Ready-to-cook millet flakes based on minor millets for modern consumer

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Abstract There is an increased demand among the consumers for convenient foods for various reasons. Millets such as little, proso, barnyard and ragi were explored for processing into Ready-To-Cook (RTC) millet flakes to meet the needs of modern consumers. Physico-functional and nutrient composition of RTC millet flakes were evaluated against the control (oats flakes and rice flakes). Variation in physical, functional and nutrient composition were observed among the flakes.

Research highlights

- Minor millets are nutritionally superior to major cereals and possess therapeutic benefits for the modern life style. Utilization of millet is limited owing to drudgery associated with its processing. There is a need to provide millet based convenient foods to the modern consumers to reap health benefits associated with millets.
- The research highlights the findings of development of consumer friendly Ready-To-Cook (RTC) millet flakes based on little millet (*Panicum miliare*), proso millet (*Panicum miliaceum*), barnyard millet (*Echinochloa frumentacea*), finger millet (*Eleusine coracana*) without any added chemicals or preservatives.
- The nutritional composition and functional properties of RTC millet flakes were good indicating better utilization than their respective grains. The RTC flakes provide convenience in terms of utilization, storage and acceptability.
- RTC millet flakes exhibited excellent sensory profile in the form of traditional food i.e. *avalakki/poha*. Among the different flakes, the little millet flakes were highly accepted by the consumers.
- The RTC little millet flakes exhibited good shelf life of four months at ambient storage condition (24–31 °C and relative humidity of 42–82 and 61–98 %). The flakes possessed good sensory quality and were microbiologically safe.

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The RTC flakes of minor millets were smaller in size and density but more fragile and crisp than the commercial oats and rice flakes. Higher flake volume (16.35 ml) and lower bulk density was recorded in little millet flakes (0.15 g/ml). Good cooking properties were recorded in all millet flakes. Lowest fat content (0.40 g/100 g) was recorded in little millet flakes whereas proso millet flakes exhibited highest crude protein (14.72 g/100 g) and dietary fiber (21.56 g/100 g). Among the millet flakes, RTC little millet flake was most acceptable in terms of sensory quality and also exhibited good shelf life of four months at ambient temperature of 24–31 °C. The microbial load decreased during storage period and was within permissible limits.

Keywords Ready-to-cook millet flakes · Little millet (*panicum miliare*) · Proso millet (*panicum miliaceum*) · Barnyard millet (*echinochloa frumentacea*) · Ragi (*elusine coracana*)

Introduction

Advancement in science and technology has paved the way in upsurge of food industry. Ready-To-Cook foods are those foods which are partially cooked and can be utilized in a very convenient form within a short duration and it can be considered as one of the alternative home cooked meal. A fast-paced urban lifestyle, increasing dominance of nuclear family structure, rising disposable income, convenience of use have made RTC foods popular. Provision of such RTC foods based on nutritious grains such as millets would be more meaningful in the modern times in the management of life style disorders>

Millets are a group of small seeded species of cereal crops belonging to Gramineae family. The word ‘mil’ refers to thousands of grains that can be held in a handful and millets are

called small, coarse or minor millets probably because of size, utility and coarseness. The group includes millets such as little millet (*Panicum miliare*), foxtail millet (*Setaria italica*), kodo millet (*Paspalum scrobiculatum*), common millet (*Panicum miliaceum*), barnyard millet (*Echinochloa frumentacea*), pearl millet (*Pennisetum glaucum* L.) and ragi (*Elusine coracana*). Millets are also superior to major cereals with respect to nutrient composition and nutritional benefits for the modern life style. They are rich sources of dietary fiber, phyto-chemicals and micro-nutrients (Lue et al. 1991; Chakraborty et al. 2009). Although minor millets are nutritionally superior to cereals, their utilization is limited owing to drudgery associated with its processing (Yenagi et al. 2013). There is a need to restore the lost interest in millets that deserves recognition for its nutritional qualities and potential health benefits in management of diabetes mellitus, obesity and hyperlipidemia (Ravindran 1991; Kumari and Thayumanavan 1997; Itagi 2003; Patil et al. 2014 and Ugare et al. 2014). Provision of such nutritionally superior grains in consumer friendly RTC convenient form would, promote enhanced utilization for better nutrition of the modern consumers and also encourage the farming and processing sectors.

