EVALUATION OF PHYSICO-FUNCTIONAL CHARACTERISTICS AND NUTRITIONAL STATUS OF SOME PIGMENTED WHOLE GRAIN AVAILABLE IN BANGLADESH

SUMAIYA SUBRIN

DEPARTMENT OF BIOCHEMISTRY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

DECEMBER, 2020

EVALUATION OF PHYSICO-FUNCTIONAL CHARACTERISTICS AND NUTRITIONAL STATUS OF SOME PIGMENTED WHOLE GRAIN AVAILABLE IN BANGLADESH

BY

SUMAIYA SUBRIN
REGISTRATION NO. 14-06001

A Thesis
Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE
IN
DEPARTMENT OF BIOCHEMISTRY
SEMESTER: DECEMBER, 2020

Approved by:

____

(Dr. Ashrafi Hossain)
Professor, Department of Biochemistry
Supervisor

____

(Dr. Md. Abdus Satter)
Chief Scientific Officer, IFST, BCSIR
Co-supervisor

____

(Prof. Dr. Ashrafi Hossain)
Chairman
Examination Committee

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207.
Bangladesh.

Ref **Date :**

CERTIFICATE

*This is to certify that thesis entitled, **"EVALUATION OF PHYSICO-FUNCTIONAL CHARACTERISTICS AND NUTRITIONAL STATUS OF SOME PIGMENTED WHOLE GRAIN AVAILABLE IN BANGLADESH BANGLADESH"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) in BIOCHEMISTRY,** embodies the result of a piece of bona fide research work carried out by **SUMAIYA SUBRIN,** Registration No. **14-06001** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

....

Dated:
Place: Dhaka, Bangladesh

(Prof. Dr. Ashrafi Hossain)
Supervisor
Department of Biochemistry
Sher-e-Bangla Agricultural University
Dhaka-1207

ACKNOWLEDGEMENT

Foremost, I express my gratitude to the almighty Allah, the most Beneficent and the most Merciful, and heartfelt thanks for the invisible blessing, guidance, protection, help and wisdom in all aspect of my life.

The author would like to express her sincere gratitude to her respected supervisor Dr. Ashrafi Hossain, Professor, and Chairman, Department of Biochemistry, Sher-e-Bangla Agricultural University, Dhaka, for her continuous support to complete MS study and research. The author also express respect for her patience, motivation, enthusiasm and immense knowledge. It wouldn't have been possible to complete this research work without her cooperation and support.

The author would like to express her bow and appreciation of her co-supervisor Dr. Md. Abdus Satter, Chief Scientific Officer, Department of IFST (Institute of Food Science and Technology), BCSIR (Bangladesh Council of Scientific and Industrial Research, Dhaka) for providing her all necessary facilities and permission of using the IFST laboratories of BCSIR, Dhaka. My sincere thanks also go to all the respected scientists (Md. Abdul Jalil, Principal Scientific Officer, Faridul Islam, Senior Scientific Officer and Nusrat Abedin, Senior Scientific Officer, BCSIR, Dhaka), Md. Abdullah Al Muhit, Research Fellow and all the laboratory technicians of IFST of BCSIR, Dhaka for their continuous help.

The author sincerely thanks to Dr. Md. Golam Ferdous Chowdhury, Senior Scientific Officer, Department of Postharvest Technology, BARI (Bangladesh Agricultural Research Institute), Gazipur, for the guidance and laboratory facilities to carry out some parts of this research work. The author also wise to express her gratitude to the officials and other staff of Department of Postharvest Technology, BARI, who rendered their help during the period of her work.

The author is grateful to Mosammat Salma Zannat, Senior Scientific Officer, Soil Chemistry Section, Central Laboratory, Soil Resource Development Institute, Dhaka for her heartfelt cooperation in proximate data analysis and the author also grateful to Professor Dr. Nurul Islam, Department of Botany, University of Dhaka, Professor Dr. Jamilur Rahman, Department of Genetics and Plant Breeding and Munshi Mohammad Sumon, Assistant Professor, Department of Biochemistry, Sher-e-Bangla Agricultural University, Dhaka for their cooperation in collecting seed materials.

