Progressive Agriculture 29 (2): 186-194, 2018 ISSN: 1017 - 8139

Progressive Agriculture
Journal homepage:http://www.banglajol.info/index.php/PA

Comparison of nutritional and functional properties of BK2 foxtail millet with rice, wheat and maize flour

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Abstract

The proximate composition, mineral contents and functional properties of BK2 FTM flour was determined and compared with three major cereals commonly consumed in Bangladesh like rice, wheat and maize flour. The samples were cleaned of foreign materials, milled and sieved through 60 µm meshes. The results showed that the BK2 FTM flour contained significantly higher ($P<0.05$) amount of energy (382.01 kcal) and fat (5.01 g/100g) compared to other major cereals. It also took the second highest value of protein, 9.06%, whereas wheat contained 10.39%, Rice, 6.31% and maize, 6.86%. Similarly, BK2 FTM flour enriched with iron 7.01 mg/100g, copper 1.43 mg/100g and phosphorous 595.12 mg/100g. The foaming capacity and bulk density of BK2 FTM flour were very similar to wheat flour. However, it varied significantly ($p<0.05$) as compared to rice and maize flour.

Key words: BK2 FTM flour, major cereals, proximate composition, functional properties

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Introduction

Cereals can be defined as a grain or edible seeds of the grass family (Chapman and Carter, 1976). Since the beginning of civilization, cereals are the staple foods both for human consumption and livestock feed (BNF, 1994). At present, it is the single most important source of calories in the majority of world population. Different studies have shown that developing countries depend more on cereal grains for their nutritional needs than the developed country (WHO/FAO, 2003) and it is the most important sources of carbohydrate (FAO, 2002). More than 50% of the world's population intake calorie daily from cereal based products. It is a rich source of vitamins, minerals, carbohydrates, fats and proteins which provides more energy than any other crop. Cereals are the largest contribution of human nutrition. In the world, the major cereals are rice, wheat and maize and the minor cereals are barley/jab, joar, bazar and cheena. In addition, other minor cereals like sorghum and millet are mostly contributed major calorie intake in certain regions of the world, spatially in the semi-arid parts of Africa and India (FAO, 2011).

Rice (Oryza sativa) is the single most important source of calories for human nutrition. It contributes approximately 21% of the caloric intake of per capita in the world and is the most widely consumed staple food in Asian countries (IRRI, 2010). Around 90 % of the Bangladeshi people consume rice as their staple food (Banglapedia, 2011). It is composed of 12.4% water, 76.8% carbohydrates, 6.5% protein, negligible amount of fat, 0.66% and 344 kcal energy (Shaheen *et al.* 2013).

Wheat (*Triticum aestivum*) is an important source of carbohydrates (Shewry*et al.*1992). The nutritional value of wheat is extremely important as it takes the second place among the cereal species (Curtis *et al.* 2002). Globally, it is the leading source of vegetal protein in human food. It contains about 13% of protein, which is relatively high compared to other major cereals (Eurostat, 2002). Wheat is the most popular energy grain for the production of confectionary products to produce bread, cookies, cakes, pastries, spaghetti, macaroni and noodles with desirable texture and flavor (Potter and Hotchkiss, 1996; Akhtar *et al.* 2008).

Maize *(Zea mays* L) also referred to as corn, originated from western hemisphere (Fast and Caldwell, 2000). It is a cheap form of starch and is a major source of energy for animal feed (Macrae *et al.* 1993). Maize has become a staple food in many parts of the world compared to wheat and rice. It contained about10% water, 76% carbohydrates, 9.3% protein, 4.7% fat, 7 % fiber and 344 kcal energy. It is also a good source of B vitamins, thiamin, niacin, pantothenic acid (B5) and folate (Shaheen *et al.* 2013).