Material and methods

Little, proso and barnyard millets were procured from Millet Research center of Regional Agricultural Research Station, Hanumanamatti and were destoned and dehulled in a commercial millet dehulling machine. Ragi was procured from local market. Dehulled millet grains and ragi were explored for conversion into RTC millet flakes by the application of conventional batch processing methods. The grains were tempered at 10–15 % and subjected to controlled gelatinization in rotary steamer at 180 °C under pressure of 20 to 24 lbs./psi for 20 min, followed by air cooling the grains to surface dryness. The grains were then rolled to flakes in a roller with an aperture size of 0.25 mm. The rolled flakes were sun dried for 4–6 h to approximate moisture content of about 10.5 % and stored for further investigations. Physical characteristics of RTC millet flakes were assessed by procedures of Mishra and Gupta (1995) and Graham (2002). Chromatic measurements were carried out in Konica Minolta, CM- 2600/2500d model Spectrophotometer. Texture of RTC flakes was analyzed in texture analyzer (Stable Micro Systems, Surrey, UK) on the option of breakfast cereal products. Water holding capacity (Deshpande and Poshadri 2011), oil absorption capacity, water absorption index, solubility index (Nawabueze 2006) and cooking properties (Sareepuang et al. 2008) were evaluated. Nutrient composition was assessed by AOAC (1995) procedures, dietary fibre by the methods of Asp et al. (1983), minerals were estimated in Atomic Absorption Spectrophotometer (model: AAS GBC Avanta). Sensory quality

of highly acceptable RTC millet flakes was assessed in the form of wet *avalakki* using 9 point hedonic scale (Amerine et al. 1965) by semi trained sensory panel of Food Science and Nutrition Department. Storage quality of RTC little millet flakes was evaluated by packaging in 200 µ gauge polyethylene pouches and stored at room temperature of 24 °C (42–82 % RH) to 31 °C (61–98 % RH) for 180 days. Storage quality was evaluated in terms of moisture uptake, sensory quality and microbial load viz., bacteria, fungi, *E.coli* and yeast at 0, 90 and 180 days. Microbial load was expressed as number of colony forming units (CFU g⁻¹) per dry weight flakes (AOAC 1996).

Statistical analysis

Statistical analysis was carried out using SPSS package. One way ANOVA was used to assess the significant differences. Data related to texture was analyzed using Exponent (Stable Micro Systems, Surrey, UK) software and average force expressed in g force.

Results and discussion

The physical characteristics of RTC millet flakes are presented in Table 1. Similar results of physical characteristics of little millet RTC flakes was observed by Kotagi (2011). Colour of food is an important attribute which influences acceptability (Ilo and Berghofer 1999). Among millet flakes, lighter hue was observed in proso and little millet RTC flakes. Kotagi (2011) reported that little millet flakes recorded light hue. Bulk density is an index of flake flatness and lower bulk density is a criteria for good flaking quality (Sailaja 1992). Little millet RTC flakes recorded least bulk density (0.15 g/ml) over barnyard, proso and ragi RTC flakes. The bulk density gives a good idea of the storage space required for a known quantity of particular flakes. Lower expansion ratio was recorded in ragi flakes (4.48) as compared to little, barnyard and proso flakes being ragi recorded higher bulk density so lower is the expansion ratio. It was observed that the force required to break the flakes was high for RTC proso millet flakes (45,765.00 force/g) as depicted in Table 1. This could be due to controlled gelatinization prior to flaking and also to higher dietary fiber content (Table 3). Rooney and Pflugfelder (1986) suggested that water uptake by endosperm to be one of the critical factors affecting gelatinization during steam flaking. In the present experiment of RTC flakes development, tempering was limited to around 10–15 % which controlled gelatinization. The matrix of the rolled flakes could have rendered itself hard due to the subsequent retrogradation

