0}c)	M (%)	P.Y (%)	T (^{0}c)	M (%)	P.Y (%)	T (^{0}c)	M (%)	P.Y (%)	M (%)	E.V (g/ml)	M (%)	E.V (g/ml)	M (%)	E.V (g/ml)
220	12.1	12.3	220	11.4	6.5	220	10.5	2.3	12.1	-	11.4	1.2	10.5	-
250	16.3	57.7	250	15.5	50.4	250	15.2	48.8	16.3	4.7	15.56	5.0	15.2	6.2

(T- Temperature of particulate medium, M- Moisture, P.Y- Popping yield, E.V- Expansion Volume)

Table 2: Nutrient compostion of raw and popped millets

Nutrients	**Miosture%**		**Protien (g)**		**Fat(g)**		**CH)**		**Ash(g)**		**DF(g)**		**Ca (mg)**		**P(mg)**		**Fe(mg)**	
Millets	R	P*	R	P*	R	P*	R	P*	R	P*	R	P*	R	P*	R	P*	R	P*
Finger Millet	13.0	4.8	6.9	9.7	3.3	2.2	77.9	83.9	1.2	1.0	3.3	2.2	266.6	187.0	278.3	186.5	2.1	9.9
Pearl Millet	12.3	3.4	10.4	9.0	1.0	1.0	71.8	82.3	1.5	0.92	1.0	1.0	291.9	126.6	279.3	129.6	7.4	8.0
Little Millet	11.5	2.6	7.3	9.4	7.5	3.4	74.3	82.3	2.4	1.7	7.5	3.4	15.1	8.7	223.0	143.6	8.7	10.0
F value																		
R Vs P*	204.2**		94.3**		49.2**		46.7**		0.96		47.3**		34.25**		215.0**		36.3	
Millet	301.1**		60.1**		120.0**		29.0**		76.6**		65.4**		92.64**		177.0**		129.1	
R.VsP*X Millet	121.0**		118.2**		461.4**		16.75**		77.6**		52.3**		102.3**		103.1**		187.1	

(CHO- Carbohydrates, DF- Dietary fiber, Ca- calcium,P- Phosphorous, Fe- Iron, R- raw, P* - popped)

Table 3: Antinutrient content in raw and popped millets

Antinutrient	**Tannins**		**Oxalates**		**Phytic Acid**	
Millet	R	P*	R	P*	R	P*
Finger Millet	895.17	539.33	968	440.67	0.14	0.12
Pearl Millet	359.33	140.33	439.33	419.33	0.04	0.03
Little Millet	560	201	922.67	571.33	0.16	0.15
F-Value						
Raw Vs Popped	280.55**		165.19**		6.35**	
Millet	32.36**		72.96**		36.14**	
Raw Vs Popped X Millet	159.01**		47.19**		27.17**	

(R- raw, P* - popped)

4. Conclusion

The study highlights that processing of millets improvises the nutritional content and the not-so-popular little millet can be used as a nutritious food component with improved industrial applications thus broadening the market for little millet, pearl millet and finger millet and can also be used to provide economical, healthy and nutritious choices for the low income populations where little millet is traditionally grown.

Author Contributions

Indu Bhargavi. K designed the study and carried out the analytical work and interpreted the results and drafted the manuscript according to the data collected.

Mrs. Syeda Farah. S helped in designing and carrying out of the experimentation.

Dr. Asna Urooj has been the guiding throughout the course of work and helped in the reviewing of the paper.

Conflicts of Interest (*required*)

There was no conflict of interest in the work.

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