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PHYSICO-FUNCTIONAL AND NUTRITIONAL PROPERTIES OF PIGMENTED AND NON-PIGMENTED MAIZE AVAILABLE IN BANGLADESH

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Key words: Physico-functional properties, Proximate composition, Pigmented maize

Abstract

Consumption of diversified pigmented whole grain maize is encouraged to combat hidden hunger. The present research was conducted to evaluate physico-functional and nutritional properties of pigmented and non-pigmented maize in Bangladesh. Results revealed that white maize had the highest brightness value while purple, and deep red maize showed the lowest brightness value. The lowest bulk density (0.565 ± 0.005 g/ml) and percentage change (15.05 ± 0.31%) in sedimentation was in purple maize flour. White maize flour showed the highest change (35.43 ± 0.59%) in sedimentation value. Red and purple maize contained the highest amount of ash (2.27 ± 0.059 and 2.27 ± 0.05%, respectively) and mixed maize contained the highest crude fibre (4.17 ± 0.049%). Purple, deep red, and mixed colored maize had the highest (72 to 73%) carbohydrate whereas indigenous deep red and mixed colored maize had the lowest (6%) protein content. All most all samples had similar Mg and S content. Purple, deep red and mixed maize were found to be promising for Ca. White maize had the highest amount (19.79 ± 0.1 mg/100 g) of Zn. Yellow maize showed to contain the highest amount (4.99 ± 0.37 mg/100 g) of Fe. Overall, whole grain pigmented and non-pigmented hybrid and indigenous maize were comparable for physico-functional and nutritional properties.

Introduction

Maize or corn (*Zea mays* L.) belonging to *Poaceae* is considered as the world's most consumed cereal. It is one of the most adaptable crops having wider adaptability. The kernels are consumed as food or feed and utilized in food and chemical industries (Ranum *et al.* 2014). Maize may be classified according to kernel type, presence of sugar; waxy and non-waxy; dent and flint. Maize is also classified as pigmented and non-pigmented (white). Pigmented maize usually has different pericarp colors such as yellow, orange, red, pink, purple, blue, black etc. (Gwitz *et al.* 2014). Usually different maize has different usages in different parts of the world. White maize is preferred in Africa and Central America while yellow maize is preferred in the United States of America. Different colored maize is also used in preparation of traditional foods. Now a days colored maize has gained much interest for modern food industries due to pigments which has bioactivity or antioxidant activity (Mohanlal *et al.* 2013). It was estimated that, in 2021, the total production of maize was 1161 million MT (FAOSTAT 2022). However, From the agro edaphic point of view, maize also can be grown well in Bangladesh. According to BBS (2020), in 2018-19, maize production in Bangladesh increased by 18% and the area of production increased by 14% compared to the year 2016-17.

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Maize is a rich source of energy, digestible carbohydrate, moderate protein, minerals and other phytonutrients. Energy and nutrition in maize is comparable with other two major cereals-wheat and rice (Upadhyay *et al.* 2018, USDA 2019).

In Bangladesh, rice is staple food but primary use of maize is as feed and later as food. There is lack of sufficient data on specific utilization and quantity of maize as food in Bangladesh. However, there was annual demand for green cob about 800 tons of grain equivalent, 200 tons as popcorn, and 24 to 30 thousand tons as starch and considerable possibilities for using maize as human food and for exports (Dewan. *et al.* 1998). Limited researches have focused on nutritional composition of pigmented and non-pigmented whole grain maize consumed by Bangladeshi population (Ali *et al.* 2008). Furthermore, physicochemical, functional and nutritional composition of maize are valuable for preparation of various food. Therefore, the present research was aimed to analyze the physical and functional properties of pigmented and non-pigmented whole grain maize, to analyze the nutritional composition of whole grain maize, and to analyze micronutrients of whole grain maize.

Materials and Methods

Non pigmented or white maize, and pigmented Sher-e-Bangla Agricultural University (SAU) red maize and purple maize were collected from this University. The pericarp color was white, red and purple of the white maize, SAU red maize and purple maize, respectively. The endosperm color of the kernels of all maize was white. The BARI Hybrid Maize-9 had yellow pericarp and endosperm. Deep red maize and multi colored kernel maize were indigenous varieties. Pericarp color of deep red maize kernel and multi colored maize kernel was deep red to black and yellow to deep red, respectively. Endosperms of the both samples were white (Fig. 1).