Table 1 Physical characteristic of RTC millet flakes

Parameters	RTC millet flakes (Mean $\pm$ SD)				Control (Mean $\pm$ SD)		'F' value	C.D
	Little	Barnyard	Proso	Ragi	Oats flakes	Rice flakes		
1000 flakes weight (g)	2.50 ^d $\pm$ 0.11	3.13 ^{cd} $\pm$ 0.22	3.94 ^c $\pm$ 0.09	3.99 ^c $\pm$ 0.15	15.43 ^b $\pm$ 1.09	17.17 ^a $\pm$ 0.16	611.95	1.757**
1000 flakes volume (ml)	16.53 ^c $\pm$ 0.55	16.13 ^c $\pm$ 0.32	16.03 ^c $\pm$ 0.15	9.33 ^d $\pm$ 1.04	24.33 ^b $\pm$ 0.57	28.33 ^a $\pm$ 1.15	260.70	1.769**
Bulk density (g/ml)	0.15 ^d $\pm$ 0.00	0.19 ^{cd} $\pm$ 0.01	0.24 ^c $\pm$ 0.00	0.43 ^b $\pm$ 0.05	0.63 ^a $\pm$ 0.03	0.60 ^a $\pm$ 0.02	131.68	0.031**
Specific volume (g/L)	2.77 ^c $\pm$ 0.00	3.31 ^d $\pm$ 0.02	4.32 ^b $\pm$ 0.03	2.58 ^f $\pm$ 0.00	4.85 ^a $\pm$ 0.01	3.92 ^c $\pm$ 0.00	743.70	0.640**
Expansion ratio	9.59 ^a $\pm$ 2.14	9.27 ^a $\pm$ 1.56	4.62 ^b $\pm$ 0.12	4.48 ^{bc} $\pm$ 0.77	0.59 ^d $\pm$ 0.01	1.68 ^{cd} $\pm$ 0.08	32.95	1.33**
Length (mm/in.)	3.69 ^c $\pm$ 0.55	3.86 ^c $\pm$ 0.49	3.92 ^c $\pm$ 0.43	4.05 ^c $\pm$ 0.52	7.26 ^b $\pm$ 1.19	12.00 ^a $\pm$ 1.11	179.24	0.240**
Breadth (mm/in.)	3.51 ^c $\pm$ 0.51	3.48 ^c $\pm$ 0.59	3.54 ^c $\pm$ 0.34	3.49 ^c $\pm$ 0.48	5.78 ^a $\pm$ 1.12	4.93 ^b $\pm$ 0.27	25.50	0.144**
L/B ratio (mm/in.)	1.05 ^c $\pm$ 0.05	1.12 ^c $\pm$ 0.11	1.10 ^c $\pm$ 0.08	1.16 ^{bc} $\pm$ 0.10	1.26 ^b $\pm$ 0.11	2.43 ^a $\pm$ 0.15	235.80	0.095**
Thickness (mm/in.)	0.68 ^a $\pm$ 0.17	0.55 ^a $\pm$ 0.21	0.46 ^b $\pm$ 0.07	0.67 ^a $\pm$ 0.18	0.62 ^a $\pm$ 0.08	0.45 ^b $\pm$ 0.16	4.22	0.057**
Colour- 'L'	78.52 ^c $\pm$ 0.05	65.52 ^d $\pm$ 0.04	78.63 ^c $\pm$ 0.05	53.24 ^e $\pm$ 0.13	84.99 ^a $\pm$ 0.10	88.75 ^b $\pm$ 0.52	10,220.00	2.466**
'a'	1.19 ^d $\pm$ 0.03	3.35 ^b $\pm$ 0.05	1.61 ^c $\pm$ 0.03	3.63 ^a $\pm$ 0.08	0.12 ^c $\pm$ 0.00	1.68 ^c $\pm$ 0.10	1361.00	0.782**
'b'	14.60 ^b $\pm$ 0.05	17.26 ^a $\pm$ 0.04	17.06 ^a $\pm$ 0.02	8.25 ^d $\pm$ 0.09	10.73 ^c $\pm$ 0.07	10.46 ^c $\pm$ 0.24	3121.00	1.317**
Texture-Hardness (g)	36,279.00 ^b $\pm$ 3006.11	35,021.00 ^a $\pm$ 3624.06	45,765.00 ^a $\pm$ 2584.64	34,894.00 ^d $\pm$ 3405.51	27,784.00 ^c $\pm$ 1784.23	42,750.00 ^c $\pm$ 2189.79	50.46	10.91**
Cripsness (kg.sec)	72.90 ^b $\pm$ 6.01	70.49 ^b $\pm$ 7.22	91.89 ^a $\pm$ 5.09	70.38 ^b $\pm$ 6.87	85.66 ^a $\pm$ 4.37	55.90 ^c $\pm$ 3.56	50.17	0.487**

