Effect of Heat Treatment Parameters on Shelf Life, Nutritional Value and Antinutritional Factors of Barnyard Millet

Abstract

Barnyard millet has been used as food since ages and it is the vital source of highly nutritious macronutrients, micronutrients and nutraceutical constituents. It is important to reinstate the missing interest in millets that desperately need recognition due to its nutritional qualities and substantial health benefits in management of diabetes mellitus, obesity and hyperlipidemia. A number of nations have long grown and utilized barnyard millet as a viable food source. It has been a neglected crop up until now despite the important nutrients and their improved bioaccessibility with different processing procedures. In this study, we employed roasting to extend shelf life, increase in nutrient content, and decrease antinutritional components. To extend the shelf life and increase the bioavailability of vital nutrients, barnyard millet has been roasted at a range of temperatures (between 100°C and 130°C) for a range of times (5, 10, and 15 minutes). Total polyphenols showed bioaccessibility of 8.2%, 9.1% and 9.4% for raw, 105°C for15 minutes and 130°C for 15 minutes roasted at 0 month. Preferably, 130°C for 15 minutes roasted sample showed enhanced shelf life (6 months) and better bioaccessibility of total polyphenols (670 mg/100 g) while nutrient retention is almost similar in all roasted samples.

Key words: Barnyard millet, heat treatment, shelf life, polyphenols, nutritional value and antinutritional factors.

INTRODUCTION

Developing countries such as India, China and a few African countries have been currently focusing on droughtresistant grains due to the water shortage and swiftly enhancing population. Additionally, allocation of morefunds to the scientific research on millets for their use as food source has been increased. Millets show pest anddisease resistance, short growing season and productivity during dearth conditions when compared to mostimportant cereals [Saleh *et al.*, 2013; Anju and Sarita, 2010].Diet plays a potential role in overcomingthese diseases [Surekha *et al.*, 2013]. Therefore, there has been an increasing demand for the functional andhealth foods comprising high antioxidants, minerals and fiber [Goswami *et al*., 2015].Barnyard millet (BM) has been used as food since ages. It is the vital source of highly nutritiousmacronutrients, micronutrients and nutraceutical constituents [Surekha *et al*., 2013]. It is vital minor millet dueto its high quantity of protein (12%) that shows appropriate digestibility (81.13%) together with lowcarbohydrate level (58.56%) of slow digestibility (25.88%) [Surekha *et al*., 2013]. It is also abundant in dietaryfiber (13 g/100g) with fair amounts of soluble (4.66 g/100g) and insoluble (8.18 g/100g) fractions and bettersource of digestible protein (81.13 g/100g digestibility) [Goswami *et al.*, 2015]. BM lacks gluten, hence plays anessential role in the preparation of gluten free foods for gluten intolerant population. In addition, it can easily beblended with other food grains [Goswami *et al*., 2015]. BM is most commonly used as food by poor farmingfamilies and also at times brewed for beer and used as a feed for birds. It has extensively been used in bakeryproducts such as cookies [Surekha *et al*., 2013] and biscuits [Anju and Sarita, 2010] recently. It is important toreinstate the missing interest in millets that desperately need recognition due to its nutritional qualities andsubstantial health benefits in management of diabetes mellitus, obesity and hyperlipidemia [Kumari andThayumanavan 1997, Takhellambam*et al*., 2015]. Therefore, we have used roasting process to enhance bioavailability of nutrients.

MATERIALS AND METHODS

Barnyard milletwas procured from Regional agricultural research station (RARS, Tirupati). All the chemicals were ofanalytical grade and purchased from Himedia, Tirupati, India.Antioxidant activity (DPPH) has been evaluated in raw and roasted (100° and 130° C) BM samples by using AOACmethod at 0, 1, 2, 3, 4, 5 and 6 months.Tyrosine has been studied in raw and roasted (100° and 130°C) BM by using AOAC method at 0, 1, 2, 3, 4, 5and 6 months. The tyrosine content was estimated with progressive storage as a measure of proteolysis insample by using the method of Strange *et al*. [Strange *et al.*, 1977].Tannins have been evaluated in raw and roasted (100° and 130°C) BM samples by using modified vanillin–HClmethod [Price *et al*., 1978] at 0, 1, 2, 3, 4, 5 and 6 months.Phytate has been estimated in raw and roasted (100° and 130°C) BM samples by using the method of Haug andLantzsch [1983], at 0, 1, 2, 3, 4, 5 and 6 months.Polyphenols of raw and processed BM samples were extracted by refluxing the sample powders (2 g) inacidified methanol (20 mL) for 2 h at 60±5° C [Chetan and Malleshi, 2007]. Thereafter, samples were filtered toestimate the quantity of TPP and tannins.Total Polyphenols have been studied in raw and roasted (100° and 130°C) BM by using Folin-Ciocalteu method at 0, 1, 2, 3, 4,5 and 6 months, with some alterations.Bioaccessibility of raw and roasted BM samples was analyzed by using an *in vitro* method described by Luten*et al*. [1996] which involves gastrointestinal digestion with suitable alterations.All the experiments were done in triplicates. p values < 0.05 were considered significant. Analysis of variance(ANOVA) was used to test the differences between raw and roasted groups of BM flours. The data shown intables are an average of triplicate observations.