The author sincerely thanks to the Ministry of Science and Technology, Government of Bangladesh, for providing financial support (NST fellowship) to conduct thesis research work.

The author is grateful to the Chairman, Prof. Dr. Ashrafi Hossian along with all the teachers and stuff of the Department of Biochemistry, Sher-e-Bangla Agricultural University, Dhaka, for their cooperation. The author also thankful to all of her friends for always being there for supporting her throughout her MS programme and in this thesis research work.

Last but not the least, the author would like to thank her family for supporting her morally throughout her work.

The Author

ABSTRACT

Maize and rice are the highest consumed cereals in the world. Pigmented and non-pigmented maize can be utilized like rice if its complete properties are known. There are some pigmented and non-pigmented maize and rice varieties available in Bangladesh for human consumption. The present research was conducted to evaluate and compare physico-functional and nutritional properties of colored maize and rice. Maize such as-yellow maize, red maize, white maize, purple maize, mixed colored maize, deep red maize; and rice such as red rice was used for investigation. Study revealed that white maize was the brightest grain among the samples with its highest L* value while purple maize, deep red maize and red rice showed the lowest L* value. The lowest bulk density (0.565 ± 0.005 g/mL) and % change (15.05 ± 0.31%) in sedimentation was recorded for purple maize flour but white maize flour showed the highest change in sedimentation value (35.43 ± 0.59%). All most all samples were comparable for proximate composition. Red maize and purple maize contained the highest amount of ash (2.27 ± 0.059% and 2.27 ± 0.05% respectively) while mixed maize contained the lowest amount of ash (1.22 ± 0.09%). Mixed maize contained the highest crude fibre (4.17 ± 0.049%) which was comparable to red rice on the other hand white maize had the lowest crude fibre (3.31 ± 0.06%). Purple maize along with mixed maize and deep red maize had the highest carbohydrate content (72 to 73%) whereas local mixed maize and deep red maize had the lowest protein content (6%). Red maize had the highest protein content which was comparable to yellow maize, and the lowest carbohydrate content (65.76 ± 0.57%) which was comparable to white maize and red rice. Red rice performed better than the other samples for oil content (6.19%). In case of Mg and S content, all most all samples showed similarity; and the purple maize, mixed maize and deep red maize were promising for Ca content. White maize had the highest amount of Zn (19.79 ± 0.1 mg/100 g) while it had the lowest amount of Ca (140.16 ± 10.8 mg/100 g), and Mn (0.51 ± 0.05 mg/100 g). Yellow maize showed the highest amount of Fe (4.99 ± 0.37 mg/100 g); and the lowest Cu content (0.14 ± 0.02 mg/100 g) which was similar to mixed maize (0.13 ± 0.01 mg/100 g). The red rice was poor in Zn (4.02 ± 0.13 mg/100 g) and Fe (0.61 ± 0.14 mg/100 g) content. Overall, whole grain maize and rice samples were comparable from the physico-functional and nutritional properties. Therefore, whole grain pigmented and non-pigmented maize can be utilized like rice as rich source of nutrition as regularly consumed cereals to combat nutritional deficiency.

LIST of CONTENTS

LIST of CONTENTS (Cont.)

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

and others (at elli)	*et al.*
Association of Official Analytical Chemist	AOAC
American Association of Cereal Chemists	AACC
Atomic Absorption	AA
Bangladesh Agricultural Research Institute	BARI
Bangladesh Council of Science and Industrial Research	BCSIR
Bangladesh Bureau of Statistics	BBS
Calcium	Ca
Copper	Cu
Crude protein	CP
Cubic Centimeter (Solid materials)	cc
Degree Celsius (Centigrade)	ºC
Food and Agricultural Organization	FAO
Food and Agriculture Organization Corporate Statistical Database	FAOSTAT
Gram	g
Hour	h
Hydrogen ion conc.	pH
Iron	Fe
Institute of Food Science and Technology	IFST