Values with different superscripts in a row are significantly different $p \leq 0.01$ **Significant at $p \leq 0.01$; NS-Not significant

Table 2 Functional properties of RTC millet flakes

Parameters	RTC millet flakes (Mean $\pm$ SD)				Control (Mean $\pm$ SD)		'F' value	C.D
	Little	Barnyard	Proso	Ragi	Oats flakes	Rice flakes		
Water holding capacity (%)	5.89 ^{de} $\pm$ 0.55	7.82 ^d $\pm$ 1.89	3.02 ^e $\pm$ 0.34	11.69 ^c $\pm$ 2.51	16.39 ^b $\pm$ 0.21	30.28 ^a $\pm$ 1.27	146.28	2.137**
Water absorption index (%)	193.65 ^c $\pm$ 0.67	182.27 ^c $\pm$ 1.61	160.77 ^d $\pm$ 1.32	257.76 ^b $\pm$ 2.23	131.93 ^e $\pm$ 2.01	572.25 ^a $\pm$ 13.77	2361.00	8.664**
Water solubility index (%)	4.51 ^b $\pm$ 0.28	5.26 ^a $\pm$ 0.46	0.03 ^d $\pm$ 0.00	3.25 ^c $\pm$ 0.14	4.52 ^b $\pm$ 0.12	3.69 ^c $\pm$ 0.10	181.10	0.927**
Oil absorption capacity (%)	120.00 ^a $\pm$ 0.00	120.00 ^a $\pm$ 0.00	119.77 ^a $\pm$ 0.00	120.00 ^a $\pm$ 0.00	100.37 ^b $\pm$ 0.00	80.30 ^c $\pm$ 0.00	20,860.00	3.004**
Cooking time (min)	0.20 ^c $\pm$ 0.00	0.24 ^c $\pm$ 0.00	0.89 ^b $\pm$ 0.26	0.25 ^c $\pm$ 0.01	1.40 ^a $\pm$ 0.05	1.22 ^a $\pm$ 0.02	73.69	1.590**
Increase in weight after cooking (%)	505.04 ^b $\pm$ 40.08	502.60 ^b $\pm$ 52.62	437.00 ^b $\pm$ 75.74	624.38 ^a $\pm$ 39.99	261.04 ^c $\pm$ 14.11	224.10 ^c $\pm$ 1.36	36.13	20.963**
Solid loss (g/g)	0.05 ^{ab} $\pm$ 0.00	0.04 ^{ab} $\pm$ 0.01	0.03 ^c $\pm$ 0.00	0.08 ^a $\pm$ 0.01	0.08 ^{ab} $\pm$ 0.01	0.03 ^c $\pm$ 0.00	5.10	0.192**

