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ORIGINAL ARTICLE

Nutritional evaluation of popped and malted indigenous millet of Assam

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Abstract For better utilization of millets, two processing techniques, viz., popping and malting were standardized using two local varieties of foxtail millet (*Setaria italica*). In popped samples, crude fat and crude fibre contents were significantly lower than raw millet in both the yellow and purple varieties, while the carbohydrate and energy values were significantly higher. In malted samples, crude protein and fat contents were significantly lower than in raw millet in both the varieties, whereas the carbohydrate contents were higher. Starch digestibility was highest (42.4%) in yellow popped samples and lowest in yellow malted samples (21.8%). Protein digestibility was highest (13.2%) in purple popped and lowest (2.4%) in yellow malted samples.

Keywords Foxtail millet · Setaria italica · Digestibility · Proximate composition · Popping · Malting

Introduction

Millets are the staple food in the diet of millions inhabitating in arid and semi-arid regions of the world. Out of 30 million tone of millet produced in the world, about 90% is utilized in developing countries and only a tiny volume is used in the developed countries (FAO 1990). India is the leading millet producer covering 38.6 per cent of total millet production of world and one of the major countries of higher millet utilization (FAO 1995). Millets in India occupy 4–5% of the cultivated area and are confined to vast stretches of dry land and hill areas. By virtue of their composition, small millets are quite comparable to other staple cereals like rice or wheat in their nutritive value, some of them are even better in protein, fat and mineral contents (ICAR 1987; Gopalan et al. 2000). Despite the presence of antinutrients, poor digestibility of protein and carbohydrates and low palatability (Thompson and Yoon 1984; Pawar and Parlikar 1990; Chitra et al. 1996); difficult processings and the poor sensory properties, millets are favourite of the poor mostly due to economic reason. They constitute a cheap source of protein, minerals and vitamins to the poorest of the poor for whom the need for these vital ingredients is very important (Pal et al. 1996). But their utilization is limited due to the presence of anti-nutrients, poor digestibility and low palatability (Thompson and Yoon 1984; Pawar and Parlikar 1990; Chitra et al. 1996). Further, the non availability of refined and processed millet in ready to use form also restricted their use and acceptability only to the poor mass. To increase its popularity among all masses, certain processing techniques such as popping and malting can be easily adopted at household and even at cottage level. A few varieties of millets are sporadically grown and consumed in some parts of Assam and adjoining North-Eastern states with limited utilization. In order to induce dietary diversification in local palate through utilization of locally available millets, the present study was designed with the following objectives, viz., to standardize the popping and malting of millets and to

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determine the effect of popping and malting on its nutrient composition and starch and protein digestibility.

Materials and methods

Purple and yellow varieties of foxtail millets (*Setaria italica*) were selected for the study. To standardize the popping procedure, the method described by Malleshi and Desikachar (1981a) was adopted. The malting of millets was standardized using the method described by Gokavi and Malleshi (2000). Moisture, crude protein, fat, total mineral and crude fibre content of the samples were determined following AOAC (1970) methods. The carbohydrate content was determined by difference (Gopalan et al. 2000). The energy value was determined by multiplying the percentage of crude protein, crude fat and carbohydrate by factors 4, 9 and 4, respectively and the estimation was recorded as kcal/100 g (Gopalan et al. 2000). In vitro starch digestibility was assessed with modification of the methods given by Som et al. (1992) and Kalia (2002). Two per cent slurry of the food material was cooked on a boiling water bath for 15 min. Thirty ml of 0.2 M glycine-HCl buffer (pH 2.2) containing 10 mg of pepsin were added to 50 ml slurry and incubated at 37 °C for 2 h. After incubation, the slurry was neutralized with 0.2 N NaOH and the volume was made up to 100 ml. Five ml of 0.05 M phosphate buffer (pH 6.9) containing 15 mg of pancreatin and 15 mg of amylase were added to 10 ml aliquot and incubated for 2 h at 37 °C. After 30 min, the reaction was stopped by keeping the digest on a boiling water bath for 5 min. Aliquots (0.5 ml) of the sample were mixed with 2 ml of dinitrosalicylic acid reagent for determination of reducing sugar. The absorbance was measured at 550 nm and concentration of the sample was calculated from the standard curve prepared using 0.24–1.2 mg/ml of maltose standard solution. The starch digestibility was expressed as mg of maltose released per g of sample.