Millets are a group of small-seeded grasses, generally grown all over the world. It is an important food crops in the semiarid tropics of Asian and African continents especially in India, Mali, Nigeria, and Niger. The most widely grown millet is pearl millet and Foxtail millet (*Setaria italica*) is the second-most widely planted species of millet. It can be cultivated in all types of soils and sustains adverse agro-climatic conditions due to its excellent adaptive capacity (Atiq *et al.* 2007). Nutritionally too, it is an important food crop and contributes around 10-12 % protein, 351 kcal energy, 2.29-2.7 % lysine, 0.59 mg thiamine, 2-3% fat and 3-4% of dietary fiber. It is reported that major cereals consumption contributes 70-80% of total energy in the majority of Indian diets and millets contribute to only about 2% of total calorie (Radhika *et al.* 2011). But it has almost equal nutritional value with rice, wheat and maize flour. Though it is highly nutritive and can be grown in infertile and unused land in the semi-arid tropics, but still it is not equally consumed/used as compared to rice, wheat or maize flour in the community or in any food industries in Bangladesh. So, the objective of this study is to compare the nutritional value of BK2 FTM flour with commonly consumed cereals like rice, wheat and maize flour in Bangladesh.

Materials and Methods

The BK2 FTM was collected from Plant Breeding Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Wheat was collected from Bangladesh Wheat Research Institute (BWRI), Dinajpur and rests of the cereals (rice and maize) were collected from Dhaka local market, Dhaka, Bangladesh. The samples were dried and cleaned to remove the foreign materials and was prepared by the following schematic flow diagram as shown in Figure 1. Then the flours were packaged in air-tight plastic containers for further analysis.

The Nutritional composition**s** of BK2 FTM, rice, wheat and maize flours were determined according to Ceirwyn (1995). The moisture content was determined by drying in an oven at 105°C until a constant weight was obtained. Ash was determined by weighing the incinerated residue obtained at 700°C after 8 h. Crude fat was extracted by the Soxhlet method with petroleum ether and crude dietary fiber was analyzed by using the standard method as described by AOAC (2005). The crude protein was determined by the micro-Kjeldahl method and a conversion factor of 5.68 for BK2 FTM, 5.26 for rice, 5.47 for wheat and 5.54 for maize were used to quantify the crude protein content (Thachuk, 1969). The carbohydrate content was estimated by subtracting the sum of the percentage of moisture, fat, protein and ash from 100% according to AOAC (2005). Carbohydrate (%) = 100 – (moisture % + fat % + protein % + ash %). The total energy value of the samples were calculated according to the method of Mahgoub (1999) using the formula; Total energy (Kcal/100g)=[(% available carbohydrates ×4.1) + (% protein×4.1) + (% fat ×9.3)].

Mineral contents of the samples were determined by AOAC (2003). Sodium and potassium were determined by flame photometry (Flame Photometer Model: PFP7, Germany). Calcium and magnesium was determined by the method described by Jackson (1973) and Iron, phosphorous, copper and zinc were determined using Atomic Absorption Spectrophotometer (Model: VARIAN-220) according to the method of AACC (2000). The water absorption capacity and oil absorption capacity of the flours were determined by the method of Sosulski *et al.* (1976) and the swelling capacity was determined by Okaka and Potter (1977). The foaming capacity (FC) and foam stability (FS) were determined by Narayana and Narasinga (1982) and the emulsion activity and stability were determined by Yasumatsu *et al.* (1972). The bulk density of flour was determined according to the method of Appiah*et al.*(2011) and the water absorption index (WAI) and water solubility index were determined by Anderson *et al*. (1970).

All experiments were performed in three replications. The data were subjected to statistical one-way ANOVA test and Fisher's Least Significant Difference (LSD) to compare among the treatments at 5% significant level by using SPSS version 22.