LIST OF ABBREVIATIONS (Cont'd)

International Maize and Wheat Improvement Center	CYMMIT
Kilogram	Kg
Liter	L
Magnesium	Mg
Manganese	Mn
Microgram	ug/µg
Micron	um/µ
Milligram	mg
Milliliter	mL
Millimicron	mu/mµ
Metric Ton	MT
Million Hector	MH
Molar	M
Normal	N
Normality	N
Parts per Million	ppm
Phosphorus	P
Potassium	K

LIST OF ABBREVIATIONS

Sodium	Na
Standard error	SE
Sulphur	S
Tri chloro acetic acid	TCA
Zinc	Zn

Chapter I

INTRODUCTION

Maize or corn (*Zea mays* L.) and rice (*Oryza sativa*) belong to *Poaceae* family and considered as the world's most consumed cereals. Maize was domesticated in Central America (Mexico) that originated approximately 7000 years. It is one of the most adaptable crops having wider adaptability. Maize grows well from 10-30 °C, on a fine sandy-loam to a heavy clay-loam soil with a soil pH from 5.0-8.5. Maize cultivation requires 500 mm to 5000 mm of rainfall (CYMMIT report 1998). The kernels are consumed as food or feed and utilized in food and chemical industries (Ranum *et al.*, 2014). Figure 1 (a) shows the different parts of a maize plant.

Figure 1 (a). Maize plant (https://www.netmeds.com)

Figure 1 (b). Rice plant (https://www.science.org)

Rice is the most important cereal crop and the major staple food for almost 33 countries including Asia and the Pacific, Latin America and the Caribbean, North Africa and Sub-Saharan Africa regions but not in Antarctica. Rice cultivation is one of the oldest form of intensive agriculture and practiced from 7,000 years ago. Among two cultivars, a principal cultigen, *Oryza sativa* was domesticated in the Indochinese region. Rice can grow in the land up to 3000 m from sea level (Bambaradeniya *et al.*, 2004). Figure 1 (b) shows the different parts of a rice plant.

A completely grown maize kernel has endosperm, germ, pericarp and tip. Figure 2 (a) shows the structure of a maize kernel. Maize may be classified according to kernel type such as dent, flint, flour, sweet, pop, Indian, and pod corn. Maize can be classified as sugary and starchy based on sweetness or the presence of sugar; waxy and non-waxy; and dent (floury) and flint. These divisions are based on the quality, quantity and pattern of endosperm composition in the kernel and are not indicative of natural relationships. 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; Runam *et al.*, 2014). Dent, flint, sweet and pop corns are widely used as food in home and industry. Usually different maize has different usages in different parts of the world. White maize is preferred Africa and Central America while yellow maize is preferred in United States. Different colored maize is also used in preparation of traditional foods.

Rice can come in different shapes, pericarp colors and size which are genetically regulated (Shao *et al.*, 2011). Generally brown rice is the whole grain rice with intact bran layer or pericarp, the seed coat and nucellus, the germ or embryo, and the endosperm. Figure 2 (b) shows the structure of a whole grain rice kernel. Rice is consumed in various forms other than staple food in all over the world. Rice starch, rice bran, rice bran oil, flaked rice, puffed rice, parched rice, rice broken, etc. are the major usage of rice around the world (Chaudhari *et al.,* 2018). Rice is an excellent source of carbohydrate, protein, and has low fat, low salt and no cholesterol (Chaudhari *et al.*, 2018).

Now a days colored cereals such as maize and rice are point of interest for modern food industries due to pigments which has bioactivity or antioxidant activity (Gwitz *et al*., 2014; Mohanlal, *et al.,* 2013; Runam *et al.,* 2014) .

