



Storage stability of popped pearl millet based ready to eat breakfast cereal

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ABSTRACT

The study was carried out for the assessment of storage stability of popped pearl millet based Ready to Eat (RTE) breakfast cereal. The RTE breakfast cereal based on popped pearl millet was developed and standardised and storage study was done under ambient conditions (25 ± 28.0 °C and $65 \pm 10\%$ RH) after packaging in Metalized Pouches of 1.36 mm thickness for 3 months. The RTE- breakfast cereal was evaluated for moisture, water activity (a_w), Free Fatty Acids and Peroxide Value and overall acceptability at an interval of 15 days. Microbial count (yeast and mold count) were also determined during the entire period of storage. The results revealed a marginal increase in all the parameters during storage and overall acceptability value was 7.29. No significant change was noticed in the RTE – breakfast cereal and was found with acceptable attributes at ambient conditions. The study illustrated the storage stability and safety of popped pearl millet-based RTE breakfast cereal at ambient storage in metalized pouches throughout three months storage period. Consistent increase in deteriorative quality parameters (moisture content, water activity, FFA, PV) was observed during the storage period. However, no significant difference on sensory evaluation of RTE- breakfast was observed during the storage period. Although there were increases in deteriorative parameters, but none of the parameters suggested initiation of spoilage in the product. The total plate count, yeast, mould count was not detected during the storage period, further indicated safety of the popped pearl millet breakfast cereal product for consumption.

Key words: Free fatty acid, Pearl millet-based breakfast cereal, Peroxide value, Sensory evaluation, Storage,

Important meal of day is the breakfast as it supplies the necessary nutrients to the brain and body after a long gap of time. Breakfast cereals are the healthy choice, as they are made of whole grains which are rich in carbohydrates, low in fat and generally have good amount of fibre and protein. Almost all over the world the breakfast cereals have established firmly on the breakfast tables of the people. They are available in wide variety in terms of taste, forms and colour etc. Ready to Eat (RTE) breakfast cereals are also expected to meet the essential nutrients requirement in daily life. In many RTE cereals the dietary fibre is present, as part of the whole grain or added in the form of wheat bran, oat bran, dried fruits and nuts, or by the additions of other fibre. The breakfast cereals give a countless options for meeting daily recommendations so that intake of whole

grain to be taken by the persons of all age groups. Cereals that are most often used in the formulation of RTE-BC include maize, wheat, oats and rice. The minor cereals-based products; such as pearl millet and other millets are still limited (Kumari *et al.* 2018, Pradeep *et al.* 2013).

Pearl millet commonly known as *bajra* is nutritious and of value especially in the semi-arid-tropics because of its short growing season and higher productivity under heat and drought conditions and is generally cultivated with minimum agricultural inputs. It is nutritionally superior to rice and wheat; good source of carbohydrates, protein, dietary fibre and micronutrients. The nutritional superiority of this millet compared to other cereals also add value for commercial exploitation. Pearl millet is profoundly nourishing, energising and creative that could be creditable extension to anybody's eating regimen yet the bioavailability is low because of certain factors like rapid development of rancidity or bitterness in the flour after 5-10 days of storage (Jalgaonkar *et al.* 2016, Kaced *et al.* 1984, Tiwari *et al.* 2014 and Yadav *et al.* 2012). Processing have varied effects on the mineral composition of the flours, it reduces the anti-nutritional factors and increases the water absorption capacity, oil absorption capacity, least gelation concentration and bulk density of the flours, hence flours could be used in food systems where the above qualities are desirable (Sade 2009).

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Storage quality of any breakfast cereal depends on their moisture, fat content and water activity. Water activity affects the stability of products as under low water activity microbial growth stops, however, enzymatic and chemical reactions could occur and result in food product spoilage (Labuza *et al.* 1982). For any product, the moisture content is the predominant factor in defining its stability and thus shelf life. Moisture content has a significant effect on the sensory crispness and mechanical properties of saltines and corn curls (Katz and Labuza 2006). Packaging of food is also a major concern to determine the oxidative stability of cereal snack products with respect to the effect of oxygen pressure, humidity and water vapour permeability of the packaging material.

