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Suitability of Foxtail Millet (*Setaria italica*) and Barnyard Millet (*Echinochloa frumentacea*) for Development of Low Glycemic Index Biscuits

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ABSTRACT

Millets have been neglected despite their nutritive value and therapeutic use. The present study was undertaken with the aim of preparing biscuits based on foxtail millet and barnyard millet and to evaluate their sensory quality and acceptability, nutritional value and glycemic index by comparing with biscuits made from refined wheat flour. The biscuits made from millet were prepared using 45% of millet flour and 55% of refined wheat flour. All the three types of biscuits were found to be acceptable by a trained panel and diabetic subjects. The shelf life study indicated that the biscuits made from both types of millet flour can be successfully stored for a period of 60 days in a thermally sealed single polyethylene bag at room conditions. The millet flour and biscuits had higher content of crude fibre, total ash and total dietary fibre than refined wheat flour and biscuits. Biscuits from foxtail millet flour had the lowest GI of 50.8 compared to 68 for biscuits from barnyard millet flour and refined wheat flour. Thus, besides its traditional use in making *chapatti* and porridge, millet can be exploited for the development of low GI therapeutic food products like biscuits. Further studies are needed to determine long term effects of consumption of foxtail millet biscuits on blood lipid profile and glycosylated haemoglobin of diabetics and cardiovascular patients.

Keywords: Glycemic index, GI biscuits, millet

INTRODUCTION

Millets are a small-seeded annual coarse cereal grown throughout the world. Millets include five genera: Panicum, Setaria, Echinochloa, Pennisetum and Paspalum. The cultivated species include foxtail millet (*Setaria italica*) and barnyard millet (*Echinochloa frumentacea*). Foxtail millet, considered a crop for poor people, is grown mainly in China, Bangladesh and India. It requires warm weather and matures quickly in the hot summer months. Practically devoid of grain storage pest, foxtail millet has a long storage life. Barnyard millet is grown in India, Japan, China, Malaysia, East Indies, and parts of Africa and United States. It is a fast growing millet, occasionally producing ripe grains in 45 days after seeding. It is grown in sub-marginal

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conditions of soil fertility and moisture where the major cereal crops fail to realise production satisfactorily.

In western countries, millets are grown primarily as birdseed, hay or as an emergency cash crop. In developing countries, millets are consumed by people from the low economic strata and as forage crop (Baker, 2003). They are nutritionally comparable or even superior to staple cereals such as rice and wheat (Gopalan, Ramashastri & Balasubramanium, 2004). Millets are rich in vitamins, minerals, sulphur-containing amino acids and phytochemicals, and hence are termed as nutri-cereals. They have higher proportions of non starchy polysaccharides and dietary fibre. Millets release sugars slowly and thus have a low glycemic index. They have been designated as 'nutritious millets' (Bala Ravi, 2004). Despite the above facts, the nutraceutical property of millets has not been much exploited for treating degenerative disease like diabetes.

Diabetes, a multifactorial disease, is increasing at an alarming rate in India as well as throughout the world. The total number of people with diabetes is projected to rise from 171 million in 2000 to 366 million in 2030. The prevalence of diabetes among Indians is estimated to reach 79.4 million by 2030 from 31.7 million in 2000 (Wild *et al*., 2004).

As foods with low glycemic index (GI) are known to result in lower post-prandial glucose response in patients with non insulin dependent diabetes mellitus, GI has been extensively studied as a useful means to determine foods that are appropriate for diabetic subjects. The present study was undertaken to prepare biscuits from foxtail millet and barnyard millet, and to evaluate its sensory quality and acceptability by diabetic subjects. The nutritional value and glycemic index of the biscuits were also assessed.

METHODOLOGY

Preparation of biscuits

Foxtail millet and barnyard millet grains were purchased from local farmers. The grains were cleaned free from dust and foreign particles and were subjected to grinding in a commercial roller mill (Saboo millstones, Rajasthan, India). Thereafter it was passed through a 20 mesh sieve (ASEW, New Delhi, India) in order to obtain the flour for the study.

Three types of biscuits namely foxtail millet biscuits (FMB), barnyard millet biscuits (BMB) and crude refined wheat flour biscuits (CRWFB) were prepared. For FMB and BMB, the flour blend (millet flour and refined wheat flour) was in the ratio of 45%: 55%. The CRWFB was prepared from 100% refined wheat flour. The other ingredients used were similar for all three types of biscuits: baking powder, hydrogenated fat (23%), powdered sugar (14%), egg**s** (5.5%), and curd (11.5%). All the ingredients were creamed together and about 30 % water was added to prepare the dough. The prepared dough was rolled into balls, pressed to a thickness of 1cm and 5 cm diameter, and baked under standardised conditions.