**Significant at $p \leq 0.01$ Values with different superscripts in a row are significantly different $p \leq 0.01$

of starch in presence of limited moisture under pressure during the steaming process. The water absorption index (WAI) measures the amount of water absorbed by starch and can be used as an index of starch gelatinization because native starches do not absorb water at room temperature (Seth and Rajamanickam 2012). In the present investigations, WAI was found to be more in rice flakes (572.25 ± 13.77). Among millet flakes, ragi flakes recorded high WAI (257.76 ± 2.23). The differential WAI might be

attributed to the surface of flakes, which can imbibe water into the matrix, differently (Roopa and Premavalli 2008). Water solubility index (WSI) measures the volume occupied by the flakes after swelling in excess water and maintains the integrity of starch in aqueous dispersion. Study revealed that WSI was more in barnyard flakes (5.26 ± 0.46) as compared to oats and rice flakes. Millet flakes recorded higher oil absorption capacity than conventional flakes viz., rice flakes and oats flakes which could be due to high insoluble dietary fiber in

Table 3 Nutrient composition of RTC millet flakes

Nutrient/100 g	RTCmillet flakes (Mean $\pm$ SD)				Control (Mean $\pm$ SD)		'F' value	C.D
	Little	Barnyard	Proso	Ragi	Oats flakes	Rice flakes		
Moisture (g)	11.06 ^a $\pm$ 0.50	12.53 ^a $\pm$ 0.82	10.50 ^b $\pm$ 0.19	13.39 ^a $\pm$ 0.01	5.88 ^c $\pm$ 0.37	13.06 ^a $\pm$ 0.05	136.29	1.158**
Crude fat (g)	0.40 ^c $\pm$ 0.19	0.85 ^c $\pm$ 0.04	0.52 ^c $\pm$ 0.07	0.67 ^c $\pm$ 0.05	8.41 ^a $\pm$ 0.46	1.39 ^b $\pm$ 0.12	636.21	1.201**
Crude protein (g)	7.51 ^f $\pm$ 0.35	11.51 ^c $\pm$ 0.02	14.72 ^a $\pm$ 0.02	8.42 ^c $\pm$ 0.01	14.00 ^b $\pm$ 0.30	9.33 ^d $\pm$ 0.20	733.67	1.217**
Total Ash (g)	2.29 ^b $\pm$ 0.01	2.46 ^a $\pm$ 0.03	1.24 ^d $\pm$ 0.05	2.58 ^a $\pm$ 0.01	1.52 ^c $\pm$ 0.06	1.54 ^c $\pm$ 0.05	475.33	0.506**
Total Carbohydrate (g) ^S	57.71 ^b $\pm$ 0.72	55.86 ^c $\pm$ 0.85	54.64 ^c $\pm$ 0.51	53.65 ^d $\pm$ 0.14	52.84 ^d $\pm$ 0.47	67.72 ^a $\pm$ 0.27	274.33	2.703**
Energy (Kcal) ^S	264.00 ^c $\pm$ 0.88	277.00 ^d $\pm$ 3.21	286.00 ^c $\pm$ 2.15	254.00 ^f $\pm$ 0.80	343.11 ^a $\pm$ 4.04	320.75 ^b $\pm$ 0.12	650.71	6.891**
Insoluble Dietary Fiber (g)	17.70 ^b $\pm$ 0.45	15.26 ^c $\pm$ 0.46	19.63 ^a $\pm$ 0.77	16.86 ^b $\pm$ 0.15	13.66 ^d $\pm$ 0.57	5.33 ^c $\pm$ 0.57	266.63	2.641**
Soluble Dietary Fiber (g)	0.63 ^c $\pm$ 0.25	1.50 ^b $\pm$ 0.50	1.93 ^b $\pm$ 0.40	0.56 ^c $\pm$ 0.15	3.66 ^a $\pm$ 0.57	1.60 ^{bc} $\pm$ 0.52	16.74	1.224**
Total Dietary Fiber (g)	18.33 ^b $\pm$ 0.20	16.76 ^c $\pm$ 0.25	21.56 ^a $\pm$ 0.10	17.70 ^b $\pm$ 0.15	17.43 ^c $\pm$ 0.57	6.93 ^d $\pm$ 0.11	507.83	2.627**
Calcium (mg)	13.32 ^c $\pm$ 0.00	16.92 ^c $\pm$ 0.19	11.84 ^c $\pm$ 0.19	222.67 ^a $\pm$ 19.28	67.33 ^b $\pm$ 0.00	19.95 ^c $\pm$ 0.21	333.52	15.141**
Iron (mg)	16.39 ^b $\pm$ 0.28	14.85 ^c $\pm$ 0.05	11.59 ^d $\pm$ 0.19	13.89 ^c $\pm$ 0.14	9.40 ^e $\pm$ 0.13	18.76 ^a $\pm$ 0.65	466.51	4.836**
Zinc (mg)	2.86 ^d $\pm$ 0.06	3.89 ^c $\pm$ 0.10	1.54 ^e $\pm$ 0.06	2.57 ^d $\pm$ 0.01	4.56 ^b $\pm$ 0.02	5.14 ^a $\pm$ 0.22	451.47	1.926**
Copper (mg)	0.60 ^b $\pm$ 0.06	0.71 ^b $\pm$ 0.55	1.75 ^a $\pm$ 0.07	0.82 ^b $\pm$ 0.08	0.72 ^b $\pm$ 0.00	0.78 ^b $\pm$ 0.09	120.12	1.083**
Manganese (mg)	1.63 ^c $\pm$ 0.16	0.89 ^d $\pm$ 0.07	1.50 ^c $\pm$ 0.16	5.56 ^a $\pm$ 0.161	4.09 ^b $\pm$ 0.02	5.85 ^a $\pm$ 0.19	713.17	1.740**

