



Development of healthy ready-to-eat (RTE) breakfast cereal from popped pearl millet

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ABSTRACT

In the present investigation attempts have been made to develop nutrient rich Ready to Eat (RTE) breakfast cereal (BC) by the addition of standardized proportion of popped pearl millet. The breakfast cereal was prepared by mixing, baking and cooling popped pearl millet, popped amaranth, puffed wheat, flax seeds, sunflower seeds, raisins, honey, sugar, oil and water. Sensory attributes of breakfast cereal were highly acceptable and had a bowl life of 3 min. The pearl millet RTE-breakfast cereal contained high amount of proteins, dietary fibers, folic acid and minerals such as calcium, phosphorus and iron. The moisture content, protein, fat and crude fiber of breakfast cereal were 3.16 ± 0.05 , 9.34 ± 0.12 , 8.26 ± 0.057 and 0.1 g per 100 g, respectively. The minerals and vitamins like calcium, phosphorus, iron, folic acid and zinc estimated were: 62.79 ± 0.06 , 239.53 ± 0.88 , 5.02 ± 0.02 , 103.21 ± 0.04 and 3.24 ± 0.03 mg/100g, respectively. The analysis also revealed that RTE-BC contain good amount of total dietary fiber (6.13 ± 0.14). On comparison with the market samples like Kellogg's, Beggary etc., the developed breakfast cereal was at par with the market samples for protein, fat, energy, and carbohydrate and was on higher side for folate. The per serving nutrient adequacy of the developed breakfast cereal was 22.8% for energy, 12.80 % for protein, 13% for fat, 34.5% for calcium, 20.5% for iron, and 55.75% of the RDA. Thus, the nutritional superiority of this millet is an added advantage which will help in creation of its space and demand in the food industry.

Key words: Nutrients, Nutrient adequacy, Popped pearl millet

Pearl millet [*Pennisetum glaucum* (L.) R.Br.] locally known as *bajra* is a tolerant, important and most widely grown type of millet in Africa, Indian subcontinent and in arid and semi-arid regions of the world. Pearl millet grain is the staple diet for rural households in the world poorest countries (Basavaraj *et al.* 2010) and provides food to about 500 million people in the arid and semi-arid tropics particularly in Southeast Asia. Pearl millet excels all other cereals because it is a C4 plant with high photosynthetic efficiency and dry matter production capacity. It requires less input, matures in short duration and is considered as nutritious food, feed and fodder. Pearl millet is rightly termed as “nutria cereal” as it is a good source of energy, carbohydrate, protein, fat, ash, dietary fiber, iron and zinc. The protein content of pearl millet is comparable to wheat but higher than rice. With low prolamin fraction,

pearl millet is gluten free grain and is the only grain that retains its alkaline properties after being cooked which is ideal for people with gluten allergy. Pearl millet can find uses in preparing various types of health foods and food ingredients as it contains a relatively higher proportion of insoluble dietary fiber which causes slow release of sugar, thus making the food products suitable for those suffering from or prone to diabetes. Various pearl millet-based food products were found to have a lower glycemic index (GI) than those based on wheat, with the extent of reduction in the GI trait ranging from 20% for biscuits to 45% for dhokla.

Traditionally pearl millets are pulverized to whole meal and are used in the form of unleavened pancake, dumpling, thin porridge etc.; however, processing and diversification of this millet for other food uses and value added products have not been fully exploited (Akinola *et al.* 2017). Even though potential of this millet for preparation of ready-to-eat foods exists but, very little effort has gone on this aspect. Processing and product diversification of this grain has caught lot of attention recently. Nutritional evaluation of the popped pearl millet showed significant decrease in phytic acid, a major anti-nutritional factor in pearl millet. Thus, the nutritive popped grain was found to be very good snack (Chauhan *et al.* 2015, Kumari *et al.* 2018). Like popped rice or corn, the popped pearl millet too was found to have potential to be established in the market, especially

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to derive its nutritional benefits. The exploitation of pearl millet for preparation of ready-to-use products would help in increasing the consumption and thereby nutritional security of consumers. This will not only help in increasing the profitability of its growers but will also help in providing income and employment opportunities in rural area and also contribute to the food basket of the nation in addressing the food security (Verma and Patel 2013). Reddy *et al.* (1990) reported that popped amaranth flour with popped sorghum and pearl millet flour increased protein and total iron contents of the weaning foods. Ready to eat snack mix from minor cereals was found containing adequate amount of protein and minerals and was suitable for all age groups including children. Keeping in view the nutritional facts of pearl millet, a ready to eat breakfast cereal (RTE-BC) based on popped pearl millet was developed and evaluated for its nutritional profile and adequacy.

