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Research Paper

Study on physico-functional and nutrient composition of ready-to-cook (RTC) millet flakes

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■ **ABSTRACT :** Minor millets *viz*., little millet (*Panicum miliare*), proso millet (*Panicum miliaceum*), barnyard millet (*Echinochloa frumentacea*), ragi (*Elesine coracana*) were processed into Ready-To-Cook (RTC) millet flakes and evaluated for physico-functional and nutrient composition. Variation in physico-functional and nutrient composition were observed among the flakes. The RTC flakes of minor millets were smaller in size and density but more fragile and crisp than the commercial oats and rice flakes. Water solubility index (WSI) was more in barnyard flakes (5.26). Good cooking properties were recorded in millet flakes. Highest crude protein (14.72%) in proso millet and lowest (7.35%) in little millet and ragi (7.36%) flakes were recorded.

■ **KEY WORDS:** Ready-to-cook millet flakes, Pittle millet (*Panicum miliare*), Proso millet (*Panicum miliaceum*), Barnyard millet (*Echinochloa frumentacea*), Ragi (*Elesine coracana*) millet

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Millets are small grained cereals, the smallest of them include ragi (*Elesine coracana*), kodo (*Paspalum scrobiculatum*), foxtail (*Setaria italica*), proso (*Panicum miliaceum*), little (*Panicum miliare*) and barnyard millets (*Echinochloa frumentacea*). Millet is an important food in many developing countries because of its ability to grow under adverse weather conditions such as limited rainfall. They are grown extensively in India although it is not utilized as major important food crop. However they are the staple food of the millions inhabitating the arid and semiarid tropics of the world. Millets are not only nutritionally comparable but are also superior to major cereals with respect to protein, energy, vitamins and minerals. Besides, they are rich sources of dietary fibre, phyto-chemicals and micro-nutrients (Lue*et al*., 1991 and Chakraborty *et al*., 2009). In view of current life style and agricultural scenario with perspectives of modernization and global warming, there is a need to revive these crops for multiple benefits. If the millet is made available in a convenient form, the nutritional and nutraceutical benefits of millets could reach the community. The aim of this research was to evaluate the physico-functional and nutrient composition of Ready-To-Cook (RTC) millet flakes.

■ RESEARCH METHODS

Millet grains like little, barnyard and proso were obtained from Millet Research Center of Agricultural Research station, Hanumanmatti during 2012-2013. Millet grains were destoned and dehulled. Dehulled grains were processed into RTC millet flakes by the application of conventional batch processing methods. Physical characteristics of RTC flakes were assessed by standard procedures (Mishra and Gupta, 1995 and Graham 2002). Colour was measured by using Spectrophotometer (Konica Minolta, CM- 2600/2500d model). Texture of flakes was analyzed using a texture analyzer (Stable Micro Systems, Surrey, UK). Functional properties like water holding capacity (Deshpande and Poshadri, 2011), water and oil absorption capacity, water absorption and solubility indices (Nawabueze, 2006), water uptake ratio (Sareepuang *et al*., 2008) were analyzed. Cooking properties were evaluated cooking following the procedures of (Sareepuang *et al*., 2008). Nutrient composition was assessed by AOAC (1995) procedures, dietary fibre by the methods of Asp *et al.* (1983), minerals by Atomic Absorption Spectrophotometry (model: AAS GBC Avanta).

Statistical analysis :

The results of the study need to be analyzed statistically to know its significance. Hence, ANOVA (one way analysis of variance) was used to analyze and interpret the data using SPSS (Statistical packages) and significant means were separated by Duncan's Multiple Range Tests (Duncan, 1955).

■ RESEARCH FINDINGS AND DISCUSSION

The physical characteristics of RTC millet flakes was presented in Table 1. The result on physical characteristics of little millet RTC flakes in the present study is in agreement with thereports of Kotagi (2011). However, all the four flakes were significantly different from the commercial oats and rice flakes which could be due to the difference in species. Colour is an important quality factor directly related to the acceptability of food products (Ilo and Berghofer, 1999). The chrome values indicated darker shades by ragi flakes with 'L', 'a' and 'b' values of 53.24, 3.63 and 8.25, respectively. Bulk density *i.e.* weight per volume of the flakes is an index of flake flatness and lower bulk density is the criteria for good flaking quality (Sailaja, 1992). Hence lower bulk density was recorded by little millet flakes (0.15g/ml) over barnyard, proso and ragi flakes. And also it's an important parameter in the production of expanded and formed food products. The bulk density gives a good idea of the storage space required for a known quantity

Table 1 : Physical characteristic of RTC millet flakes (Mean±SD)