Values with different superscripts in a row are significantly different $p \leq 0.01$ Significant at ** $p \leq 0.01$ ^S Computed value

Table 4 Mean sensory scores of different millet flakes

RTC millet flakes	Appearance and Colour	Taste	Aroma	Texture	Overall acceptability	Total Score	Acceptability index
Little	8.50	8.12	8.12	8.37	8.25	41.36	91.91
Proso	7.75	7.12	6.75	7.12	7.00	35.74	79.42
Barnyard	7.00	7.00	6.62	6.75	6.62	33.99	75.53
Ragi	6.12	6.00	6.00	6.00	5.87	29.99	66.64
Mean	7.34	7.06	6.87	7.06	6.93	35.22	78.26
'F' value	6.04	5.32	7.40	9.09	10.88		
SEm±	0.177	0.165	0.161	0.167	0.162		
C.D.	0.694**	0.647**	0.632**	0.654**	0.633**		

Significant at ** $p \leq 0.01$

millet (21.56 %) which have capacity to hold water (Tables 2 and 3). Least cooking time was observed in little millet (0.20 min) and followed by barnyard millet (0.24 min) RTC flakes.

It was noticed that all the RTC millet flakes exhibited significantly lower fat (0.40–0.85 g/100 g, Table 3) than the native grain (0.85–4.39 g/100 g, Gopalan et al. 2004) which could be due to dehulling and decortication operations carried out during millet processing. Sailaja (1992) reported that dehulling process involved in the preparation of flakes resulted in reduction of ether extracts as fat contents were higher in outer coats of grains. Patil et al. (2014) reported that RTC little millet flakes recorded low fat (0.44 %) content which was attributed to formation of amylose-lipid complex owing to lower extractability (Samahay et al. 2007) compared to grain (1.49 %). The carbohydrate (52.84–67.72 g/100 g) content was significantly lower in all the RTC millet flakes in comparison with native grains (67.0–78.2 g/100 g, Gopalan et al. 2004).