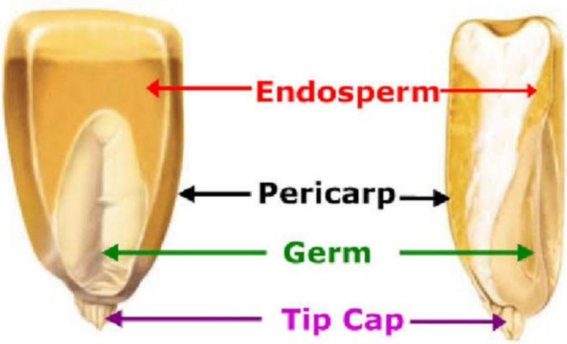

Figure 2 (a). Structure of maize seed kernel (https://www.researchgate.net)

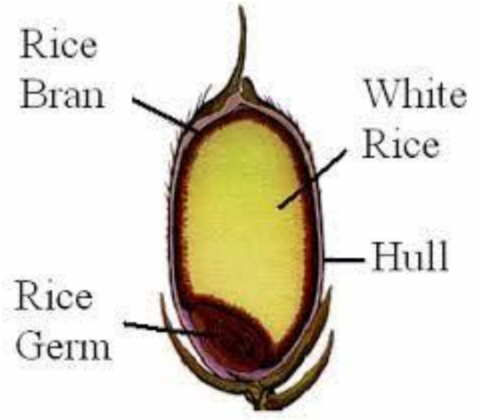

Figure 2 (b). Structure of rice seed kernel (https://www.researchgate.net)

It was estimated that, in 2019, the total production of maize was 3 million MT and the total production of rice was more than 54 million MT (FAOSTAT, 2019). Rice is the staple food for 90% of Asians. China is the top rice producer and Bangladesh is 4th in the world ranking (FAOSTAT, 2019). Therefore, Bangladesh has no deficiency in rice production. 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.

Maize has food, feed, and industrial uses. Maize is used as a major component of feed all over the world Various maize products can be obtained from dry and wet milling. Maize grits, meal, fine meal, flour, corn starch, corn syrup are some of forms of maize utilized as food day (Gwirtz *et al*., 2014; Ranum *et al.*, 2014).

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. Brown rice contained 77.24 g/100 g of carbohydrate, 7.94 g/ 100 g protein, 2.29 g/100 g fat, 3.5 g/100 g dietary fibre. Apart from carbohydrate and protein, brown rice is rich in minerals and vitamins due to the presence of bran layer and germ. However, brown rice has less consumer acceptability probably due to its longer cooking time, shorter storage period undesirable texture and longer chew ability than polished rice (Upadhyay *et al.,* 2018; USDA 2019). Generally polished rice, which contained only endosperm, is the most consumed form all over the world. Rice can be classified based on starch properties (Lee *et al.,* 2012; Shafie *et al.,* 2016). Based on pericarp color maize can be different types such as white rice, pink rice, red rice, black rice, etc. (Tensaout *et al.,* 2009). Brown rice is consumed less as regular meal but has medicinal value and use in therapeutic medicine and functional food development (Chaudhari *et al.,* 2018; Mohanlal *et al.,* 2013; Upadhyay *et al.,* 2018).

A comparative table of proximate composition of whole grain maize, wheat and rice (brown rice) is given in the Table 1.

Table 1. The chemical composition and comparative value of maize, wheat and brown rice per 100 g

Composition	**Maize**	**Wheat**	**Brown Rice**
Protein (g)	11.1	12.1	6.4
Fat (g)	3.6	1.7	2.29
Minerals (g)	1.5	2.7	0.7
Calcium (mg)	10.0	48.0	9.0
Phosphorus (mg)	348.0	355.0	143.0
Iron (mg)	2.0	11.5	4.0
Moisture (g)	14.9	12.2	13.3

** USDA (2019-2020)

Physical and functional characteristics such as pericarp color, sedimentation value of grains might influence the commercial market value of the grain itself or the end product. Chemical composition as well as physical and functional properties might be influenced by several factors. Genetically these properties might be different from grain to grain. Agronomical practices also have influence on quality parameters of crops (Gwirtz *et al.,* 2014).