In vitro protein digestibility was determined according to the method described by Walter et al. (1983). Slurried samples containing 100 mg of protein were shaken with 12.5 mg of pepsin in 50 ml of 0.1 N HCl at 37 °C for 3 h. Then neutralization was done by 0.5 N NaOH, by using pH meter. After neutralization, 6 mg of pancreatin dissolved in 25 ml of phosphate buffer (pH 8.0) was added to it, and the digestion continued for 24 h at 37 °C. Then the volume was made up to 100 ml and an aliquot (50 ml) was treated with 10% TCA overnight to precipitate the proteins. The suspensions were centrifuged (6,000 × g for 40 min) and the residue (undigested protein) was assayed for protein by micro-Kjeldahl method as mentioned in the determination of protein content. The protein digestibility by pepsin and pancreatin was calculated using the formula:

$$\text{Protein digestibility, \%} = \frac{(\text{Protein content of sample} - \text{Undigested protein})}{\text{Protein content of sample}} \times 100$$

Popping In the standardized process of popping, the whole millet grains of known weight were moistened with 10% moisture and mixed well. Then it was equilibrated in a closed container for 4 h. Sand was heated in iron *karai*. The temperature was maintained at 230 °C. Then the conditioned samples (10 g at a time) were added to sand bed and allowed the seeds to pop for 15 s. After that it was removed from flame and sieved immediately through 12 mesh size sieve.

Malting In the standardized process of malting, the whole millet grains were steeped in 4 times of water for 20 h. Then the water was drained and kept for germination at 25–30 °C for 72 h. After that the sprouted seeds were washed and spread on a blotting paper to remove excess moisture and sun dried. Then the millets were lightly toasted on a skillet at 80–110 °C for 15 min and sprouts were removed by hand abrasion. The toasted millets were then ground to fine powder in an electric grinder and sieved through 40 mesh size sieve. It was stored in air tight container.

Statistical analysis All the data of the chemical analysis were statistically analyzed following the method of Chandel (1999). Mean, standard deviation and paired *t* test were determined during the study. Three replicate samples were used for the experiments.

Results and discussion

Popping Maximum popping yield (30% in case of yellow variety and 26.3% in case of purple variety) was observed at 230 °C, which further reduced at 250 °C. Even the quality of the popped grains was better in terms of puffing and degree of doneness at 230 °C. The popping percentage was low compared to earlier studies (Malleshi and Desikachar 1985). However, a lower popping yield of 34.4% was also reported by Srivastava and Batra (1998). The lower popping percentage of millets studied in the present study could be due to the varietal differences of the grains.

Malting While standardizing malting, germination percentages at different periods were evaluated. The maximum germination percentage of 98 and 92 were recorded for both the yellow and purple varieties respectively, at a steeping period of 20 h, germination period of 72 h and at an atmospheric temperature of 25–30 °C. Malleshi and

Desikachar (1979) reported 67–98% germination in different millet varieties, which supports the observations of the present study. Further, adopting the above combinations of 20 h steeping and 72 h germination, a malting process was standardized.

Nutrient composition Compared to raw samples, slight increase (8.5%) in the protein content of popped samples of yellow variety was observed (Table 1). Likewise in popped samples of purple variety, a marginal increase of crude protein of 9.6% on dry matter basis was recorded. Reported studies on proximate composition were limited. Since seed coat contains less protein than endosperm (MacMasters et al. 1971) and it is removed while popping, this might be the reason for increased protein content of popped millet. Similarly, significantly lower per cent of crude protein was observed in malted samples (12.8%) of yellow variety. As in the case of yellow variety, even the malted samples of purple variety recorded reduced protein level. The values were reduced by 11.7% on dry matter basis. The changes in protein contents during malting may be due to the loss of carbohydrates through oxidation during the process of germination and loss of low molecular weight nitrogenous compounds during soaking and rinsing of the grains. Similar findings were reported by Kumari and Srivastava (2000). Roots and shoots are known to be rich in various nitrogenous compounds. During germination, the increase in the amount of free α-amino nitrogen in roots and shoots is a result of translocation of the products of storage protein breakdown from the kernel (Pelembe et al. 2002). This could be the probable reason for reduced protein content in malted samples.