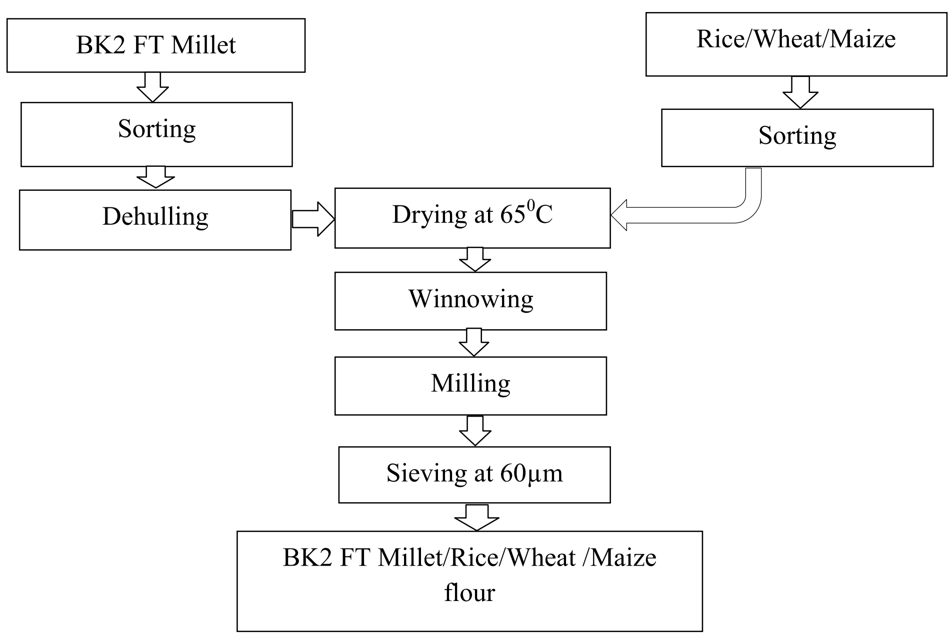
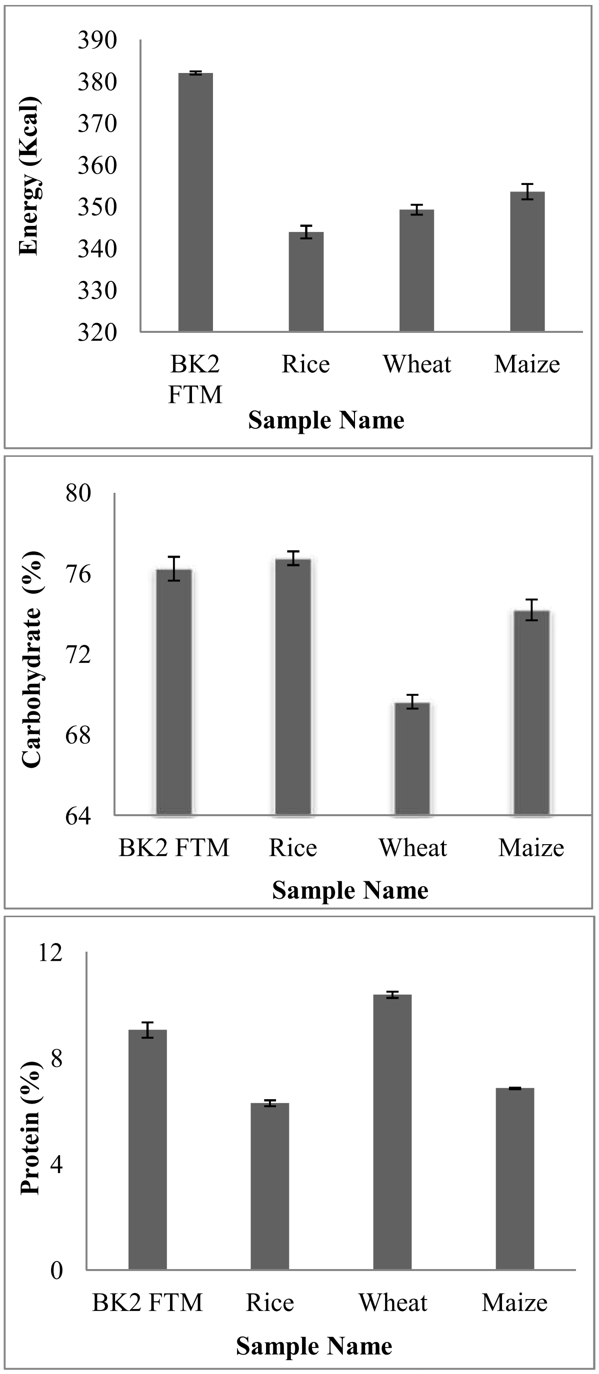