Nowadays various types of packaging materials have been developed to prevent the spoilage of food product from air exposure, pH change, moisture and retaining good sensory properties during storage. As such, the study was undertaken to evaluate the qualitative changes in popped pearl millet-based breakfast cereal at ambient condition in metallized pouch that occurred during storage. Various deterioration indicators of food products; moisture content, water activity, microbial load, FFA, PV and sensory quality were determined during storage period.

MATERIALS AND METHODS

Processing methods and preparation of popped pearl millet based RTE breakfast cereal

The breakfast cereal was developed by using 29.2% popped pearl millet (230±5° C for 20-30 seconds) was mixed manually with 10% wheat puff (200 ± 10°C for 3 min), 12% popped *amaranth* (200 ± 10°C for 30 seconds), 5% sunflower seeds, 5% flax seeds and 4% raisins in a stainless-steel bowl. Syrup mixture (sugar, water, sunflower oil and honey) 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 50-60° C (15 min) until toasted uniformly. The breakfast cereal was cooled at room temperature (27°C), packaged and stored as per the procedure followed by Kumari *et al.* (2019). Sample of pearl millet based RTE breakfast cereal was packed in metalized pouch of 1.36 mm thickness at room temperature under ambient condition (maximum temperature: 25.95±28.0°C, minimum temperature: 17.6±12.1 °C and relative humidity: 60±19%) for 3 months.

Quality attributes of pearl millet based RTE Breakfast cereal during Storage

Stored breakfast cereal was withdrawn at 15 days intervals up to 3 months of storage. Analysis of moisture content (%), water activity (a_w), FFA, PV, microbial load and overall acceptability were conducted in each 15 days with new sample packets.

Moisture content

Moisture content of the sample was estimated by

AOAC (2000). The moisture in sample was calculated in percent.

$$\text{Moisture (\%)} = \frac{\text{Initial weight (g)} - \text{Final weight (g)}}{\text{Final weight (g)}} \times 100$$

Water Activity (a_w)

Water activity (a_w) is an important determinant for shelf life of the food product. The sample water activity (a_w) was measured through ROTRONIC (model Hygro lab 3) instrument under controlled temperature condition for 3 months storage period. Each measurement was carried out in triplicate.

Peroxide Value (PV)

Peroxide value was estimated by the given method of Syed *et al.* (2007). Five grams of each stored product weighed into a conical flask (500 ml), in this 30ml acetic acid and chloroform was added and dissolved. Then 0.5 ml of saturated KI solution was added, mixed well and allowed to stand for 1 min. The 430 ml of water, 3-4 drops of starch indicator was added and mixed well. It was titrated against standard 0.01 N sodium thiosulphate until the blue colour disappeared. Similarly, blank was treated in the without sample.

$$\text{Peroxide value (meqO}_2\text{/kg of sample)} = \frac{A \times N \times 1000}{\text{Weight of sample}}$$

Free Fatty Acid (FFA)

Free fatty acid was estimated by the given method of AOAC (2000). In 50 ml neutral ethyl alcohol 5 g of dried sample was mixed into 250 ml conical flask. Afterwards few drops of phenolphthalein indicator were added. The contents were titrated against 0.1N potassium hydroxide (KOH), shake constantly until a pink colour, which persists for 15 seconds. Free Fatty Acid (FFA) content of the sample was expressed as per cent oleic acid in the sample and calculated using the given formula:

$$\text{FFA (as \% oleic acid)} = \frac{282 \times 0.02N \text{ KOH} \times \text{ml of alkali used} \times \text{dilution factor}}{100 \times \text{Weight of sample taken}} \times 100$$

The FFA calculated as oleic acid using the equation:

$$1\text{ml } 0.1N \text{ KOH} = 0.028\text{g oleic acid}$$

Microbiological load

The microbial contamination of the RTE- breakfast cereal was determined during storage. The total plate count and yeast/mold count was determined using the given method of Olunlade *et al.* (2013) in which, the media nutrient agar (NA) used for total plate count (TPC), the potato dextrose agar (PDA) used for yeast and mold counts. Serial dilutions were made for each sample and 1 ml of the appropriate dilution was poured 10⁻² and 10⁻¹ serial dilution were used for pouring plate in triplicate on selective media. Culture media was incubated at 37°C

for 24 h for enumeration of the total microbial load under anaerobic condition. Developed colonies were counted. The number of colonies found on each media were counted after incubation and expressed as log CFU/g.