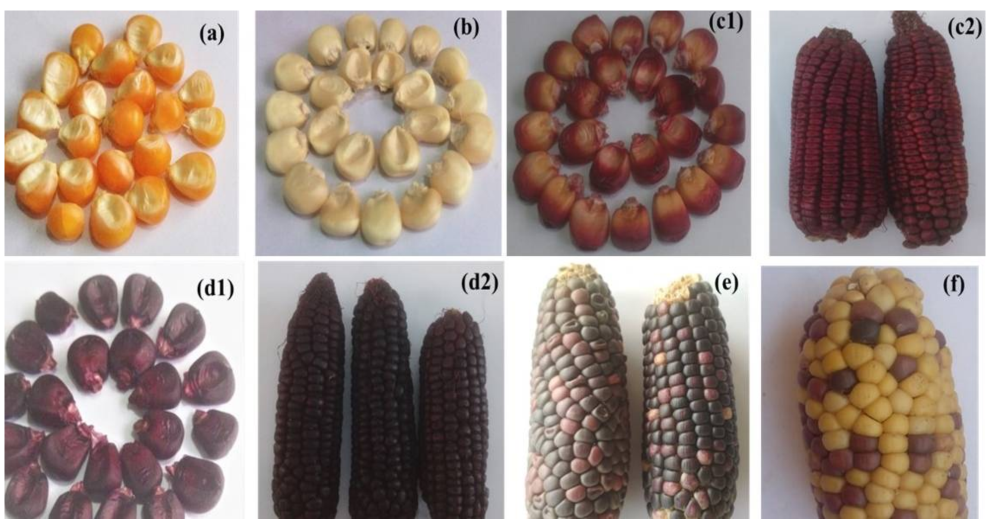

Fig. 1. Experimental samples: Yellow maize (BHM-9) (a); white maize (b); SAU red maize (kernel c1, cob c2); SAU purple maize (kernel d1, cob d2); deep red maize (e); and mixed maize (f).

Maize kernels were removed from cob, sundried and cleaned. Samples were pulverized to flour with a grinder (Miyako, model no: YT-4677A-S). Flours of all samples were stored in airtight condition and refrigerated at −20ºC till analysis.

A hunter lab scan XE model (M/S Hunter associate laboratory Inc., Reston-V.A., USA) was employed for determining the color value of samples with a view angle of 2°. The value was determined by the hunter system L*, a*, b* values. Bulk density of maize flour was determined following the method described by Edema *et al.* (2005). Sedimentation value was determined according to Ali and Bhattacharya (1976). Change in the volume was expressed in percentage change in sedimentation.

Moisture content in flour samples was determined following the method by AACC (2000). Fat was extracted by petroleum ether (b.p. 60–80 °C) employing a Soxhlet apparatus according to AOAC (2000). To determine ash content, the samples were ignited in muffle furnace at 600^{o}C for 1 hr according to AOAC (2000). Ash content was estimated from the weight difference of the crucible and expressed in the percentage. Protein content was determined from the total nitrogen (N × 6.25) using the micro Kjeldahl method (AOAC 2000). Crude fibre was determined from fat free sample according to the AOAC methods (2000). Sulpher (S) was determined using a spectrophotometer at 535 nm; Ca, Mg and micro minerals-Cu, Fe, Mn, Zn were determined by atomic absorption spectrophotometer following the procedure described by Hunter (1984).

Values are presented as mean ± standard deviation (SD) of three repetitions of each experiment and calculated as dry weight basis. Means of components in samples were compared by one way ANOVA and Tukey's test at the confidence level of 95% using IBM SPSS 20 statistical software (IBM Corp, Released 2011, IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp).

Results and Discussion

Color of a grain influences acceptance of a grain and food as well. Redness (a*) of the samples was found to range from 13.16 ± 0.67 to 1.37. ± 0.47 (Table 1). The highest redness was observed in yellow maize (BHM 9) and the lowest value was in purple maize (1.37 ± 0.47) followed by white and red maize. Low redness in the SAU red maize might be due to dominance of yellowness (b*) in both sides of kernel while the top of the kernel was red. The value of yellowness was found to range from 33.87 ± 5 to 0.52 ± 0.22 in grain samples. The highest value of yellowness was observed in mixed maize. The lowest b* value was recorded for purple maize. Brightness or whiteness of grains ranged from 83.25 ± 0.5 to 45.6 ± 2.9. The highest brightness (L*) was recorded in white maize and the lowest L* value was observed in deep red maize followed by purple and red maize. Pandey *et al.* (2016), Amador-Rodriguez *et al.* (2019) reported higher lightness for non-pigmented grain than pigmented one, and less redness in blue corn and high yellowness in white corn. The present findings are more or less similar to the findings of those studies.