Figure 1. Flow diagram for the preparation of rice, wheat and maize flour

Results and Discussion

The proximate components of the selected cereals are shown in Figure 2. It shows that BK2 FTM flour contained the highest amount of energy 382.01 kcal/100g which was significantly varied ($p < 0.05$) with rice 343.92 kcal/100g, wheat 349.23 kcal/100g and maize flour 355.30 kcal/100g. Not only that, it contains about 76.53% carbohydrate, which was very similar to rice 76.75% but higher than wheat 69.64% and maize flour 74.20%. The high carbohydrate content of millet flour suggests that it could be useful in managing protein-energy malnutrition. According to Butt and Batool (2010), carbohydrates are good sources of energy and the high concentration of it is desirable in the formulation of breakfast meals.

In case of fiber, the maize flour contained significantly higher ($p < 0.05$) amount of fiber 6.60% than BK2 FTM 3.63%, rice 3.36% and wheat flour 4.24%.



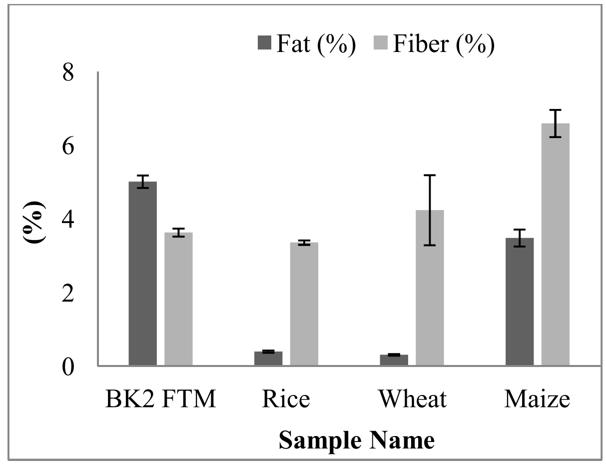


Figure 2. Proximate components of BK2 FTM with rice, wheat and maize flour

Kamara *et al.,* (2009) reported that fiber content could help in managing obesity and dealing with the problem of constipation. Chinma *et al.* (2007) reported that crude fiber helped in the prevention of heart diseases, colon cancer, diabetics etc. The protein content of BK2 FTM flour was 9.06% which was lower than wheat 10.39% but higher than rice 6.31% and maize flour 6.86%. The protein content of the flours may be useful in food formulation systems and soils with high nitrogen levels can influence protein levels (Brown, 1991). The fat content of BK2 FTM flour was 5.01% which was significantly higher ($p < 0.05$) than rice 0.40%, wheat 0.31% and maize flour 3.48%. Moss *et al.* (1987) reported that high fat content contributed to energy requirement for the human body. The high amount of fat help to enhance flavor and useful in improving the palatability of foods in which it is incorporated (Aiyesanmi, 1996). Table 1 shows that BK2 FTM flour was enriched with iron 7.01 mg/100g which varied significantly ($P < 0.05$) than rice 0.74 mg/100g, wheat 3.39 mg/100g and maize flour 2.40 mg/100g. Iron is required for making HB level. Iron and calcium occur together in the body to maintain body blood. Kamara *et al.* (2009) reported that iron is highly important because of its requirement for blood formation. In case of Ca, wheat flour had contained significantly higher ($p < 0.05$) amount of Ca 13.35 mg/100g than BK2 FTM 3.62 mg/100g, rice 9.32 mg/100g and maize flour 7.38 mg/100g. Soetan *et al.* (2010) reported that calcium played important role in the body such as a constituent of bones and teeth, muscle contraction, nerve function, and blood clotting. BK2 FTM flour was enriched with phosphorous 595.12 mg/100g, which varied significantly ($p<0.05$) compared to rice 128.19 mg/100g, wheat 141.23 mg/100g and maize flour 272.55 mg/100g.