MATERIAL AND METHODS

Pearl millet variety CZP- 9802 (*Pennisetum glaucum*) was chosen and collected from CAZARI, Jodhpur. Grain amaranths (*Amaranthus gangeticus*), wheat puff (*Triticum aestivum*), flax seeds (*Linum usitatissimum*), sunflower seeds (*Helianthus annuus*) and other ingredients such as sugar, honey, sunflower oil, and resins were procured from local market. The grains were cleaned to remove dust and other inessential materials and stored at room temperature in plastic containers. It followed popping, puffing, roasting, preparation of RTE-BC, sensory analysis, physical analysis and nutrient analysis.

Popping: About 100g of pearl millet was equilibrated to a moisture content of 18% by adding water and tempered for 6 h in a closed container. The tempered grains were popped by high temperature and short time (HTST) treatment in a domestic grain popper (Nova popcorn maker NPC-1212) at $230 \pm 5^\circ\text{C}$ (Pradeep *et al.* (2013).

Puffing and roasting: Puffing of was carried out as described by Amaranth grains were puffed by heating in an iron pan without use of sand as heating medium John *et al.* (2014). The temperature was maintained at around 220°C with stirring continuously by wooden ladle. The grains began to pop after heating for 30 sec. The grains were passed through sieve to separate puffed and unpuffed grains. Flax seeds and sunflower seeds were roasted at a temperature of about 70°C until the seeds turned to light brown color.

Formulation and preparation of RTE breakfast cereal: The breakfast cereal was prepared by the method given by Celis *et al.* (1997) with slight modification. Popped pearl millet was mixed manually with wheat puff, popped amaranth, sunflower seed, flax seeds and raisins in a stainless steel bowl. Sugar syrup was prepared using sugar and water. This mixture was continuously heated at the temp of $50\text{--}60^\circ\text{C}$ with addition of sunflower oil and honey. Finally this prepared syrup mixture was added to the dry ingredients and mixed until it was homogenously dispersed. The resulting mix was spread on baking tray covered with wax paper and baked at $50\text{--}60^\circ\text{C}$ for 15 min

until roasted uniformly. The breakfast cereal was cooled at room temperature (27°C), packaged and stored.

Sensory Analysis: Sensory evaluation of breakfast cereal, prepared with varying formulation of dry ingredients was done to obtain a product with high acceptability. The samples were subjected to sensory evaluations by 10 semi trained panelists using 9-point Hedonic scale (from Like extremely to dislike extremely) to determine the acceptability of product with respect to colour, flavour, taste, texture and overall acceptability (Obatolu *et al.* 2006). Most accepted breakfast cereal on the basis of sensory evaluation was further studied for physical characteristics and nutritional composition.

Physical Analysis: Physical analysis included bowl life and bulk density analysis. Bowl life was measured as the length of time that the cereal can retain its crispness after being soaked in milk. The breakfast cereal samples (5 g) were soaked in 30 ml of milk taken in ten beakers separately. The breakfast cereal was separated from milk at every 2 min interval and was pat dried carefully to remove the superfluous milk without breaking the breakfast cereal. Weight gain was recorded and reported on per cent basis (1998) Puppala. To measure bulk density the volume of 100 g of the product using a measuring cylinder was determined after tapping the measuring cylinder (250 ml) on a wooden plank until no visible decrease in volume was noticed. Based on the weight and volume, the apparent (bulk) density was calculated as suggested by Jones *et al.* (2000).