In Bangladesh, rice is staple food but primary use of maize is as feed and later as food. Limited use of maize as flour, grits, semolina, corn on cob (roasted), corn starch, syrup etc. are reported in Bangladesh. 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 of maize as human food export (Ali *et al.*, 2008; Tetens *et al.,* 1998).

Several hybrid and composite maize varieties are released by BARI to meet the current requirement of maize. Moreover, non-government organizations and agro-industries are promoting maize in Bangladesh to meet the current demand (BARI Annual report 2019-2020). There are some indigenous maize varieties which are pigmented or non-pigmented grown by local farmers used to prepare local meals.

Limited researches have focused on nutritional composition and comparison of nutritional status of pigmented and non-pigmented whole grain maize and rice which are consumed by Bangladeshi population. Furthermore, detailed information on physicochemical, functional and nutritional composition might increase utilization of whole grain maize and rice in different food preparation. Such study might also bring out the wellness of consumption of whole grain maize and rice. Therefore, the present research aims to investigate physicochemical, functional and nutritional composition of some pigmented and non-pigmented maize and rice grown in Bangladesh. In order to fulfill the above mentioned aims the following objectives have been undertaken:

1. To analyze the physical and functional properties for the comparison study of pigmented and non-pigmented whole grain maize and brown rice.
2. To analyze the nutritional composition of whole grain maize and brown rice to focus their wellness.
3. To analyze macro and micro nutrients for the comparison study of whole grain maize and brown rice.

Chapter II

REVIEW OF LITERATURE

The endosperm, germ, pericarp and tip cap are four primary structures in a maize kernel which consist 83%, 11%, 5%, and 1% of the maize kernel respectively. The endosperm is starchy surrounded by a protein matrix. The germ or embryo of the maize kernel contains 33.3% fat, enzymes and other nutrients such as vitamin B complex and vitamin E. The pericarp is a semipermeable barrier surrounding the endosperm and germ but not the tip cap. Pericarp contains 8.8% crude fiber, minerals and different pigmented compounds which have antioxidant activity. The tip cap is the structure through which kernel is attached with the cob. It helps to pass all moisture and nutrients during development and kernel dry down (Gwirtz *et al.,* 2014; Hu *et al.,* 2011; Rui *et al.*, 2017; Zhu *et al.*, 2018).

Maize (*Zea mays* L.) is used as a source of carbohydrate consumed by many people in addition it has many other use. Maize is staple food for many people all over the world. Maize is considered as the staple food in The African region where the consumption ranges from 52 to 328 g/person/day where maize is considered as important/staple food source. In Americas the highest consumption was 267 g/person/day in Mexico but in Western Pacific Region maize consumption was not more than 50 g/person/day (Ranum *et al.,* 2014). Maize is consumed in whole form or its milled fractions. Some of the maize products are consumed globally are presented in the Table 2.

Table 2. Various maize products consumed globally (Gwirtz *et al.*, 2014)

Food Item	Types	Example
Bread	Flat, unleavened, unfermented	Tortilla, arepa
	Fermented and/or leavened	Pancakes, cornbread, hoe cake, blintzes
Porridges	Fermented, unfermented	Atole, ogi, kenkei, ugali, ugi, edo, pap, maizena, posho, asidah
Streamed products		Tamales, couscous, rice-like products, Chinese breads, dumplings, chengu
Beverage	Alcoholic	Koda, chichi, kafir beer, maize beer
	Nonalcoholic	Mahewu, magou, chichi dulce
Snacks		Empanadas, chips, tostadas, popped corn, fritters

Evaluation of its physical, functional and chemical properties is required to confine its use as food or food ingredients. Grain color, bulk density and sedimentation value of maize flour are some of properties important for food preparation.