Sensory evaluation of RTE- breakfast cereal during storage

Breakfast cereal was evaluated for sensory parameters like colour, taste, crunchiness and overall acceptability at different intervals of 0, 15, 30, 45, 60, 75 and 90 days by the panel of 10 selected judges. A panel consisting of 10 people (age group 20 to 30 years) evaluated the product for individual characters as colour, taste, crunchiness and overall acceptability. The 9- point hedonic scale was used to assess the degree of liking that ranged from 'Like very much' to 'Dislike very much' with 'Neither like Nor Dislike' (NLND) as midpoint. Data were analyzed and expressed the number of responses, as percentage (Ranganna 1986; Rath *et al.* 2004).

Data analysis was performed using the statistical package of SPSS, Version 16.0 with a probability of $P < 0.05$. The data of chemical and sensory evaluation were analysed using statistical parameters.

RESULTS AND DISCUSSION

Nutritional composition of the developed popped pearl millet breakfast cereal was determined as protein (9.34%), fat (6.26%), ash (1.48%), iron (5.02 mg per 100 g), zinc (3.24 mg per 100 g), calcium (62.79 mg per 100 g) and phosphorus (239.53mg per g).

Moisture content

The moisture content of any RTE product is important for its shelf life. Generally, moisture content decreases or increases during storage depending upon the storage condition and packaging material. The variation in moisture content was noticed in popped pearl millet RTE breakfast cereal. The value of moisture increased from 3.37% to 4.45% (Table 1) at the end of 3 months of storage period. The results showed that the moisture content ($<12\%$) of breakfast cereal was within the permissible limit all through the storage period.

The increase in moisture content was due to hygroscopic nature of the breakfast cereal, packaging

material permeability and storage environment (change in temperature and relative humidity), as also reported by Nagi *et al.* (2012) for an increase in moisture content of cereal bran enriched biscuit in flexible packaging. The metalized packaging was found better because of higher moisture and oxygen barrier properties.

Water activity

For controlling the shelf-life of food products, water activity is an important mean. The water activity of breakfast cereal increased significantly ($P \leq 0.05$) from 0.17 to 0.40 (approximately 42% increase) in metalized packaging during 3 months storage period (Fig 1). Santa *et al.* (2014) in their study on evaluated changes in cereal muesli with seeds during storage have reported that water activity compared to the fresh prepared muesli ($a_w = 0.56$) decreased, in paper tube it was 0.33, in paper bag – 0.16 and in Doypack – 0.47, whereas Hsieh *et al.* (1990) reported that mechanical properties of biomass based products were affected by the water activity levels. Hence, in present case the water activity of the RTE-BC stored in Metalized Pouch was within the permissible limit (>0.5) during 90 days of storage.

Microbial analysis

In popped pearl millet-based breakfast cereal, no microbial growth was detected on first day of storage. The result exhibited that the number of micro-organism were found to be increased from 0 to 1.99 log CFU/g during storage. All packaged ready to eat breakfast cereal had gradual increase in total plate count (TPC) but remain within acceptable limit during the study period. Parallel results stand reported by earlier investigators like Pradeep *et al.* (2014) in their study on formulation of RTE breakfast cereal reported that the product prepared from popped millets and legumes exhibited good overall acceptability with a shelf life period of 90 days. Deshpande *et al.* (2004) reported total plate count of 4.7 log CFU/g for soy fortified barley based *sattu*. Mridula *et al.* (2013) in their study on

Table 1 Effect of storage period on moisture content and water activity of popped pearl millet RTE-BC