Dietary fiber is one of the primary determining factors to evaluate quality of products constituting the base of nutrition pyramid and it is one of the important nutraceutical components with wide range of health benefits. The soluble and total dietary fiber (TDF) content increased in RTC flakes as compared to native grain. The increase in soluble dietary fiber could be due to depolymerization and/or solubilization of non-starch polysaccharides during steam gelatinization under pressure. Increased TDF could have resulted from the formation of enzyme resistant macromolecules containing starch, protein, lipid, and/or non-starch polysaccharides (Huber 1991). Patil et al. (2014) suggested that the increase in dietary fiber content in flakes could be due to development of resistant starch during moist steaming and cooling cycles performed during processing. High TDF content was recorded in proso RTC millet flakes (21.56 g/100 g) millet flakes. The iron content of flakes was high compared to native grains (0.7 g/100 g), which could be contaminated iron due to machinery. Similar results were also indicated in little millet flakes (32.23 mg/100 g) by Patil and associates (2014). Such

phenomenon could be observed in elevated levels of iron in rice flakes (20 mg/100 g) than paddy (Gopalan et al. 2004).

Sensory evaluation of RTC flakes revealed that little millet flakes in the form of *avalakki* was highly acceptable with the acceptability index of 91.91 % compared to other millet *avalakkis* (Table 4). This could be due to better physical attribute of little millet flakes (Table 2). Patil et al. (2014) reported RTC little millet *avalakki* exhibited an acceptability index of 81.11. Ragi *avalakki* was not attractive (6.12) due to the dark hues (Table 1) and the panelists opined that it exhibited fibrous texture and was chewy with a mean total score of 29.99 and acceptability index of 66.64.

Storage quality evaluation of little millet RTC flakes revealed low moisture uptake from 11.06 at initial to 12.26 % in the fourth month, indicating good shelf life of the flakes (Fig. 1). Similar findings was reported by Patil et al. (2014) in little millet flakes. The stored little millet RTC flakes indicated that sensory profile in the form of wet *avalakki* decreased during storage period however the product was acceptable upto 4 months of storage with an acceptability index of 76.66 (Table 5).

The population of bacteria, fungi, *E.coli* and yeast at 0, 90 and 180 days of storage in little millet flakes are depicted in Table 6. Highest population of bacteria was recorded with 10^{-2} dilution at zero days (2.62 log₁₀ CFU g⁻¹ flakes) which gradually decreased at 180 days of storage (0.67 log₁₀ CFU g⁻¹).

Fig. 1 Moisture content of RTC little millet flakes during storage

Table 5 Mean sensory scores of RTC little millet flakes during storage

Parameters	Months of storage (Mean $\pm$ SD)					Total mean	'F' value	SEm $\pm$	C.D
	0	1	2	3	4				
Appearance and colour	8.50 ^a $\pm$ 0.84	8.40 ^a $\pm$ 0.51	8.20 ^a $\pm$ 0.63	8.20 ^a $\pm$ 0.42	8.10 ^a $\pm$ 0.56	8.28 $\pm$ 0.59	0.47	0.02	NS
Taste	8.12 ^a $\pm$ 0.69	8.10 ^a $\pm$ 0.73	8.00 ^a $\pm$ 0.00	7.70 ^{ab} $\pm$ 1.15	6.60 ^b $\pm$ 1.77	7.70 $\pm$ 1.18	4.36	0.04	0.15**
Aroma	8.12 ^a $\pm$ 0.82	8.10 ^a $\pm$ 0.63	8.00 ^a $\pm$ 0.56	7.70 ^b $\pm$ 0.56	6.00 ^c $\pm$ 0.47	7.58 $\pm$ 0.60	4.33	0.02	0.18**
Texture	8.37 ^a $\pm$ 0.00	8.37 ^a $\pm$ 0.47	8.37 ^a $\pm$ 0.66	7.80 ^{ab} $\pm$ 0.63	6.80 ^b $\pm$ 1.54	7.94 $\pm$ 0.92	3.92	0.03	0.13**
Overall acceptability	8.25 ^a $\pm$ 0.67	8.20 ^{ab} $\pm$ 0.42	8.20 ^{ab} $\pm$ 0.42	7.80 ^{ab} $\pm$ 0.91	7.00 ^b $\pm$ 1.69	7.89 $\pm$ 1.03	3.19	0.03	0.10*
Total Score	41.36 ^a $\pm$ 2.67	41.17 ^a $\pm$ 1.28	40.77 ^a $\pm$ 1.26	39.20 ^{ab} $\pm$ 2.71	34.50 ^b $\pm$ 4.74	39.78 $\pm$ 3.24			
Acceptability index	91.91 ^a $\pm$ 5.94	91.48 ^a $\pm$ 2.85	90.60 ^a $\pm$ 2.82	87.11 ^{ab} $\pm$ 6.03	76.66 ^b $\pm$ 10.54	88.40 $\pm$ 7.20			