Significantly lower fat content (36.2%) was observed in popped millet of yellow variety than its raw counterpart. In case of purple variety also, the fat content on dry matter basis was found to be higher (32.4%). In cereals, fat content is found to be more in outer seed coat, hence higher fat content in unprocessed samples (MacMasters et al. 1971). As the popped seeds were more with endospermic material, the fat content was lower in popped samples than in raw seeds. Significantly lower fat content was observed in malted millet (53.3%) of yellow variety than its raw counterpart on dry matter basis. In case of purple variety also significant reduction of crude fat content was recorded (59.7%). Hydrolysis of lipid and oxidation of fatty acids take place during germination of seeds. The hydrolyzed products do not accumulate in the seed, but the glycerol becomes a part of carbohydrate pool and the fatty acids are oxidized through α and β oxidation, resulting in decrease in fat on malting (Mayer and Mayber 1963).

Comparing the values, the total mineral 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 mineral content of

Table 1 Proximate composition (% dwb) of raw and processed foxtail millets (yellow and purple variety)

Nutrients	Raw		Popped		Malted		*t* value			
							Raw vs. popped		Raw vs. malted	
	Yellow	Purple	Yellow	Purple	Yellow	Purple	Yellow	Purple	Yellow	Purple
Crude protein	11.1±0.17	11.8±1.30	12.0±0.32	12.9±0.35	9.7±0.06	10.4±0.28	2.7^{NS}	3.5^{NS}	18.5*	5.1^{NS}
Fat	8.6±0.17	8.7±0.01	5.5±0.24	5.9±0.35	4.0±0.24	3.5±0.21	57.7*	12.0^{NS}	16.0*	33.0*
Total minerals	3.3±0.02	3.7±0.08	2.7±0.03	2.3±0.06	3.0 ±0.02	2.9±0.07	19.8*	14.2*	42.6*	18.0^{*}
Crude fibre	8.2±0.09	8.8±0.07	3.7±0.20	2.9±0.07	7.4±0.08	7.7±0.04	56.7*	58.0*	109.9**	14.5*
Carbohydrate	68.8±0.23	67.0±0.08	76.1±0.38	76.0±0.71	75.9±0.28	75.6±0.04	16.9*	15.9*	19.5*	95.9**
Energy (kcal/100 g)	396.9±1.24	393.4±0.02	401.9±1.16	408.5±1.67	378.2±0.78	375.4±0.93	89.1**	12.9*	13.1*	26.7*

NS Non significant

* $p \leq 0.05$, ** $p \leq 0.01$, ($n=3$)

popped samples of purple variety on dry matter basis (37.5%). Reduced level of mineral in popped millet samples could be due to greater concentration of minerals present in the germ and the bran layers than in endosperm (MacMasters et al. 1971), which contribute to a greater extent towards the amount of total minerals content in whole seeds. There was significant decrease in minerals content of malted samples of both yellow and purple varieties (8.9% and 22.7%, respectively). There was removal of seed coat during malting, which contributes towards the reduction in the total mineral content of malted samples (MacMasters et al. 1971).

The fibre content of popped millet in both the varieties were significantly lower than in raw millet (54.4% and 67.0%, respectively). In millet seeds there are two sources of fibre 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 fibre content in popped sample compared to that of raw samples (Hulse et al. 1980). In the case of yellow variety, malted samples showed significantly lower crude fibre content in both the varieties (9.4% and 12.8%, respectively). Although there were reports of much higher reduction (72.0%) in crude fibre content of refined malted millet (Malleshi and Desikachar 1981b), a reduction of 8.8, 36.0 and 51.5% in malt flours of sorghum, pearl millet and finger millet was also reported (Malleshi and Klopfenstein 1998). This extent of differences might be due to the type of grain and degree of removal of the seed coat. It was reported that a significant decrease in neutral detergent fibre on malting occurred due to cell wall degradation during sprouting process (Aisien 1982; Glennie 1984). In addition, the exclusion of rootlets and shoots of sprouts also appears to influence the fibre content of malted cereals (Chavan and Kadam 1989).

Irrespective of variety, carbohydrate content of popped millet on dry matter basis was significantly higher (10.6% in yellow and 13.4% in purple variety) than in raw counterparts. 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). Increase in carbohydrate contents of malted samples of yellow and purple variety were 17.5 and 12.7%, which were significantly higher than their raw counterparts. Gokavi and Malleshi (2000) reported that during germination, partial degradation of amylopectin occurs and content of amylose increases which contributes to the total carbohydrates. The starch content decreases during germination and this coincides with increases in soluble carbohydrates (Opoku et al. 1983).