Storage period	Moisture content (%)	Water activity a_w
0	4.87 $\pm$ 0.01	0.175 $\pm$ 0.001
15	4.90 $\pm$ 0.05	0.181 $\pm$ 0.001
30	4.99 $\pm$ 0.05	0.285 $\pm$ 0.001
45	5.06 $\pm$ 0.01	0.289 $\pm$ 0.001
60	5.19 $\pm$ 0.01	0.312 $\pm$ 0.001
75	5.23 $\pm$ 0.07	0.388 $\pm$ 0.001
90	5.35 $\pm$ 0.07	0.401 $\pm$ 0.001

Values are mean $\pm$ SD of three replicates

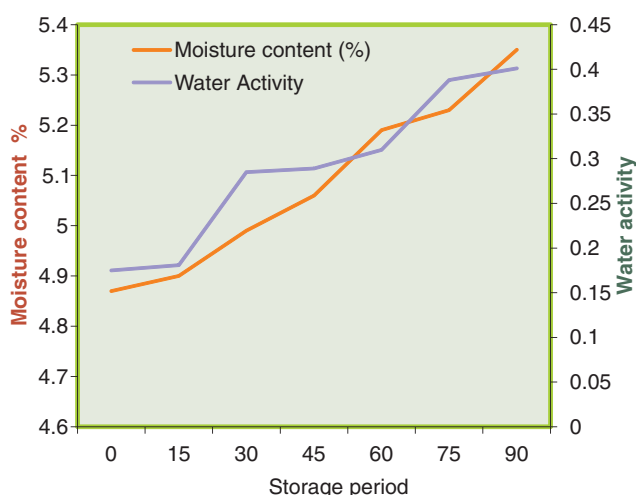


Fig 1 Effect of storage period on moisture content and water activity of RTE breakfast cereal.

Table 2 Microbial population of popped pearl millet RTE-BC during storage

Packaging material	Total Plate Count (TPC) (Log CFU/g)							Yeast/Mold count (Log CFU/g)						
	Storage at ambient condition							Storage at ambient condition						
	0	15	30	45	60	75	90	0	15	30	45	60	75	90
MP	ND	ND	ND	ND	1.60	1.84	1.99	ND	ND	ND	ND	ND	ND	ND

microbial quality of energy bar during 90 days of storage observed increased total plate count of 4.6 log CFU/g, whereas Shanti *et al.* (2000) reported that in dried food product small quantities of free water do not support the growth of microorganisms.

Yeast and mold growth were not detected in the RTE-BC during 90 days of storage period. These results exhibited that breakfast cereal product was acceptable and its contamination level was low, hence, it could be concluded that the product was safe from consumer point of view. Similarly, Yadav *et al.* (2014) reported that yeast and mould count was not observed during 90 days storage period for pasta prepared from a blend of wheat and pearl millet flour (9:1) with vegetable paste (2% dry solids) stored in polyethylene bags (50 µm) under ambient conditions. Dod *et al.* (2003) reported that pearl millet-based products had good shelf life.

Free fatty acid and peroxide value

Storage period had a noticeable effect on free fatty acid, peroxide value of breakfast cereal. A significant increase in the Free Fatty Acid and Peroxide Value was pragmatic with storage period (Table 3). During 3 months of the storage period, FFA and PV in breakfast cereal increased from