Parameters	RTC millet flakes				Control	
	Little	Barnyard	Proso	Ragi	Oats	Rice flake
1000 flakes weight (g)	2.50^{d}±0.11	3.13^{cd}±0.22	3.94^{c}±0.09	3.99^{c}±0.15	15.43^{b}±1.09	17.17^{a}±0.16
1000 flakes volume (ml)	16.53^{c}±0.55	16.13^{c}±0.32	16.03^{c}±0.15	9.33^{d}±1.04	24.33^{b}±0.57	28.33^{a}±1.15
Bulk density (g/ml)	0.15^{d}±0.00	0.19^{cd}±0.01	0.24^{c}±0.00	0.43^{b}±0.05	0.63^{a}±0.03	0.60^{a}±0.02
Specific volume (g/L)	2.77^{e}±0.00	3.31^{d}±0.02	4.32^{b}±0.03	2.58^{f}±0.00	4.85^{a}±0.01	3.92^{c}±0.00
Expansion ratio	9.59^{a}±2.14	9.27^{a}±1.56	4.62^{b}±0.12	4.48^{bc}±0.77	0.59^{d}±0.01	1.68^{cd}±0.08
Length (mm/inch)	3.69^{c}±0.55	3.86^{c}±0.49	3.92^{c}±0.43	4.05^{c}±0.52	7.26^{b}±1.19	12.00^{a}±1.11
Breadth (mm/inch)	3.51^{c}±0.51	3.48^{c}±0.59	3.54^{c}±0.34	3.49^{c}±0.48	5.78^{a}±1.12	4.93^{b}±0.27
L/B ratio(mm/inch)	1.05^{c}±0.05	1.12^{c}±0.11	1.10^{c}±0.08	1.16^{bc}±0.10	1.26^{b}±0.11	2.43^{a}±0.15
Thickness (mm/inch)	0.68^{a}±0.17	0.55^{a}±0.21	0.46^{b}±0.07	0.67^{a}±0.18	0.62^{a}±0.08	0.45^{b}±0.16
Colour- 'L'	78.52^{c}±0.05	65.52^{d}±0.04	78.63^{c}±0.05	53.24^{e}±0.13	88.75^{a}±0.52	84.99^{b}±0.10
'a'	1.19^{d}±0.03	3.35^{b}±0.05	1.61^{c}±0.03	3.63^{a}±0.08	1.68^{c}±0.10	0.12^{e}±0.00
'b'	14.60^{b}±0.05	17.26^{a}±0.04	17.06^{a}±0.02	8.25^{d}±0.09	10.46^{c}±0.24	10.73^{c}±0.07
Texture-Hardness (force/g)	36279.00^{b}±3006.11	35021.00^{b}±3624.06	45765.00^{a}±2584.64	34894.00^{b}±3405.51	42750.00^{a}±2189.79	27784.00^{c}±1784.23
Cripsness (kg/sec)	72.90^{b}±6.01	70.49^{b}±7.22	91.89^{a}±5.09	70.38^{b}±6.87	85.66^{a}±4.37	55.90^{c}±3.56

Note: Different superscript in a row are significantly different $p \leq 0.01$

of particular flakes. Lower flake volume (9.33ml) and higher bulk density (0.43g/ml) was recorded by ragi as compared to little, barnyard and proso flakes. This might be due to incomplete gelatinization of starch during subsequent flaking (Sailaja, 1992). Rooney and Pflugfelder (1986) however, indicated that the critical factors affecting steam flaking relate directly to the water uptake into the endosperm, which permits gelatinization to occur. In extrusion cooking, expansion is the primary quality parameter associated with product crispiness, water absorption, water solubility, and crunchiness (Sawant *et al*., 2013). Expansion ratio describes the degree of puffing undergone by the sample as it exits the extruder (Seth and Rajamanickam, 2012). The correlation of expansion ratio with bulk density has been reported by many researchers (Bhattacharya, 1997 and Jin *et al*., 1995). Lower expansion ratio was recorded by ragi flakes (4.48) as compared to little, barnyard and proso flakes as ragi recorded higher bulk density so lower is the expansion ratio. And in addition, the relation of protein to expansion of extrudates has been reported by Shannon *et al*. (2010). More the protein, less be the expansion so increased bulk density. The hardness of millet based flakes was determined by measuring the force required to break the flakes. The higher the value of maximum peak force required in gram, which means the more force required to breakdown the sample, the higher the hardness of the sample to fracture. Hardness of proso flakes was in par with oats flakes (Table 1).