Bulk density ranged from 0.57 ± 0.0 g/ml to 0.75 ± 0.0 g/ml (Fig. 2). There was no significant difference in bulk density of flour samples except the purple maize. Purple maize showed the lowest bulk density (0.57 ± 0.0 g/ml). Ikujenlola *et al.* (2014) reported bulk density (0.73 g/ml) for QPM which is similar to the present results. Chen *et al.* (2015) reported that low bulk density was related to low particle size of red rice flour. They also documented that enzymatic digestibility by α- amylase increased with decreasing particle size.

Results presented in Fig. 3 showed that percentage change in sedimentation value indicating gelatinization of starch. The sedimentation value of samples ranged from 15.1 ± 0.3 % to 35.4 ± 0.6 %. The highest sedimentation value was observed for white maize (35.4 ± 0.6 %) and the lowest percentage change was observed for purple maize flour (15.1 ± 0.3%). Sedimentation value of maize flour of the present study is similar to the reported sedimentation value (15.0 ± 0.1 %) in commercial and quality protein maize flour (Edema *et al.* 2005).

Table 1. Color properties of whole grain pigmented and non-pigmented maize.

Sample name	a*	b*	L*
Yellow maize	13.16 ± 0.67[a]	27.92 ± 3.3[ab]	75.27 ± 1.9[ab]
Red maize	2.97 ± 0.21[c]	17.54 ± 1.6[c]	55.09 ± 1.5[c]
White maize	1.7 ± 0.09[c]	23.52 ± 2[bc]	83.25 ± 0.47[a]
Purple maize	1.37 ± 0.47[c]	0.52 ± 0.22[d]	50.78 ± 5[c]
Mixed maize	7.9 ± 1.6[b]	33.87 ± 5[a]	73.14 ± 3[b]
Deep Red maize	10.3 ± 1[ab]	15.48 ± 0.58[c]	45.6 ± 2.9[c]

Values are mean ± SD presented as dry weight basis; different alphabets in each column shows the significant difference ($p < 0.05$).

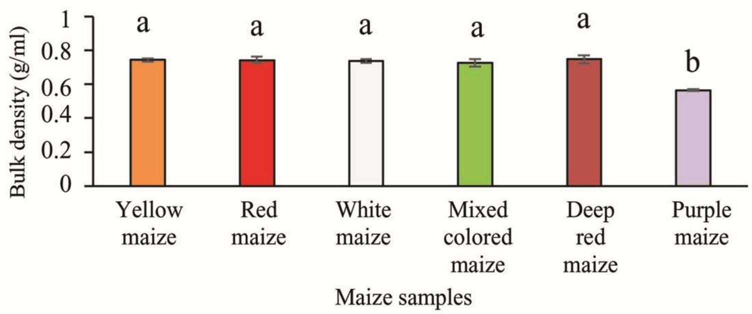

Fig. 2. Bulk density (g/ml) of grains flour.

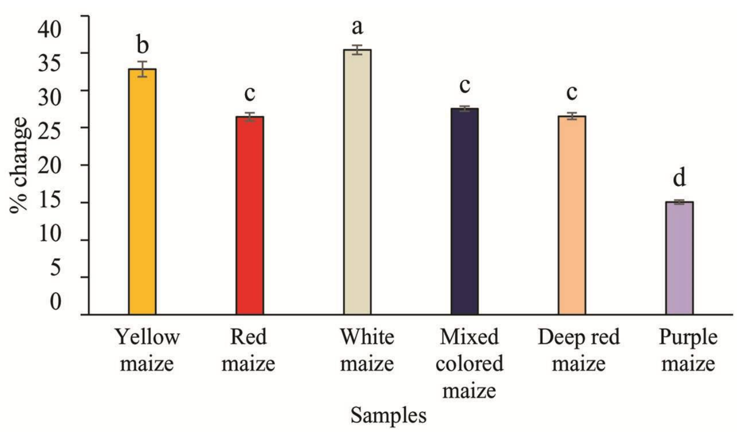

Fig. 3. Change (%) in sedimentation of grains flour.