Nutrient composition: Moisture, crude protein, ash, crude fiber and fat contents were determined according to the methods outline in AOAC (2000). Carbohydrate was calculated by subtracting the sum of moisture, protein, fat, and ash from 100, as advocated by Merrill & Watt (1973). The total calcium, phosphorus, Fe and Zn were estimated as per AOAC. The vitamins E, Niacin and Folic acid were estimated by methodology suggested by AOAC (2005). The soluble, insoluble and total dietary fiber were estimated by the AACC International method (2001) and AACC (2003).

The nutrient adequacy of the popped pearl millet breakfast cereal was assessed by calculating the per cent RDA for per serving size of breakfast cereal comprising of 40 g of the cereal with 120 ml of skimmed milk. The values were calculated per 100 g of dry matter.

Statistical Analysis: The experiments were performed with three independent trials, and data are presented as mean $\pm$ standard deviation (SD). Duncan's Multiple Range Test was applied to differentiate among the means of different samples ($P \leq 0.05$).

RESULTS AND DISCUSSION

Popping is a process that is widely used for making foods from cereals, and millets. It is a type of starch cookery, where grains are exposed to high temperature for short time. Popping of millet grains invariably improves taste and flavor. It is one of the easy and economic processing method to prepare ready-to-eat products. Popping essentially creates a crisp, aerated product with desirable sensory qualities.

This is highly advantageous with respect to pearl millet, as unprocessed pearl millet has very low shelf life. The popping not only improves the shelf life but also improves the nutritional quality with respect to bio availability of nutrients (Pradeep *et al.* 2013, Mishra *et al.* 2014). In the present study, the pearl millet was popped and breakfast cereal was prepared in three different ratio of popped pearl millet to standardize the ingredient composition of the ready to eat cereal (Table 1).

Sensory evaluation of RTE breakfast cereal from popped pearl millet: Organoleptic evaluation of the three pearl millet based breakfast cereal formulations were undertaken on the basis of sensory characteristics such as color, flavor, texture, taste and over all acceptability (Table 2).

Three variant named A1, A2 and A3 were developed from incorporation of whole popped pearl millets each at, 42%, 29.2% and 34.4% respectively. Acceptability evaluation scores of RTE-breakfast cereal (Table 2) reveals that of all products for each attribute, variant A2 was most acceptable with an overall acceptability score of 8.04 ± 0.14 followed by A1. There was a significant difference ($P \geq 0.05$) between variant A1 and variant A2. In terms of appearance, A2 was most preferred followed by variant A1 and A3 respectively. Colour wise preference also followed the same pattern. Texture of variant A2 was given the rank one by the assessors. The product had homogenous texture (8.00 ± 0.00) and contained roasted cereal flavor (8.00 ± 0.25) which was a desirable property. Bunkar *et al.* (2012) also

reported that popping induces desirable aroma and snack products based on them are highly acceptable. Since, A2 sample was highly acceptable as compared to others thus, this variant was used as standardized product and selected for further studies.

The bowl life of the ready to eat breakfast cereal was found to be 3 minutes. The bulk density of the product was 196 kg/m^3 . Bulk density may vary from 80 kg/m^3 to 280 kg/m^3 and more for commercial breakfast cereals (Jones *et al.* 2000).

Nutrient composition of RTE – BC from popped pearl millet: The ready-to-eat breakfast cereal had light cream colour and desirable aroma. The moisture content (3.16 ± 0.05) of the cereal was low as most of the ingredients used for its preparation were popped, which in turn favoured its shelf life (Table 3). The product formed a good source of protein (9.34 ± 0.12), fat (8.26 ± 0.057) and carbohydrate (78.3 ± 0.10) (Table 3). Since the product was ready-to-eat popped pearl millet breakfast cereal, it was found ideal to include popped amaranth which is a familiar cereal, unique for its popping quality, high content of protein and also rich in lysine. Lara *et al.* (2007) reported that amaranth is a potential source of nutrients for breakfast cereal and crunchy bars. Its protein content will further increased if taken with milk. The results showed that the incorporation of puffed amaranth, flax seed and sunflower seed in breakfast cereal were helpful in increasing the nutrient content. Hence this can be helpful in elevating protein deficiency diseases among population.