RESULTS AND DISCUSSION

Dehulled and heat-treated BM has been found to improve type 2 diabetics in which low glycemic index fordehulled millet (50.0) and heat-treated (41.7) was observed [Ugare*et al*., 2011]. Numerous processingtechniques are employed to improve the nutrients, bioaccessibility and decrease antinutritional factors amongwhich roasting plays an essential role. Studies have shown that roasting process significantly increases theamount of iron which may be because of the influx of leached iron from the roasting pan into the sample atelevated temperature. However, a reduction in protein, fat, crude fiber was noticed due to the extinction of a fewamino acids and breakdown of fat [Obadina*et al*., 2016].

DPPH (2,2-diphenyl-1-picrylhydrazyl)

Antioxidant activity of raw BM at 0 month was 125±2 µg/mL but after 6 month storage it was 117±1 µg/mL.Antioxidant activity of raw BM reduced remarkably by 6.4% with time showing maximum at 6 month storage.Although roasting process showed 13% reduction in antioxidant activity y*et al*l roasted samples exhibitedremarkably less reduction (4-8%) in antioxidant activity with 6 month storage duration emphasizing that theroasting process substantially retained the antioxidant potential of BM (Table 1). Roasting process did not affectantioxidant activity of BM, therefore, it is recommended to follow this process for improving shelf life. Severalstudies have demonstrated that thermal treatments probably decrease or increase the phenolic compounds andantioxidant activities based on the severity of heat treatment and duration of treatment and the type of cerealstudied [Hegde and Chandra, 2005]. Numerous studies have suggested that outer layers of millets have a highamount of phenolic compounds and antioxidant activity [Liyana-pathirana and Shahidi, 2007]. In addition, theamount of antioxidants in millets and antioxidant activities vary depending on the factors like species, cultivarand environmental conditions [Bonoli*et al*., 2004]. Processing methods such as soaking and roasting have beennoticed to influence the amount of total phenolic, flavonoid and antioxidant activity of a few dry beans.Roasting or boiling of kodo millet and finger millet reduced the antioxidant activity [Hegde and Chandra, 2005,Pushparaj and Urooj, 2014].

Tannins

Tannins of raw BM showed 25% increase at 6 month storage compared to 0 month. At 0 month the tannins ofBM was1.5±0.5% and at 6 month storage also their level was 2.2±0.2%. Similarly, all the roasted samples alsoshowed an enhancement (24%) with the highest amount of tannins at 130°C 15 minutes treated BM sample(Table 1). Conversely, earlier studies have shown higher TPP in roasted finger millet sample which wasspecifically because of increased tannin quantity as noticed in little millet [Pradeep and Guha 2011]. Tanninsexert numerous health benefits like anti-inflammatory, antiulcer, neuroprotective effect. Another study showed

that roasting reduces anti-nutrients of foxtail millet like tannins and phytic acid from 221.1 to 92.4 mg CAE/100g and 306 to 180.5 mg/100 g but it was assumed to be due to milling of roasted samples [Khapre*et al*., 2021].Ramachandra *et al*., [1977] showed that white grains had lower phenolic content compared to brown grainfoxtail millet (FM) variety and dehulling remarkably enhances *in vitro* protein digestibility (IVPD) [Pawar andMachewad, 2005]. Dehulled and roasted BM sample in this study may show an increased IVPD. Tannins beingnatural polyphenols reduce protein digestibility by attaching with proteins and inhibiting enzymes [Aganga*et al*., 2001].

Phytates

The amount of phytates in BM showed a decrease of 10% from 0 month to 6 month storage period. In the sameway, the amount of phytates in roasted (100°C for 5, 10 and 15 minutes and 130°C for 5, 10 and 15 minutes) BM alsoshowed 15-25% increase 6 months of storage. Phytates, phenols and tannins present in cereals are abundant inantioxidants which play an essential role in health, aging and metabolic diseases [Krings*et al*., 2000]. Phyticacid available in the grains exhibits antioxidant activity by making chelates with pro-oxidant transition metals.Though phytic acid is an antinutrient due to its mineral binding ability, it has been observed to reduce the risk ofcolon and breast cancer in animals [Pushparaj and Urooj, 2014].