Similarly, the energy values of popped millet of both the varieties were significantly higher than in raw counterpart. An increase of energy value in malted samples was also significantly higher than in raw. Increase in energy value of popped samples is due to the increase in the amount of protein and carbohydrate.

Starch and protein digestibility Starch digestibility of popped millets significantly increased in both the varieties recording 42.4% in yellow and 37.5% in purple variety (Table 2). This has been attributed to the release of starch granules from the protein matrix, making the starch content more susceptible to enzymatic digestion. An increase in digestibility after thermal treatments may be attributed to some factors like cell wall encapsulated starch, and physical disintegration of seeds (Tovar et al. 1991). Similarly, significantly higher starch digestibility was also observed when samples were malted. The increase was recorded as 21.8% in yellow variety and 26.6% in purple variety. Bhise et al. (1988) and Chau and Cheung (1997) also reported that germination which is a

Table 2 Effect of popping and malting on starch and protein digestibility of millet samples

	Raw	Popped	Malted	*t* value	
				Raw vs. popped	Raw vs. malted
Starch digestibility, mg maltose eqvt released/g					
Yellow variety	75.2±0	107.1±3.0 (+42.4)	91.6±1.41 (+21.81)	15.2*	16.4*
Purple variety	77.9±0.50	107.0±0.64 (+37.5)	98.6±0 (+26.6)	292.0**	59.2*
Protein digestibility,%					
Yellow variety	79.6±1.31	88.1±0.91 (+10.7)	81.5±1.5 (+2.4)	30.1*	11.7^{NS}
Purple variety	76.7±0.6	86.8±1.18 (+13.22)	84.2±1.17 (+9.8)	24.7*	18.6*

Figures in the parentheses are per cent increase (+) of digestibility in processed state over raw

NS Non significant

* $p \leq 0.05$, ** $p \leq 0.01$, ($n=3$)

primary step of malting significantly improved in vitro starch digestibility in sorghum. It was reported that the solubility of cell wall (Prentice 1976), partial digestion of starch and degradation of amylase inhibitors enhance the overall carbohydrate digestibility on malting (Finney 1983; Marero et al. 1988). Several previous studies indicated that the decrease in the levels of anti-nutrients during soaking, germination and heat treatment might be mostly responsible for the improved in vitro starch digestibility (Singh et al. 1982; Thompson and Yoon 1984; Kataria et al. 1989; Kaur and Kapoor 1990). Furthermore, the enhanced in vitro starch digestibility during these processes might be partly due to the swelling and rupturing of starch granules as well as the activation of amylase and phosphorylase (Kataria and Chauhan 1988; Kaur and Kapoor 1990).

The protein digestibility of both yellow and purple varieties increased significantly after popping. The increase in digestibility was recorded as 10.7% and 13.2% for yellow and purple variety, respectively. This might be due to the localized rupture of the cell wall which occurred in the expanded endosperm during popping (Hulse et al. 1980). The anti-nutritional factors are also get reduced during puffing (Sankara Rao and Deosthale 1983) and this could be the probable reason for increased in vitro protein digestibility. Similarly, in both the varieties, protein digestibility had increased when seeds were malted. In purple variety, the increase was significant (9.8%) while the increase was statistically non significant in yellow variety (2.4%). A similar observation of 7% increase in sorghum protein digestibility was reported by Dreyer (1968). It was reported that the effect of malting on sorghum was attributed to the fact that the corneous protein matrix of the endosperm is more effectively digested by the phytoenzyme liberated during malting than by the enzymes of the gastro-intestinal tract. Makokha et al. (2002) also reported that malting significantly increased (5.8%) protein digestibility. Similarly, according to Archana and Kawatra (2001), malting appreciably improved the in vitro protein (14–26%).

Conclusion

Millets have considerable scope to be utilized as weaning food, because it has better nutritional quality as compared to some other cereals in many respects and studies on this line are progressing. However, locally available foxtail millet (*Koni dhan*) is underutilized because of lack of suitable processing technology. The processed millet obtained as the outcome of the present study will be useful in developing low cost dietary formulations for children as well as geriatrics.

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