Table 1. Mineral contents of BK2 FTM with rice, wheat and maize flour

Minerals (mg/100g)	BK2	Rice	Wheat	Maize
Sodium	0.41 ± 0.02^{c}	2.20 ± 0.07^{b}	5.31 ± 0.12^{a}	5.32 ± 0.05^{a}
Potassium	311.41 ± 9.95^{a}	126.58 ± 0.54^{c}	212.64 ± 2.12^{b}	315.34 ± 3.07^{a}
Iron	7.01 ± 0.37^{a}	0.74 ± 0.01^{c}	3.39 ± 0.39^{b}	2.40 ± 0.17^{b}
Calcium	3.62 ± 0.17^{d}	9.32 ± 0.13^{b}	13.35 ± 0.45^{a}	7.38 ± 0.17^{c}
Phosphorous	595.12 ± 1.04^{a}	128.19 ± 0.26^{c}	141.23 ± 0.92^{c}	272.55 ± 2.45^{b}
Magnesium	60.66 ± 2.08^{d}	37.66 ± 2.51^{b}	111.00 ± 3.60^{a}	74.00 ± 6.24^{c}
Zinc	1.46 ± 0.04^{b}	1.27 ± 0.04^{b}	2.85 ± 0.06^{a}	1.22 ± 0.21^{b}
Copper	1.43 ± 0.08^{a}	0.26 ± 0.04^{b}	0.72 ± 0.12^{c}	0.20 ± 0.07^{b}

Data present as mean value ± standard deviation. Means in a row with same superscript are not significantly different at ($p < 0.05$).

The level of potassium was almost same for BK2 FTM and maize flour (311.41 mg/100g, 315.34 mg/100g) which were significantly higher ($p < 0.05$) than rice126.58 mg/100g and wheat flour 212.64 mg/100g. Potassium has been found as a vital element in kidney function and ultra filtration (Abagale *et al.* 2013). For magnesium, all the selected cereals varied significantly ($p < 0.05$) with each other and the corresponding values were 60.66 mg/100g, 37.66 mg/100g, 111.00 mg/100g and 74.00 mg/100g respectively. Ensminger (1986) reported that magnesium reduced the severity of asthma and the frequency of migraine attack as well a slower high blood pressure and the risk of cardiac arrest especially in people with atherosclerosis. Highest amount of zinc was found in wheat flour 2.85 mg/100g followed by BK2 FTM 1.46 mg/100g, rice 1.27 mg/100g and maize flour 1.22 mg/100g. BK 2 FTM flour had contained significantly higher ($p < 0.05$) amount of copper 1.43 mg/100g than rice 0.26 mg/100g, wheat 0.72 mg/100g and maize 0.20 mg/100g flour. Kamara *et al.* (2009) reported that copper was an essential and beneficial element in human metabolism. Three different types of major cereals such as rice, wheat, maize and FTM flours were analyzed for their functional properties and showed in Table 2. The water absorption capacity (WAC) and oil absorption capacity (OAC) of BK2 FTM, rice, wheat and maize flours varied significantly ($p < 0.05$) with each other and the corresponding values were (225.82%, 217.84%), (233.15%, 205.86%), (191.65%, 243.64%) and (188.15%, 226.37%), respectively. The water and oil binding capacity of food protein depends upon the intrinsic factors like amino acid composition, protein conformation and surface polarity or hydrophobicity (Suresh and Samsher, 2013).

The WAC represents the ability of the products to associate with water in a condition when water is controlled such as dough's and pastes (Akubor and Badifu, 2001). The OAC of flour is equally important as it improves the mouth-feel and retains the flavor. The high OAC of flour suggests that it could be useful in food formulation where oil holding capacity is needed such as sausage and bakery products (Ahmed *et al.* 2014). In case of WAI, no significant differences ($p < 0.05$) were observed among the cereals, but for WSI, BK2 FTM 14.70% and rice flour 15.03% were not significantly ($p < 0.05$) varied but they were significantly differed ($p < 0.05$) with wheat 10.80% and maize flour 12.30%. The FC of BK2 FTM flour 0.76% was very similar to wheat flour 0.78% and they varied significantly ($p < 0.05$) from rice 0.27% and maize flour 0.40%. FC is assumed to be dependent on the configuration of protein molecules. Akubor *et al.* (2013) noted that the FC and FS dependent on protein concentration, protein solubility, swelling power and other factors. The BD (0.82 g/ml) of rice flour was significantly higher ($p < 0.05$) than BK2 FTM, wheat and maize flour and the values were 0.59 g/ml, 0.55 g/ml and 0.71 g/ml respectively.