Minerals and Vitamins composition of RTE-BC: Minerals are important for many physiological functions of the human body. The developed breakfast cereal formed a good source of minerals such as phosphorus (239.53 ± 0.88), calcium (62.79 ± 0.06), iron (5.02 ± 0.02) and zinc (3.24 ± 0.03) (Table 4). Phosphorus is an important mineral for energy

Table 1 Recipe formulation for the development of pearl millet based RTE breakfast cereal

Ingredient	Recipe combination (Formulation)		
	A1	A2	A3
Popped pearl millet	42	29.2	34.8
Sugar	20	20	20
Water	6.3	6.3	6.3
Sunflower oil	6.3	6.3	6.3
Flax seeds		5.0	7.0
Sunflower seed	4.0	10.0	4.0
Popped amaranth	12.0	12.0	12.0
Raisins	4.0	4.0	4.0
Wheat puff	3.2	10.0	3.4
Honey	2.2	2.2	2.2
Total	100	100	100

Table 3 Nutrient composition of RTE-Breakfast cereal

Component	RTE Breakfast cereal
Moisture g/100g	3.16 ± 0.05
Ash g/100g	1.48 ± 0.03
Protein g/100g	9.34 ± 0.12
Total fat g/100g	8.26 ± 0.057
Crude Fiber g/100g	0.1
Carbohydrate g/100g	78.3 ± 0.10
Energy value Kcal/100g	422.4 ± 0.52

Values are mean $\pm$ SE of three replicates.

Table 2 Sensory evaluation of breakfast cereals with different formulations of popped pearl millet

Formulation	Colour	Flavour	Taste	Texture	Overall acceptability
A1	$7.70a \pm 0.21$	$7.70a \pm 0.26$	$7.60a \pm 0.13$	$7.50a \pm 0.25$	$7.56a \pm 0.17$
A2	$8.10b \pm 0.10$	$8.00a \pm 0.25$	$8.10a \pm 0.17$	$8.00a \pm 0.00$	$8.04b \pm 0.14$
A3	$7.40a \pm 1.10$	$8.00a \pm 0.86$	$6.55b \pm 1.10$	$7.05a \pm 0.94$	$7.10a \pm 0.85$

A1: RTE- BC with 42% popped pearl millet, A2: RTE- BC with 29.2% popped pearl millet, A3: RTE- BC with 34.4% popped pearl millet. Values are mean $\pm$ SE of 10 panelists. Means followed by different superscripts in a column differ significantly at $P < 0.05$.

Table 4 Mineral and vitamin profile of breakfast cereal

Minerals (mg/100g)	
Calcium	62.79±0.06
Phosphorus	239.53±0.88
Zinc	3.24±0.03
Iron	5.02±0.02
<i>Vitamins</i>	
Vitamin E (g/100g)	3.86±0.05
Niacin (g/100g)	0.39±0.0
Folic Acid (mg/100g)	103.21±0.04

Values are mean ± SE of three replicates.

production and is an essential component of ATP (the energy store of the body). It also forms an essential part of nervous system and cell membranes (Coulibaly *et al.* 2012). The product was also found to contain very good amount of folic acid (103.21±0.04) and vitamin E (3.86 mg/100g).

Fibers belong to the group of biologically active compounds, and their consumption is of fundamental importance to health. The breakfast cereal is considered to have "high fiber content" (Table 5). In the present investigation the prepared breakfast cereal was found to be rich in fiber, of which 83.19% was soluble and 16.80% was insoluble. The insoluble fraction is related to an increase in fecal matter, therefore, ensuring intestinal peristalsis, avoiding constipation and eliminating the risk of hemorrhoids and diverticulitis. The soluble fraction, in turn, has beneficial effects on insulin metabolism and cholesterol and can be consumed by diabetics because it exerts a hyperglycemic effect by delaying gastric emptying, therefore reducing intestinal transit and glucose absorption (Bernaud and Rodrigues 2013). Because the amount of

Table 5 Dietary Fiber composition of RTE-breakfast cereal (g/100g)

Dietary Fiber	Values	%
Soluble	5.10±0.20	83.20
Insoluble	1.03±0.06	16.80
Total	6.13±0.14	-

Values are mean ± SE of three replicates.

soluble dietary fiber in breakfast cereal was high, it is classified as a functional food.