Table 2 represents the functional properties of RTC flakes. Water holding capacity was maximum for extruded products which content higher level of cereal

Table 2 : Functional properties of RTC millet flakes (MeanïSD)

Parameters	RTC millet Flakes				Control	
	Little	Barnyard	Proso	Ragi	Oats	Rice flakes
Water holding capacity (%)	$5.89^{de}\pm0.55$	$7.82^{d}\pm1.89$	$3.02^{e}\pm0.34$	$11.69^{c}\pm2.51$	$16.39^{b}\pm0.21$	$30.28^{a}\pm1.27$
Water absorption capacity (%)	$199.38^{c}\pm0.20$	$272.74^{b}\pm30.60$	$200.00^{c}\pm0.00$	$299.47^{b}\pm0.50$	$119.88^{d}\pm0.120$	$639.79^{a}\pm0.36$
Water absorption index	$193.65^{c}\pm0.67$	$182.27^{c}\pm1.61$	$160.77^{d}\pm1.32$	$257.76^{b}\pm2.23$	$131.93^{e}\pm2.01$	$572.25^{a}\pm13.77$
Water solubility index	$4.51^{b}\pm0.28$	$5.26^{a}\pm0.46$	$0.03^{d}\pm0.00$	$3.25^{c}\pm0.14$	$4.52^{b}\pm0.12$	$3.69^{c}\pm0.10$
Oil absorption capacity (%)	$120.27^{a}\pm0.00$	$120.20^{a}\pm0.00$	$80.13^{c}\pm0.00$	$120.17^{a}\pm0.00$	$100.37^{b}\pm0.00$	$80.30^{c}\pm0.00$
Cooking time (min)	$0.20^{c}\pm0.00$	$0.24^{c}\pm0.00$	$0.89^{b}\pm0.26$	$0.25^{c}\pm0.01$	$1.40^{a}\pm0.05$	$1.22^{a}\pm0.02$
Increase in weight after cooking (%)	$505.04^{b}\pm40.08$	$502.60^{b}\pm52.62$	$437.00^{b}\pm75.74$	$624.38^{a}\pm39.99$	$261.04^{c}\pm14.11$	$224.10^{c}\pm1.36$
Solid loss (g/g)	$0.05^{ab}\pm0.00$	$0.04^{ab}\pm0.01$	$0.03^{c}\pm0.00$	$0.08^{a}\pm0.01$	$0.08^{ab}\pm0.01$	$0.03^{c}\pm0.00$

Note: Different superscript in a row are significantly different $p \leq 0.01$

Table 3: Nutrient composition of RTC millet flakes (MeanïSD)

Nutrient/100 g	RTC Millet flakes				Control	
	Little	Barnyard	Proso	Ragi	Oats	Rice Flakes
Moisture	$13.08^{a}\pm0.50$	$12.53^{a}\pm0.82$	$10.50^{b}\pm0.19$	$13.39^{a}\pm0.01$	$5.88^{c}\pm0.37$	$13.06^{a}\pm0.05$
Fat	$0.40^{c}\pm0.19$	$0.85^{c}\pm0.04$	$0.52^{c}\pm0.07$	$0.67^{c}\pm0.05$	$8.41^{a}\pm0.46$	$1.39^{b}\pm0.12$
Protein	$7.35^{e}\pm0.35$	$11.51^{c}\pm0.02$	$14.72^{a}\pm0.02$	$7.36^{e}\pm0.01$	$14.00^{b}\pm0.30$	$9.33^{d}\pm0.20$
Crude fibre	$2.46^{c}\pm0.30$	$9.23^{b}\pm0.40$	$1.06^{c}\pm0.40$	$2.58^{c}\pm0.08$	$13.57^{a}\pm0.17$	$0.52^{d}\pm0.02$
Total ash	$2.29^{b}\pm0.01$	$2.46^{a}\pm0.03$	$1.08^{d}\pm0.05$	$2.29^{b}\pm0.01$	$1.52^{c}\pm0.06$	$1.54^{c}\pm0.05$
Carbohydrate (by difference)	$74.37^{a}\pm0.65$	$64.15^{c}\pm1.02$	$72.05^{b}\pm0.30$	$73.70^{a}\pm0.11$	$56.60^{d}\pm0.12$	$74.14^{a}\pm0.21$
Energy (kcal)$	$263.21^{e}\pm0.88$	$277.22^{d}\pm3.21$	$286.64^{c}\pm2.15$	$254.35^{f}\pm0.80$	$343.11^{a}\pm4.04$	$320.75^{b}\pm0.12$
Insoluble dietary fibre	$17.70^{b}\pm0.45$	$15.26^{c}\pm0.46$	$19.63^{a}\pm0.15$	$16.86^{b}\pm0.77$	$13.66^{d}\pm0.57$	$15.33^{c}\pm0.57$
Soluble dietary fibre	$0.63^{c}\pm0.25$	$1.50^{c}\pm0.50$	$1.93^{b}\pm0.15$	$0.56^{c}\pm0.40$	$3.66^{a}\pm0.57$	$1.60^{b}\pm0.52$
Total dietary fibre	$18.33^{b}\pm0.20$	$16.76^{d}\pm0.25$	$21.56^{a}\pm0.15$	$17.70^{b}\pm0.10$	$17.33^{c}\pm0.57$	$16.93^{d}\pm0.11$
Calcium (mg)	$13.32^{c}\pm0.00$	$16.92^{c}\pm0.190$	$11.84^{c}\pm0.190$	$222.67^{a}\pm19.28$	$67.33^{b}\pm0.00$	$19.95^{c}\pm0.21$
Iron (mg)	$16.39^{b}\pm0.28$	$14.85^{c}\pm0.05$	$11.59^{d}\pm0.19$	$13.89^{c}\pm0.14$	$9.40^{e}\pm0.13$	$18.76^{a}\pm0.65$
Zinc (mg)	$2.86^{d}\pm0.06$	$3.89^{c}\pm0.10$	$1.54^{e}\pm0.06$	$2.57^{d}\pm0.01$	$4.56^{b}\pm0.02$	$5.14^{a}\pm0.22$
Manganese (mg)	$1.63^{c}\pm0.16$	$0.89^{d}\pm0.07$	$1.50^{c}\pm0.16$	$5.56^{b}\pm0.161$	$9.09^{a}\pm0.02$	$5.85^{b}\pm0.19$
Copper (mg)	$0.60^{b}\pm0.06$	$0.71^{b}\pm0.55$	$1.75^{a}\pm0.07$	$0.82^{b}\pm0.08$	$0.72^{b}\pm0.00$	$0.78^{b}\pm0.09$