Total Polyphenols

TPP of raw BM enhanced remarkably (22%) with time showing maximum at 6 month storage. In fresh sample at 0 month) theTPP of BM was 11±0.5% whereas at 6 month storage it was increased to 14±2%. All the roasted samples alsodemonstrated remarkable enhancement (24-37%) with the maximum TPP at 130°C 15 minutes (Table 1). Inaccordance with our studies, earlier studies also showed that roasting process increases TPP remarkably infinger millet and pearl millet [Hithamani and Srinivasan, 2014]. In another study, roasting of proso millet for 10mins at 110°C has shown significantly increased the total phenolic content from 295 to 670 mg/100 g (ferulicacid equivalent). It was explained that roasting aids the hydrolysis of C-glycosylflavones and release ofsuccessive phenolic compounds [Azad *et al*., 2019]. On the other hand, in another study, the roasting of pearlmillet has significantly reduced the phenolic content from 169.85 to 90.60 mg/ 100 g [Obadina*et al*., 2016,Yousuf *et al*., 2021]. Phenolics of BM and several other millets have also exhibited their potential as reducingagents, singlet oxygen scavengers and metal chelators [Chandrasekara and Shahidi, 2010].

Bioaccessibility

BM comprises a few phytochemicals with strong antinutrient effects [Saleh *et al*., 2013] which canextraordinarily reduce nutrient bioavailability and quality [Devisetti*et al*., 2014]. The analysis of bioavailablepolyphenols is important to evaluate the antioxidative efficacy of the compounds [Hithamani and Srinivasan,2014]. In our study, TPP showed bioaccessibility of 8.2%, 9.1% and 9.4% for raw, 105°C for 15 minutes and 130°C for 15 minutes roasted BM samples respectively at 0 month. Similarly, TPP showed bioaccessibility of 11%,13.3% and 15.6% for raw, 105°C for 15 minutes and 130°C for 15 minutes roasted BM samples respectively at 6months. However, 6 months stored samples did not show significant difference in bioaccessibility. TPP, showed10-13% enhancement in bioaccessibility for 105°C for 15 minutes and 130°C for 15 minutes roasted samplescompared to raw samples [Fig 1]. In accordance with this, earlier studies also demonstrated increasedbioaccessibility of TPP in finger millet and pearl millet [Hithamani and Srinivasan, 2014]. Hence, roastingprocess shows a profound importance both in increasing the shelf life of BM and bioaccessibility of its TPP.It has been shown that the rats fed with a diet of native and treated starch from BM had the lowest bloodglucose, serum cholesterol and triglycerides when compared with rice and other minor millets [Kumari andThayumanavan 1997].Roasting can improve protein digestibility from 22.3 to 60.1% most likely due to vulnerability of protein tohydrolysis [Yousuf *et al*., 2021]. A few studies have shown that processing initiates injury to cell structures andfacilitate the release of bioactive compounds from the matrix, therefore, enhancing the extractability of boundphenolics in the materials [Zeng *et al*., 2016]. It has been shown that rats fed with a diet of native and treatedstarch from BM had the lowest blood glucose, serum cholesterol and triglycerides than rice and other minormillets [Kumari and Thayumanavan 1997].

CONCLUSION

Although millets show potential health benefits, there is no much research and novelty on millet grains/flourswhen compared to conventional cereal grains like maize, sorghum, rice and wheat [Abah*et al*., 2020]. Inaddition, the nutritional value of BM and its ability to be incorporated in novel foods is interesting but itsutilization is inadequate until now. Our study has shown that roasting at 100° and 130°C temperatures did notdecrease nutrients significantly and improved shelf life significantly. Preferably, 130°C for 15 minutes roastedsample showed enhanced shelf life and better bioaccessibility of TPP while nutrient retention is almost similarin all roasted samples.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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Table 1. Effect of roasting on nutritional quality of barnyard millet

Anti-Nutritional Compounds	Treatment	Time of Storage in Months						
		0	1	2	3	4	5	6