Nutrient composition of the of ready-to-eat popped pearl millet breakfast cereal in comparison with market samples: The developed ready-to-eat popped pearl millet breakfast cereal nutrient composition was compared with the market samples Kellogg's muesli and Beggary's muesli (Table 6). The developed breakfast cereal was on par with the market samples for energy, fat and carbohydrates. However, the popped pearl millet breakfast provided higher amount of protein as compare to the market samples. Further it was observed that the market sample Kellogg's muesli provided comparatively higher proportions of all micronutrients and iron. However the popped breakfast cereal provided good amount of other macro and micro nutrients when compared with market samples.

Nutrient adequacy of ready-to-eat popped pearl millet breakfast cereal: The per serving nutrient adequacy of the developed breakfast cereal was recorded for energy, protein, fat, calcium, iron, niacin, vitamin E and folate by calculating the per cent RDA. The three servings of the ready-to-eat breakfast cereal will meet 25% RDA for energy and protein and iron nearly 55% RDA for folic acid (Table 7).

The study revealed that popped pearl millet, grain amaranths and puffed wheat can be mixed with roasted sunflower seeds and flax seeds to prepare a RTE- breakfast cereal. The breakfast cereal developed in the present study

Table 6 Nutrient composition of ready-to-eat popped pearl millet breakfast cereal and market sample

Nutrients per 100 g	Breakfast cereal	Market Sample (Kellogg's muesli)	Market Sample (Beggary's muesli)
Energy (kcal)	422.4	382.5	399
Carbohydrate (g)	78.3	75.3	77.2
Protein (g)	9.34	8.5	9.1
Total Dietary Fiber (%)	6.13	6.0	13.5
Fat (g)	8.26	6.5	6.0
Iron (mg)	5.02	14.0	
Calcium (mg)	62.79		
Phosphorus (mg)	239.53		
Zinc (mg)	3.24		
Vitamin E (g)	3.86		
Folic Acid (mg)	103.21	63.0	
Niacin (mg)	390		

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Table 7 Nutrient adequacy of ready-to-eat popped pearl millet breakfast cereal

Nutrients	Breakfast cereal/ 100g	40g serving with 120 ml skimmed milk	RDA	% RDA per serving
Energy (kcal)	422.4	528.9	2320	22.8
Carbohydrate (g)	78.3	37.3		
Protein (g)	9.34	7.65	60	12.8
Total dietary fiber (%)	6.13	2.45	40	6
Fat (g)	8.26	3.30	25	13
Iron (mg)	5.02	3.48	17	20.5
Calcium (mg)	62.79	206.71	600	34.5
Phosphorus (mg)	239.53	190.8	600	31.80
Zinc (mg)	3.24	1.30	12	10.8
Vitamin E (g)	3.86	1.54	8-10	19.25
Folic Acid (mg)	103.21	111.5	200	55.75
Niacin (mg)	3.9	1.56	16	9.75

was nutritionally superior. The production methodology is economical and can be easily adopted at home to industrial scale using locally available underutilized grains. The utilization of whole grain has positive nutritional implications because the bran is retained in the product. It is also cost effective as there are no by-products formed during processing. Sensory analysis also exhibited good overall acceptability. This technology can be adopted and further up-scaled among interested entrepreneurs to process pearl millet based breakfast cereals for commercial purposes.