Moisture content in maize was observed to range from 10.31 ± 0.22 to 11.39 ± 0.28% (Table 2). Yankah *et al.* (2020) reported 13.0 ± 0.4% of moisture in maize which is higher than the present report. Ash content in samples ranged from 1.22 ± 0.1 to 2.27 ± 0.1%. Red and purple maize contained the highest ash (2.27 ± 0.1%) and the mixed colored maize contained the lowest ash (1.22 ± 0.1%). There was no significant difference in ash content in yellow, white, and deep red maize. Ash content in the maize samples in the present study is similar to the ash content (1.1

± 0.0% to 1.3 ± 0.0%) in white and blue maize (Camelo-Méndez *et al.* 2017). However, Ikya *et al.* (2013) reported less ash content in maize than the present finding. Fibre content in samples was found to range from 3.31 ± 0.01% to 4.17 ± 0.05%. Among samples, mixed colored maize contained the highest fibre (4.17 ± 0.05%) and white maize contained the lowest fibre (3.31 ± 0.1%). Furthermore, yellow, red, and purple maize had similar fibre content. Ikya *et al.* (2013) and Edema *et al.* (2005) reported less (1.92 and 1.48 to 1.09%, respectively) fibre content in maize than the present finding.

Table 2. Proximate composition of whole grain pigmented and non-pigmented maize (%) dry weight basis.

Sample name	Moisture (%)	Ash (%)	Crude fibre (%)	Carbohydrate (%)	Protein (%)	Oil (%)
Yellow maize	10.87 ± 0.06^{ab}	1.69 ± 0.01^{b}	3.58 ± 0.03^{c}	67.69 ± 0.5^{c}	11.77 ±0.45^{ab}	4.37 ± 0.1^{cd}
Red maize	10.63 ± 0.36^{ab}	2.27 ± 0.1^{a}	3.54 ± 0.05^{c}	65.76 ± 0.6^{d}	12.6 ± 0.5^{a}	4.97 ± 0.1^{b}
White maize	10.82 ± 0.33^{ab}	1.68 ± 0.01^{b}	3.31 ± 0.01^{d}	67.18 ± 0.4^{cd}	11.36 ± 0.3^{b}	5.63 ± 0.2^{a}
Purple maize	10.57 ± 0.22^{ab}	2.27 ± 0.1^{a}	3.55 ± 0.03^{c}	72.38 ± 0.3^{b}	7.4 ± 0.3^{c}	3.9 ± 0.2^{d}
Mixed maize	10.31 ± 0.22^{b}	1.22 ± 0.1^{c}	4.17 ± 0.05^{a}	73.59 ± 0.1^{a}	5.58 ± 0.2^{d}	4.9± 0.04^{b}
Deep red maize	11.39 ± 0.28^{a}	1.69 ± 0.01^{b}	3.97 ± 0.1^{b}	72.71 ± 0.2^{ab}	5.89 ± 0.23^{d}	4.7 ± 0.2^{bc}

Values are mean ± SD presented as dry weight basis; different alphabets in each column shows the significant difference ($p < 0.05$).

Carbohydrate content in samples ranged from 65.76 ± 0.6 to 73.59 ± 0.1%. The indigenous mixed maize had the highest carbohydrate which was similar to deep red maize. Red maize contained the lowest (65.76 ± 0.6%) carbohydrate among the samples. This observation is more or less similar to carbohydrate content (66.2%) in maize reported by Dewan *et al.* (1998). However, Ramírez-Jiménez *et al.* (2018) and Edema *et al.* (2005) reported higher carbohydrate content in maize than the present finding. Protein content in samples ranged from 5.58 ± 0.2 to 12.6 ± 0.5%. Red maize contained the highest protein (12.6 ± 0.5%) which was similar to yellow maize. Local maize- mixed colored and deep red maize contained the lowest protein (5.58 and 5.89% respectively). Protein content in maize in the present study is similar to the protein (5.58 ± 0.2 to 11.77 ± 0.5%) in blue and white maize reported by Camelo-Méndez *et al.* (2017). Oil content in samples ranged from 3.9 ± 0.2 to 5.63 ± 0.2%. White maize contained the highest (5.63 ± 0.2%) oil. On the other hand, purple maize contained the lowest (3.9 ± 0.2%) oil. Oil content in the present study is similar to those value reported by Ramírez-Jiménez *et al.* (2018).

Calcium content of different colored maize ranged from 140.16 ± 10.8 mg/100 g to 317.39 ± 16.3 mg/100 g. Purple maize contained the highest Ca (317.39 ± 16.3 mg/100 g) which is similar to mixed and deep red maize while white maize contained the lowest Ca (140.16 ± 10.8 mg/100 g). Ca content in maize found much higher than the value (5.96 mg/100 g) reported by Gallego-Castillo *et al.* (2021). Mg content of different colored maize ranged from 214.81 ± 6.8 to 245.06 ± 18.3 mg/100g. There was similarity ($p > 0.05$) in Mg content in all samples. Hossain *et al.* (2008) reported 646.9 to 263.6 mg/100 g of Mg in 12 maize samples which are much higher than the present findings. In different colored maize, S content ranged from 37.37 ± 13.9 to 90.39 ± 18.5 mg/100g. There was no significant difference among yellow, red, mixed, and deep red maize for S content. Present finding is similar with S content (72.87 to 179.5 mg/100 g) reported by Hossain *et al.* (2008).