Sensory quality

All the 3 types of biscuits were evaluated for sensory quality by a trained panel of 10 members, who indicated the extent of their likes or dislikes in terms of taste, odour, appearance, texture, overall acceptability. Since the biscuits were prepared for the benefit of diabetic subjects, the biscuits were also tested for acceptability among 25 conveniently selected diabetic subjects using the same scoring approach as the panel.

Storage stability

Triplicate samples of 75 g each of the three types of biscuits were kept in thermally sealed polyethylene bags for exactly 2 months at room temperature ranging from 32-37^{0}C and a relative humidity of 65-85%. The biscuits were prepared without adding any preservatives and commercial packaging was used. The sensory quality was evaluated at intervals of 30 days by the panel as described above.

Nutritional quality

All the three types of flour were analysed for proximate composition- crude protein, crude fat, crude fibre, total ash and carbohydrate content calculated by difference (AOAC, 1984). The physiological energy was calculated as (% crude protein x 4) + (% crude fat x 9) + (% carbohydrate x 4). All the three flour were also analysed for total starch (Cerning & Gilbot, 1973; Clegg, 1956) and total dietary fibre [TDF] (Asp & Johansson, 1981). The mineral content (chromium, zinc, magnesium, manganese, copper, phosphorus and potassium), and vitamins (thiamine, riboflavin and niacin) were estimated from the food composition table for Indian foods (Gopalan, Ramashastri & Balasubramanium, 2004).

Glycemic index (GI) determination

Thirteen apparently healthy females aged 22-27 years, with body mass index of 16.5 to 26.3 kg / m^2, normal blood pressure and not suffering from any ailments were randomly selected from the university's girls hostel. The purpose of the study was explained to each subject and written consent to participate in the study was obtained. The subjects were given general instructions to avoid any physical exertion, medication, fasts and feasts during the experimental period.

The glucose tolerance test (GTT) was carried out on the overnight fasted subjects with a glucose load of 50 g. Blood glucose was measured at 0, 15, 30, 60, 90 and 150 minutes. All the three types of biscuits containing 50 g of available carbohydrate corresponding to 95 g of FMB, 96 g BMB and 90 g of CRWFB were served on alternate mornings. The subjects were asked to finish eating within 10-15 minutes. Blood glucose was measured at specified intervals by finger prick using the glucometer- Glucotrend 2 (Roche Diagnostics Gmbh, Mannheim, Germany). Blood glucose was analysed by the glucose-oxidase method. The subjects were interviewed on any after-effects experienced from consuming the biscuits.

The incremental area under blood glucose response curve (iAUBGR) was calculated using the formula given below (Wolever *et al.*, 1991):

iAUBGR = (At ÷ 2) + At + (B-A)t ÷ 2 + Bt +(C – B)t + Ct + (D- C)t ÷ 2 + Dt + (E-D)t ÷ 2 …

where ABCDE represents positive blood glucose increment and t is time interval between the blood samples. The GI value for each individual was calculated as:

iAUBGR curve after biscuit / iAUBGR curve after glucose X 100

The average GI of 10 replicates was taken as the GI value of each type of biscuit.

Statistical analysis

All the data are presented as mean ± SD (standard deviation) of three replicates. The student *t*-test was used to measure the difference on sensory quality and acceptability of biscuits. Paired *t*- test was applied to determine the difference between fresh and stored biscuits. The nutrients and glycemic index values from the three types of biscuits were subjected to ANOVA test to determine significant differences.

RESULTS AND DISCUSSION

The evaluation of the biscuits by a trained panel showed no significant difference in the sensory quality of FMB compared to CRWFB whereas the BMB had a significantly lower sensory score compared to both FMB and CRWFB (Table 1). The data on acceptability test obtained from the diabetic

Table 1. Scores for sensory quality by semi-trained panelists[a], acceptability by diabetics[b] and storage stability[c] of biscuits.