Amador-Rodriguez *et al.*, (2019) determined nutrient composition of four different pigmented creole or native maize. The Negritas community white grain (NG) was collected from Zacatecas, Mexico; white grain from the Ahualulco community (SG) from San Luis Potosí, Mexico, and another two grains from San José de Gracia, Aguascalientes, Mexico,were white corn grain (WG), and a blue corn grain (BG). Seeds were stored at 4 ^oC. The color of the raw and processed grain was determined in the study. The instrumental color analysis was carried out in a MiniScan XE colorimeter. The CIELab system was used to determine the values of L*, a* and b* where L* indicated lightness, a* indicated green-red tonality and b* indicated blue-yellow tonality. They found that the value of L* ranged from 62.34 ± 0.05 to 88.17 ± 0.32, the value of a* ranged from 0.05 ± 0.06 to 3.13 ± 0.02 and the value of b* ranged from -1.64 ± 0.05 to 10.06 ± 0.20 for four different pigmented maize samples.

Edema *et al*., (2005) reported bulk density 0.46 and 0.47 for quality protein maize flour and commercial maize flour respectively, while it increased to 0.55 when mixed to soy flour. Percentage change in sedimentation value represents gelatinization of starch. Sedimentation value of yellow maize flour was 15.0 ± 0.08 mL reported by Nutan and Saroj (2015).

Upadhyay and Karn (2018) analyzed about nutritional composition and health benefits of brown rice. They reported in their study that the moisture, protein, carbohydrate, dietary fibre, Ca, Fe, Mg, P, K and Zn contents were 10.37 g. 7.94 g, 77.24 g, 3.5 g, 23 mg, 1.47 mg, 143 mg, 333 mg, 223 mg and 2.02 mg respectively per 100 g.

Camelo-Méndez *et al.,* (2017) determined proximate composition of Mexican blue maize flour and commercial white maize flour. The reported moisture, protein, lipid, and ash content was 9.8 ± 0.1, 9.1 ± 0.0, 5.2 ± 0.0, and 1.1 ± 0.0 g/100 g respectively in blue corn, while they were 7.0 ± 0.2, 8.4 ± 0.1, 4.7 ± 0.0, and 1.3 ± 0.0 g/100 g respectively in white maize flour.

Yankah *et al*., (2020) reported in their research about the comparative study of the nutritional composition of local brown rice. Their findings showed that the percentage of fat, protein, carbohydrate, moisture and ash were 4.67 ± 0.01, 4.28 ± 0.19, 77.94 ± 0.32, 12.31 ± 0.14 and 0.79 ± 0.00 respectively. They also found that the composition of Fe, Zn and Ca were 0.00 ± 0E-7 mg/100 g, 12.15 ± 0.21 mg/100 g and 16.60 ± 0.16 mg/100 g respectively.

Ikya *et al*., (2013) analyzed maize to prepare maize based products. They reported 8.92% crude protein, 4.85% fat, 1.92% fibre, 0.99% ash, 84.31% carbohydrate in the maize flour used for product.

Chaudhari *et al.,* (2018) reported about medicinal properties of rice. They found that the moisture, protein, fat, carbohydrate, fibre, ash, Fe and Zn contents were 14 %, 7.3 g, 2.2 g, 71.1 g, 4.0 g, 1.4 g, 3 mg% and 2 mg% respectively.

Edema *et al.,* (2005) analyzed commercially available maize flour and quality protein maize flour for proximate composition. The moisture content ranged from 7.15% to 6.9%, fat content from 4.09% to 4.80%, crude protein 8.96% to 11.76%, crude fibre 1.48% to 1.09%, ash content 1.33% to 1.02%, and carbohydrate from 77.06% to 74.43% in commercial maize flour and quality protein maize flour respectively.

Ramírez-Jiménez *et al.*, (2018) reported the changes on the proximate composition in maize flour after different processing. Corn was harvested from Mexico in 2016 to investigate the changes. Grains were prepared manually, cleaned from dust and debris, stored in polyethylene containers at 4 ^{o}C. Authors reported proximate composition in raw corn and processed instant corn flours. In the raw corn, the content of protein, fat, ash and carbohydrates 7.97 ± 0.08 %, 4.30 ± 0.18 %, 1.13±0.01% 86.4±0.42% respectively.