Table 2. Comparison of functional properties of BK2 FTM with rice, wheat and maize flou**r**

Properties Name	Sample name			
	BK2	**Rice**	**Wheat**	**Maize**
WAC (%)	225.82 ± 4.38^{a}	233.15 ± 1.96^{b}	191.65 ± 3.34^{c}	188.15 ± 1.57^{d}
OAC (%)	217.84 ± 4.24^{a}	205.86 ± 6.78^{b}	243.64 ± 2.38^{c}	226.37 ± 3.05^{d}
WAI (%)	7.57 ± 0.38^{a}	7.56 ± 0.09^{a}	7.67 ± 0.11^{a}	7.58 ± 0.05^{a}
WSI (%)	14.70 ± 0.44^{a}	15.03 ± 0.53^{a}	10.80 ± 0.40^{c}	12.30 ± 0.16^{b}
FC (%)	0.76 ± 0.03^{a}	0.27 ± 0.03^{b}	0.78 ± 0.03^{a}	0.40 ± 0.02^{b}
FS (%)	0.32 ± 0.03^{b}	0.12 ± 0.02^{c}	0.62 ± 0.02^{a}	0.12 ± 0.02^{c}
BD (g/ml)	0.59 ± 0.02^{c}	$0.82 \pm .01^{a}$	0.55 ± 0.01^{c}	0.71 ± 0.02^{b}
SC (%)	0.29 ± 0.02^{d}	16.14 ± 0.07^{c}	18.23 ± 0.09^{b}	23.18 ± 0.12^{a}
EA (%)	40.01 ± 0.01^{c}	42.87 ± 0.01^{b}	43.67 ± 0.18^{a}	43.87 ± 0.28^{a}
ES (%)	41.41 ± 0.20^{a}	36.38 ± 0.26^{b}	38.02 ± 0.76^{c}	40.14 ± 0.15^{a}

Here WAC- Water absorption capacity, OAC- Oil absorption capacity, SC- Swelling capacity, EA- Emulsion activity, ES- Emulsion stability, WAI-Water absorption index, WSI- Water solubility index, FC-Foaming capacity, FS- Foaming stability and BD-Bulk density. Data present as mean value ± standard deviation. Means in a row with same superscript are not significantly different at ($p<0.05$).

The present study revealed that bulk density dependent on the particle size and initial moisture content of flours. The high bulk density of flour suggests their suitability for use in food preparations. On the other hand, low bulk density would be an advantage in the formulation of complementary foods (Akpata and Akubor, 1999). The swelling capacity among the cereals was significantly varied ($p < 0.05$) with each other and the corresponding values were 0.29%, 16.14%, 18.23% and 23.18% respectively. The swelling capacity of flours depends on size of particles, types of variety and types of processing methods or unit operations (Suresh and Samsher, 2013). The highest emulsion activity 43.87% was observed in maize flour which was not significantly varied ($p < 0.05$) with wheat flour 43.67% but they were significantly differed ($p < 0.05$) with rice 42.87% and BK2 FTM flour 40.01%. Kaushal *et al.* (2012) found that hydrophobicity of protein has been attributed to influence their emulsifying properties. The highest emulsion stability was observed in BK2 FTM flour 41.41% and it was not significantly varied ($p < 0.05$) with maize flour 40.14% but they were significantly differed ($p < 0.05$) as compared to rice 36.38% and wheat flour 38.02%. Increasing EA and ES during processing are primary functional properties of protein in such foods as comminuted meat products, salad dressing, frozen desserts and mayonnaise (Suresh and Samsher, 2013).

Conclusion

The various nutritional assessments revealed that BK2 FTM flour showed almost same nutritional value in terms of rice, wheat and maize flour. It has more energy and fat than those cereals. It also contained more iron, copper and phosphorous than rice, wheat and maize flour. Not only that, it has also more or less similar functioning capacity with wheat and maize flour. Therefore, it can be equally used with rice, wheat and maize as a staple food or BK2 FTM flour can be supplemented as staple flour.

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