Table 3. Minerals content (macro) whole grain pigmented and non-pigmented maize (mg/100 g) dry weight basis.

Sample name	Ca (mg)	Mg (mg)	S (mg)
Yellow maize	251.7 ± 18.4[bc]	240.48 ± 14.3[a]	82.28 ± 23[a]
Red maize	216.72 ± 6.4[c]	245.49 ± 17.9[a]	70.99 ± 13[a]
White maize	140.16 ± 10.8[d]	230.24 ± 7.7[a]	37.37 ± 13.9[b]
Purple maize	317.39 ± 16.3[a]	214.81 ± 6.8[a]	55.74 ± 18.2[ab]
Mixed maize	294.97 ± 11.4[a]	245.06 ± 18.3[a]	67.03 ± 18.2[a]
Deep Red maize	290.01 ± 2.7[ab]	241.43 ± 14[a]	90.39 ± 18.5[a]

Values are mean ± SD presented as dry weight basis; different alphabets in each column shows the significant difference ($p < 0.05$).

Table 4. Minerals content (micro) in whole grain maize (mg/100 g) dry weight basis.

Sample name	Cu (mg)	Fe (mg)	Mn (mg)	Zn (mg)
Yellow maize	0.14 ± 0.0[de]	4.99 ± 0.4[a]	0.83 ± 0.1[b]	5.64 ± 0.1[e]
Red maize	0.26 ± 0.0[a]	2.57 ± 0.2[b]	0.90 ± 0.0[bc]	18.0 ± 0.2[b]
White maize	0.24 ± 0.0[ab]	1.39 ± 0.2[c]	0.51 ± 0.1[d]	19.75 ± 0.1[a]
Purple maize	0.21 ± 0.0[bc]	1.31 ± 0.1[c]	0.72 ± 0.0[c]	9.55 ± 0.2[c]
Mixed maize	0.13 ± 0.0[e]	1.60 ± 0.1[c]	1.34 ± 0.0[a]	8.62 ± 0.2[d]
Deep Red maize	0.18 ± 0.0[cd]	1.36 ± 0.0[c]	1.38 ± 0.0[a]	5.14 ± 0.1[e]

Values are mean ± SD presented as dry weight basis; different alphabets in each column shows the significant difference ($p < 0.05$).

Cupper content of different colored maize ranged from 0.13 ± 0.0 to 0.26 ± 0.0 mg/100 g. Red maize contained the highest Cu content (0.26 ± 0.0 mg/100 g) followed by white maize (0.24 ± 0.0 mg/100 g). Mixed colored maize contained the lowest Cu content followed by Yellow maize. Unlike the present findings, Cu content in 12 maize range was reported to be from 3.81 to 0.41 mg/ 100 g (Hossain *et al.* 2008). Iron content in samples ranged from 1.31 ± 0.1 to 4.99 ± 0.4 mg/100 g. Yellow maize contained the highest (4.99 ± 0.4 mg/100 g) iron followed by red maize. Purple maize contained the lowest (1.31 ± 0.1 mg/100 g) iron. Observation of Fe content in maize was found to be similar to its content reported by Bressani *et al.* (2004). Content of Mn in samples ranged from 0.51 ± 0.1 to 1.38 ± 0.0 mg/100 g. Deep red maize contained the highest (1.38 ± 0.0 mg/100 g) Mn which is similar to mixed colored maize while white maize contained the lowest (0.51 ± 0.1 mg/100 g) Mn. Hossain *et al.* (2008) reported more or less similar value (0.48 mg/100 g). Zinc content in samples ranged from 5.14 ± 0.1 mg/100 g to 19.75 ± 0.1 mg/100 g. White maize contained the highest Zn (19.75 ± 0.1 mg/100 g) followed by red maize. Deep red maize contained the lowest Zn (5.14 ± 0.1 mg/100 g) which was similar to yellow maize. Iken *et al.* (2002) and Bressani *et al.* (2004) reported less amount of Zn content in maize (4.6 mg/100 g).

Considering all obtained results, it may be concluded that all maize including newly released SAU purple and indigenous maize varieties were comparable for their physico-functional and nutritional aspects.

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