DPPH (Antioxidant Activity) μg/mL	Raw	125±2	126±4	123±3	121±3	119±4	118±3	117±1
	100□-5’	116±3	114±2	114±1	114±4	116±3	112±4	109±3
	100□-10’	115±5	113±5	113±5	112±3	115±1	110±3	110±1
	100□-15’	116±3	112±4	114±2	112±1	114±1	107±1	106±2
	130□-5’	117±3	114±3	112±3	115±3	113±2	108±2	106±1
	130□-10’	110±5	109±4	109±4	110±5	108±5	107±1	105±2
	130□-15’	109±4	111±4	108±3	107±5	109±3	105±5	104±3
Total Polyphenols mg/g	Raw	11±0.5	12±0.5	11±0.7	11±1	12±1	13±3	14±2
	100□-5’	13±1	14±0.3	13±0.5	12±0.3	15±0.2	16±1	17±2
	100□-10’	12±1	13±1	14±1	13±0.4	15±0.6	14±0.5	16±0.5
	100□-15’	13±1	14±0.7	14±0.1	12±0.3	14±0.3	15±0.5	17±1
	130□-5’	13±0.4	13±0.8	13±0.4	13±0.5	15±0.4	16±0.4	18±0.7
	130□-10’	12±0.6	13±0.4	14±1	12±1	16±0.8	15±1	18±1
	130□-15’	12±0.9	13±1	13±0.8	11±0.8	16±0.4	16±0.2	19±2
Tannins	Raw	1.5±0.5	1.7±0.7	1.8±0.3	1.6±0.2	1.9±0.1	2±0.3	2±0.2
	100□-5’	2.8±0.4	2.8±0.3	3±0.4	2.9±0.3	3±0.1	3.1±0.1	3.3±0.3
	100□-10’	3±0.8	3.1±0.2	2.9±0.8	3.3±0.5	3.8±0.2	3.6±0.2	3.5±0.1
	100□-15’	3.2±1	3.3±0.1	3.2±0.3	3.1±0.6	3.5±0.4	3.5±0.4	3.6±0.4
	130□-5’	2.9±0.8	3±0.3	2.5±0.4	3±0.7	3.6±0.7	3.8±0.4	3.8±1
	130□-10’	3.2±0.2	3.2±0.5	3.6±0.2	3.2±0.8	3.8±0.8	3.7±0.6	3.9±0.6
	130□-15’	3±0.4	3.2±0.3	3.2±0.4	3.4±0.4	3.9±0.3	3.7±0.2	3.9±0.5
Phytates g/100g	Raw	1±0.1	0.9±0.3	0.8±0.3	0.8±0.1	0.9±0.2	1±0.1	0.9±0.1
	100□-5’	0.9±0.3	0.8±0.1	0.7±0.1	0.7±0.2	0.8±0.1	0.9±0.2	0.8±0.2
	100□-10’	0.8±0.5	0.7±0.2	0.6±0.3	0.6±0.1	0.7±0.3	0.8±0.4	0.7±0.1
	100□-15’	0.7±0.4	0.6±0.2	0.5±0.1	0.5±0.1	0.6±0.2	0.7±0.1	0.6±0.1
	130□-5’	0.6±0.1	0.5±0.2	0.4±0.1	0.4±0.2	0.5±0.1	0.6±0.1	0.5±0.2
	130□-10’	0.5±0.3	0.4±0.1	0.3±0.1	0.4±0.1	0.4±0.2	0.5±0.2	0.4±0.1
	130□-15’	0.4±0.1	0.4±0.1	0.4±0.1	0.3±0.1	0.3±0.1	0.3±0.1	0.3±0.1

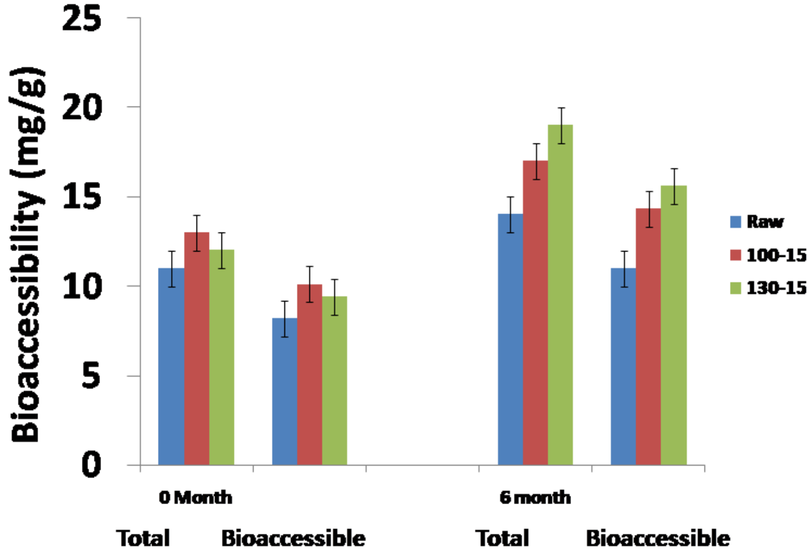

Fig.1: Bioaccessibility of total polyphenols roasted barnyard millets at zero and six months storage