Biscuits	*FMB*	*BMB*	*CRWFB*	*SEM1±*	*CD1 at 5%*
Score [a]*	7.6±0.69	6.7±0.67	7.9±0.56	0.205	0.59
Score [b]*	7.80±0.89	7.23±0.95	6.84±1.37	0.21	0.6
0 day score [c]*	7.60±0.69	6.7±0.67	7.9±0.56		
30th day score [c]*	7.0±1.15	6.0±1.15	8.4±0.69		
60th day score [c]*	6.9±1.28	5.1±0.73	8.2±0.63		
SEM2 ±	0.34	0.27	0.2		
CD2 at 5%	0.98	0.8	0.58		

* Mean ± SD; FMB: foxtail millet biscuit; BMB: barnyard millet biscuit; CRWFB: control refined wheat flour biscuit
SEM1± and CD1 values are between FMB, BMB and CRWFB for score [a] and [b] whereas SEM2± and CD2 values are between 0, 30th and 60th day for FMB, BMB and CRWFB, respectively.

Table 2. Nutrient composition of the flours

*Nutrients**	*FMF*	*BMF*	*CRWF*	*SEM±*	*CD at 5%*
Crude protein(%)	9.92±0.53	11.08±0.66	8.52±0.20	0.3	1.09
Crude fat (%)	4.71±0.15	4.46±0.11	0.82±0.08	0.1	0.2
Crude fibre (%)	8.07±0.89	8.13±1.34	0.46±0.03	0.5	1.53
Total ash (%)	2.89±0.03	3.79±0.11	0.99±0.02	0	0.05
Carbohydrate (%)	65.95±0.72	63.76±2.2	77.06±0.71	0.8	2.58
Physiological energy (kcal/100g)	346±4.35	339±6.50	350±3.46	2.5	8.27
Starch (%)	64.12±1.94	52.12±0.64	66.0±0.64	0.6	2.11
TDF (%)	26.92±0.12	31.73±0.38	10.24±0.39	0.2	0.55
SDF (%)	11.04±0.13	9.75±0.13	3.28±0.09	0.1	0.28
IDF (%)	15.88±0.02	21.98±0.51	6.96±0.31	0.2	0.57

* Mean ± SD, FMF: foxtail millet flour; BMF: barnyard millet flour; CRWF: control refined wheat flour

subjects showed that they preferred both the FMB and BMB. However, on comparing with CRWFB, the FMB scored significantly higher values. Although there was a gradual decrease in the overall acceptability of the millet biscuits during storage, all the three types of biscuits remained acceptable even after 60 days of storage at room conditions. The BMB scored significantly lower than CRWFB but FMB was significantly similar to CRWFB (Table 1). Nutrient composition of the flour is presented in Table 2. Crude protein, fat, fibre and total ash content for foxtail millet and barnyard millet flour was found to be significantly higher than in the refined wheat flour. The nutritional content values for refined wheat flour are in accordance with Desai *et al.* (2010). The higher nutritional content in the millets may be due to the fact that in refined wheat flour, the bran and the germ portion are removed thus causing it to lose its vitamins, minerals, fat, and fibre (Jacobs & Steffen, 2003). The carbohydrate content for control refined wheat flour was significantly higher than in foxtail millet flour and barnyard millet flour, probably because refined wheat flour contains mainly the endosperm portion which is a good source of carbohydrate (Jacobs & Steffen, 2003).

Barnyard millet showed a significantly lower value for starch as compared to foxtail millet flour and control refined wheat flour. The starch content values are in accordance with previous studies (Pawar & Pawar, 1997: Krishna Kumari & Thayumanavan, 1995). The dietary fibre content (total, soluble and insoluble) was significantly higher for the millet flours compared to refined wheat flour.

The nutrient composition of biscuits indicated that on replacing refined wheat flour with 45% millet flour in FMB and BMB, the crude fibre content increased by 10 times in FMB and BMB compared to CRWFB. The millet biscuits were good sources of minerals and vitamins (Table 3). The mineral and vitamins, except for manganese, potassium and riboflavin increased with an increase in proportion of millet flour. This is in close agreement with a previous study by Ravindran (1991). This is encouraging since diabetics are known to suffer from mineral and vitamin deficiency.