Note: Different superscript in a row are significantly different $p \leq 0.01$

$^{\$}$Computed value

starch and crude fibre in the composite flour (Deshpande and Poshadri, 2011; Shirani and Ravindran, 2009). The Water absorption index (WAI) measures the amount of water absorbed by the starch and may be used as an index of the gelatinization of the starch (Seth and Rajamanickam, 2012). WAI was found to be more for rice flakes (572.25 ± 13.77) followed by ragi flakes (257.76± 2.23) which might be attributed by the puffing of the flakes, thereby imbibing more water into the matrix (Roopa and Premavalli, 2008). Water solubility index (WSI) was more in barnyard flakes (5.26±0.46) as compared to oats and rice flakes which measures the volume occupied by the flakes starch after swelling in excess water, which maintains the integrity of starch in aqueous dispersion. Higher absorption of oil may be attributed to presence of less fat in the flakes hence oil absorption was found to be more for RTC millet flakes than millet grains. Maximum increase in weight after cooking was seen in ragi flakes (624.38%). The reason might be during cooking the starch content of the millet flakes absorbs moisture and swells due to gelatinization, some solid content of the flakes might dissolved into the cooking gruel. Solid gruel loss was significantly higher in ragi flakes (0.08g/g). Least cooking time was observed in little (0.20 min) and followed by barnyard (0.24min) RTC flakes.

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

The soluble and total dietary fibre (TDF) content increased in RTC flakes as compared to native grain. The increase in soluble dietary fibre could have been the result of 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). However Patil *et al.* (2014) reported that the increase in dietary fibre content in flakes compared to native grain could be attributed to development of resistant starch during moist steaming and cooling cycles performed during processing. Highest total dietary fibre content was observed in ragi RTC (21.56g/100g) flakes since it was used directly for flaking unlike other millets which were decorticated. Patil *et al.* (2014) described that iron machines involved in processing lead to high amount of iron in RTC little millet flakes (32.23mg/100g) as compared to native grains (8.18mg/100g). In the present investigation it was also observed that usage of iron machinery during processing lead to increased iron content as compared to native grain. The iron content of flakes was very high compared to native grain (0.7g/100g), such phenomenon couldbe observed in elevated levels of iron in rice flakes (20mg/100g) than paddy (Gopalan *et al.*, 2004).

Conclusion :

It was observed that RTC millet flakes had good physico-functional characteristics to commercial oats and rice flakes. Based on the results of studies carried out, we can observe that RTC millet flakes contain many health-promoting components such as dietary fibre and minerals that are comparable to those of commercial oats and rice flakes and they also have several potential health benefits.Utilization of low value minor millets with added functionality in the form of ready-to-cook millet flakes would open up new dimensions to the health conscious.

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