Values with different superscripts in a row are significantly different $p \leq 0.01$

**Significant at $p \leq 0.01$; NS Not significant

Similar findings were also reported by Ui et al. (2009), who revealed decline in number of pathogens in dry flakes and Ayo et al. (2011) in egg-soybean hull-millet composite weaning food. Further, it was observed that the fungal population was $1.53 \log_{10}$ CFU g^{-1} at zero days and was not detected at 180 days of storage. *E. coli* population at initial was $1.49 \log_{10}$ CFU g^{-1} flakes which decreased to $0.67 \log_{10}$ CFU g^{-1} flakes at 60 days. The presence of *E. coli* in ready-to-eat foods is undesirable as it indicates poor hygienic conditions, contamination or inadequate heat treatment (ICMSF 1996). Ideally *E. coli* should not be detected and as such a level of <3 g-l (the limit of the Most Probable Number test) has been given as the satisfactory criteria for this organism. However the levels of *E. coli* in present investigation falls within the acceptable limits. Yeast population was also detected initially and 90 days (2.39 and $2.39 \log_{10}$ CFU g^{-1} flakes, respectively) but was not detected at 180 days. Hence in the present study, the microbial analysis have clearly indicated that method adopted to process and store the little millet flakes was found to be microbiologically safe.

Table 6 Population of bacteria, fungi, *E. coli* and yeast at 0, 90 and 180 days of storage in little millet flakes

Storage days	$\log_{10}$ CFU g^{-1} flakes							
	Bacteria		Fungi		<i>E. coli</i>		Yeast	
	10^{-2}	10^{-4}	10^{-2}	10^{-4}	10^{-2}	10^{-4}	10^{-2}	10^{-4}
Zero	2.62	2.60	1.53	ND	1.49	1.33	2.39	1.33
90	2.10	1.43	ND	ND	0.67	ND	2.39	1.33
180	0.67	1.33	ND	ND	ND	ND	0.77	ND
BIS (2006) acceptable limits	<10,000 colony count per gram		Absent in 0.1 g of the product		Absent in 0.1 g of the product		Absent in 0.1 g of the product	

Each values are mean of 3 replicates, ND Not detected

BIS Bureau of Indian Standards

Conclusion

This simple controlled steam gelatinization under pressure and rolling technology could be employed for production of highly acceptable and nutritious RTC millet flakes for the health benefits of modern consumer. This could help in promoting utilization of minor millet grains in urban areas to open new markets and to improve farmer's income. Results revealed that RTC millet flakes recorded good amounts of proximate components, dietary fiber and minerals comparable to commercial oats flakes and rice flakes. Storage quality at room temperature in 200 μ polyethylene pouches was good, besides being microbially safe. Utilization of minor millets with added functionality as convenient RTC flakes in food sector would encourage new dimensions to the food industries.

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