Among the three types of biscuits, the mean iAUBGR curve was lowest for FMB, followed by CRWFB and BMB. The FMB

Table 3. Nutrient composition of biscuits

	FMB	*BMB*	*CRWFB*
Crude protein (%)	5.88	6.11	5.55
Crude fibre (%)	2.01	2.03	0.23
Total ash (%)	1.1	1.31	0.66
Carbohydrate (%)	52.77	52.2	55.55
Physiological energy (kcal/100g)	489	487	490
Starch (%)	33.33	30.5	33.73
TDF (%)	9.12	10.24	5.22
SDF (%)	3.48 (38.15)	3.18 (31.05)	1.67 (31.99)
IDF(%)	5.64 (61.84)	7.06 (68.95)	3.55 (68.01)
Chromium(%)	0.0073	0.0212	0.0005
Zinc (%)	0.7267	0.8667	0.3067
Magnesium (%)	33.9	34.13	27.6
Manganese (%)	0.312	0.396	0.316
Copper (%)	0.385	0.1983	0.107
Potassium (%)	137.22	na	145.15
Phosphorus (%)	126.67	124.27	87.17
Thiamine (%)	0.1836	0.1229	0.0739
Riboflavin (%)	0.09	0.0877	0.0807
Niacin (%)	1.4156	1.6489	1.2289

Figures in parentheses show per cent contribution. FMB: foxtail millet biscuit; BMB: barnyard millet biscuit; CRWFB; control refined wheat flour biscuit

Table 4. Incremental area under blood glucose response curve for biscuits

Product	*iAUBGR curve* for biscuits (mmol/L)*	*iAUBGR curve* for glucose (mmol/L)*	*S/NS*
FMB	128.13±70.50	301.05±175.35	S
BMB	173.49±126.99	298.21±175.70	NS
CRWFB	168.96±100.01	290.31±180.77	NS
SEM±	32.29	56.07	
CD at 5%	93.70	162.71	

* Mean ± SD ($p \leq 0.05$)
FMB: foxtail millet biscuit; BMB: barnyard millet biscuit; CRWFB: control refined wheat flour biscuit, S NS - Significant / Non-significant.

Table 5. Glycemic index (GI) of the biscuits

Biscuits	GI
FMB	50.8±27.9
BMB	68.0±60.3
CRWFB	68.0±52.8
CD at 5%	44.95

FMB: foxtail millet biscuit; BMB: barnyard millet biscuit; CRWFB: control refined wheat flour biscuit.

elicited 35.4% and 31.9% lower glucose response than BMB and CRWFB, respectively (Table 4). The peak values for the biscuits occurred at 30 minutes compared to 60 minutes for glucose. This finding is similar to that observed by Jenkins *et al.* (1980). This result is attributed to the difference in dietary fibre content of the biscuits which may have protected starch from enzymatic degradation (Wursch & Pi-Sunyer, 1997). Also, during the baking of biscuits, 1, 6 anhydro D-glucose units may have been liberated from the starch and other polysaccharides to form enzyme resistant complexes that are different from resistant starch (Gurcia-Alonso & Goni, 2000; Leeman, Ostman & Bjorck, 2005). Several authors have reported that during baking, a fraction of starch rendered itself inaccessible to amylases (Rizkalla *et al.*, 2007) and total dietary fibre content increases (Kavitha, Parvathi Eashwaran & Maheshwari, 2001) due to retrogradation (Fredriksson *et al.*, 2000).

The GI was found to be lowest for FMB (50.8) compared to a similar GI value of 68 for BMB and CRWFB (Table 5). This is due to FMB having higher soluble fibre and starch content than BMB. Similar results were reported showing GI was inversely related to fibre content (Meyer *et al.*, 2000). The high soluble dietary fibre content has been found to reduce gastric emptying and absorption of glucose after a meal, resulting in improved glucose tolerance. The soluble dietary fibre component has been reported to decrease the activity of digestive enzymes, thus resulting in incomplete hydrolysis of carbohydrates, protein and fats and delaying absorption (Wursch & Pi- Sunyer, 1997). This study thus shows that foxtail millet is more effective than barnyard millet or refined wheat flour with respect to its use for diabetic subjects. Normally, biscuits have a GI of 68 -72 (Foster- Powell, Holt & Brand Miller, 2002).

CONCLUSION

The use of millet flour, especially foxtail millet flour in biscuit making would greatly enhance the utilisation of this crop in developing countries for therapeutic purpose; in these regions, the crop has not been optimally utilised. The nutritional quality of refined wheat flour biscuits could be improved with supplementation of foxtail millet and barnyard millet. Foxtail millet is preferred to barnyard millet as it has a higher glycemic index. Further studies are needed to determine long term effects of consumption of foxtail millet biscuits on blood lipid profile and glycosylated haemoglobin of diabetic and cardiovascular patients.

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