REFERENCES

- AAAC. 2003. International Method 32-07.01.2003 soluble, insoluble and total dietary fiber in foods and food products. *Approved Methods of Analysis*. 11th ed. Published online at <http://methods.aaccnet.org>.
- AACC. 2001. The definition of dietary fibre. Report of the dietary fiber definition committee to the board of directors of the American Association of Cereal Chemists. *Cereal Foods World* **46**: 112–26.
- Akinola S A, Badejo A A, Osundahunsi O F and Edema M O. 2017. *Effect of preprocessing techniques on pearl millet flour and changes in technological properties* **52**: 992–9.
- AOAC. 2005. Vitamin assays, Turbidimetric Method. AOAC Official Method 960.46
- AOAC. 2000. *Official Methods of Analysis*. 17th (edn). W. Horwitz. AOAC International, Gaithersburg, MD, USA.
- Basavaraj G, Parthasarathy Rao P, Bhagavatula S and Ahmed W. 2010. Availability and utilization of pearl millet in India. *SAT e journal/ ejournal.icrisat.org*. 8:1–6. [accessed Oct 31 2018].
- Bernaude F S R and Rodrigues T C. 2013. Dietary fiber - adequate intake and effects on metabolic health. *Arquivo Brasileiro de Endocrinologia & Metabologia (São Paulo)* **57**: 397–405
- Bunkar D S, Jha A and Mahajan A. 2014. Optimization of the formulation and technology of pearl millet based “ready-to-reconstitute” kheer mix powder. *Journal of Food Science and Technology* **51**(10): 2404–14
- Celis L P C, Rooney L W and McDonough C M. 1997. A ready-to-eat breakfast cereal from food-grade sorghum. *Cereal Chemistry* **73**(1): 108+114.
- Chauhan S S, Jha SK, Jha G K, Sharma DK, Satyvathi T and Kumari Jyoti. 2015. Germplasm screening of pearl millet (*Pennisetum glaucum*) for popping characteristics. *Indian Journal of Agricultural Science*. **85**(3): 344–8
- Coulibaly A, Kouakou B and Chen J. 2012. Extruded adult breakfast based on Millet and Soybean: Nutritional and Functional qualities, Source of low glycemic food. *Journal of Nutrition and Food Sciences* **2**(7): 151.
- John H Muyonga, Brian Andabatiand Geoffrey Sepuuya. 2014. Effect of heat processing on selected grain amaranth physicochemical properties. *Food Science and Nutrition* **2**(1): 9–16.
- Jones D, Chinnaswamy R, Tan Y and Hanna MA. 2000. Physicochemical properties of ready-to-eat breakfast cereals. *Cereal Foods World* **45**: 164–8
- Kumari R, Singh K, Jha S K, Singh R, Sarkar S K and Bhatia N. 2018. Nutritional composition and popping characteristics of some selected varieties of pearl millet (*Pennisetum glaucum*). *Indian Journal of Agricultural Science* **88**(8): 344–8
- Lara N, Mejia A and Cangas A. 2007. Popped amaranth grain and its products breakfast cereal and crunchy bars: Popping process, nutritive value and shelf life. <https://www.researchgate.net/scientific-contributions/82054647>
- Merrill AL and Watt BK. 1973. *Energy value of foods: basis and derivation*. Agriculture Handbook, No. 74. United States Department of Agriculture, Washington, pp 2–4
- Mishra G, Joshi, D C and Panda B K. 2014. Popping and Puffing of Cereal Grains: A Review. *Journal of Grain Processing and Storage* **1**: 34–46
- Muyonga John H, AndabatiBrian and Sepuuya G. 2014. Effect of heat processing on selected grain amaranth physicochemical properties. *Food Science and Nutrition* **2**(1): 9–16.
- Obatolu V A, Omucti C O and Ebenerer A A. 2006. Qualities of extruded puffed snacks from maize/soybean mixture. *Journal of Food Process Engineering* **29**: 149–61.
- Pradeep P M, Dharmaraj U, Sathyendra Rao B V, Senthil A, Vijayalakshmi N S, Malleshi N G and Singh V. 2013. Formulation and nutritional evaluation of multigrain ready-to-eat snack mix from minor cereals. *Journal of Food Science and Technology* **51**(12): 3812–20.
- Puppala V. 1998. Texture comparison of traditional and extruded cornflakes. *Cereal Foods World* **43**(8): 650–2.
- Reddy S N, Waghmare S Y and Pande V. 1990. Formulation of homemade weaning mixes based on local foods. *Food Nutrition Bulletin* **12**: 138–40.
- Verma V and Patel S. 2013. Value added products from nutriceals: Finger millet (*Eleusinecoracana*). *Emiates. Journal of Food and Agriculture* **25**(3): 169–76.