0.25% to 0.61% and from 0.80 meq O₂/kg to 1.61 meq O₂/kg of oil, respectively. Similarly, Coulibaly *et al.* (2012) developed extruded adult breakfast based on millet and soybean and they observed that in all blends IPV increased significantly ($p < 0.05$) during storage. They further reported that mixtures which contain germinated millet flour had the highest rates in IPV. For development of off flavours in food the lipids oxidation is one of the major reasons. Lipid oxidation rate is influenced by storage conditions such as light exposure, moisture content, temperature, and pH and oxygen availability (Adetuyi *et al.* 2009). The steady growth in free fatty acids and peroxide value of breakfast cereal, caused by enzymatic hydrolysis of the lipids had also been reported by earlier workers (Mamta 2015) where, the peroxide value of 100% pearl millet popped mixture ranged from 6.51 to 10.04 meq/1000 g fat from day 30 to 90 days of the storage. Similarly, Khatak (2002) found higher FFA in crunchy muesli and differ significantly ($P < 0.05$) at 30 and 60 days when compared to that of 0 day; increase was 33.2 and 71.7% respectively. Similar results were reported by earlier studies on the popped pearl millet mixture in which, PV ranged from 6.51 to 10.04 meq O₂ /100 g fat from 30 to 90 days of the storage (Mamta 2015). Although, there was an increase in FFA and PV value during the storage period, but the occurrence of rancidity or bitter taste in the product was not noticed as observed by sensory evaluation report of the product.

Table 3 Effect of storage period on free fatty acid (FFA) and peroxide value (PV) of popped pearl millet RTE-BC

Storage period (Days)	Free fatty acid (% as oleic acid)	Peroxide value (meq O ₂ /kg)
0	0.25±0.05	0.80±0.11
15	0.29±0.08	0.89±0.04
30	0.35±0.02	1.00±0.02
45	0.45±0.08	1.34±0.01
60	0.52±0.02	1.47±0.03
75	0.56±0.02	1.52±0.01
90	0.61±0.11	1.60±0.02

Values are mean ± SD of three replicates

Sensory evaluation

Colour, texture, crunchiness and taste are the important characteristics for suitability of a food item, and these are also good indicators of the physicochemical changes during storage (Rao *et al.* 1995). Sensory evaluation of the standardized breakfast cereal revealed non-significant effect of storage period on the liking of cereal by the panellists with respect to colour, taste, crunchiness and overall acceptability (Table 4). At the end of three month storage, the sensory score for colour, taste, crunchiness and overall acceptability of breakfast cereal was rated

Table 4 Sensory evaluation of popped pearl millet RTE-BC during storage

	Days						
	0	15	30	45	60	75	90
Colour	8.34±0.25	8.26±0.21	8.20±0.12	8.12±0.22	8.10±0.30	8.07±0.25	8.00±0.16
Taste	8.47±0.19	8.45±0.31	8.40±0.30	8.33±0.32	8.27±0.34	8.17±0.23	8.10±0.23
Crunchiness	8.14±0.30	8.11±0.01	8.06±0.21	8.00±0.25	7.99±0.25	7.95±0.21	7.93± 0.21
Overall acceptability	8.28±0.37	8.18±0.23	8.14±0.22	8.12±0.41	8.00±0.21	8.00±0.21	7.89±0.30

Values are mean ± SD of 10 panellists and significant at $P \leq 0.05$

as 8.00, 8.10, 7.93 and 7.89, respectively, indicating a well acceptable product. The observations were in close concurrence with the observations reported by Gunjan (2011) and Pradeep *et al.* (2013). They studied the sensory analysis of the millet product which revealed that all the sensory parameters they studied were in adequate sequence with mean score of 6.8. Shaheen (2010) developed popped sorghum breakfast cereal and found that the mean sensory scores remained steady during the one month storage period. Premavalli *et al.* (2003) formulated puffed ragi, the sweetened and spiced convenience mix. Both the mixes had a shelf life of 4 and 6 months with 7.70 and 6.00 level of acceptability in each.

Conclusion

The study illustrated the storage stability and safety of pearl millet based breakfast cereal at ambient storage in metalized pouches throughout three months storage period. Consistent increase in deteriorative quality parameters (moisture content, water activity, FFA, PV) was observed during the storage period. However, no significant difference on sensory evaluation of breakfast cereal was observed during the storage period. Although there were increases in deteriorative parameters, but none of the parameters suggested initiation of spoilage in the product. The yeast, mould was not detected during the storage period, which indicated the safety of the product for consumption. Pearl millet being nutritionally better than most other common cereals having high levels of calcium, iron, zinc, lipids and high quality proteins and the observed superiority of developed product the popped pearl millet based RTE can not only provide nutritional security but diet diversity to most people.

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