Amador-Rodríguez *et al.*, (2019) determined moisture content in maize while worked with four creole or native maize varieties. The varieties were Negritas community white grain (NG) collected from Zacatecas, Mexico; white grain of the Ahualulco community (SG) collected from San Luis Potosí, Mexico, and another two grains: a white corn grain (WG), and a blue corn grain (BG) were collected from San José de Gracia, Aguascalientes, Mexico. Grains were harvested in October 2017 and stored at 20 °C and 50% average relative humidity in polyethylene bags. They have determined moisture content in 4 corn samples. Moisture content in corn ranged from 8.68 ± 0.76 to 16.54 ± 0.59%. The lowest moisture content was observed in NG (8.68) and the highest moisture content was observed in WG (16.54%).

CYMMT report (1998) showed the chemical composition and comparative nutritive value of maize. It found that the maize variety contained protein 11.1%, fat 3.6%, minerals 1.5%, carbohydrate 66.2%, calcium 0.010%, phosphorus 3.48%, iron 0.02% and moisture 14.9%.

Bressani *et al.*, (2004) explored the effect of processing conditions on Calcium, Iron, and Zinc Contents of Lime-Cooked Maize. A semi hard white corn hybrid HB-83 which was commonly used by farmers of the tropical lowlands of Guatemala for making tortillas was used in the study. The collected sample was stored at 6 °C until used. They reported calcium, zinc and iron content in the raw maize before the sample was processed. They found that calcium, zinc and iron content was 8.4 ± 0.07%, 2.24 ± 0.05% and 2.65 ± 0.23% in the raw sample respectively. They observed changes in the content of minerals in the sample processed at different conditions.

Gallego-Castillo *et al.*, (2021) have studied retention of minerals and protein in different processed maize obtained from Latin America. Among five white maize breeding experimental varieties (hybrids), the three were high kernel-zinc bio fortified varieties (ZBM), the two were non-bio fortified varieties (non-ZBM) and one commercial maize used as control. In non-ZBM varieties, in raw kernel, the content of Fe, Zn, and Ca content was 19.07 ± 3.59 µg/g DW, 23.91 ± 3.81 µg/g DW and 59.60 ± 28.44 µg/g DW respectively. In ZBM varieties, in raw kernel, the content of Fe, Zn, and Ca was 17.10 ± 0.95 DW µg/g, 33.02 ± 1.39 DW µg/g, and 56.61 ± 5.40 µg/g DW respectively. In non-QPM varieties, in raw maize kernel, the protein content was 9.57 ± 0.25% and for QPM varieties, it was 9.09 ± 0.56%. However, the tryptophan and lysine content in QPM maize was higher than non-QPM varieties. Suri *et al.,* (2016); Gwirtz *et al.,* (2013) and other researcher have cited U.S. department of agriculture nutrient database several times for nutrients content in maize. According to USDA, whole grain yellow flour contained 7 mg, 0.23 mg, 2.38 mg, 93.0 mg, 0.46 mg, 272 mg, 315.0 mg, 5.0 mg, 1.73 mg of Ca, Cu, Fe, Mg, Mn, P, K, Na, and Zn respectively. In whole grain white flour, Ca, Cu, Fe, Mg, Mn, P, K, Na, Zn content was 7 mg, 0.23 mg, 2.38 mg, 93.0 mg, 0.46 mg, 272 mg, 315.0 mg, 5.0 mg, and 1.73 mg respectively. In whole grain blue flour, Ca, Cu, Fe, Mg, Mn, P, K, Na, and Zn content was 5 mg, 0.154 mg, 1.74 mg, 110.0 mg, 0.54 mg, 263 mg, 381.0 mg, 5.0 mg, and 2.24 mg respectively.

Chapter III

MATERIALS AND METHODS

3.1. Sample collection and description of sample:

Pigmented and non-pigmented whole maize samples and one red whole rice were used in the present study. Non pigmented or white maize, SAU Red maize and Purple maize were the kind donation from Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural 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 was collected from Bangladesh Agricultural Research Institute (BARI) which had yellow pericarp and endosperm. Among maize samples, Deep Red maize and Multi colored kernel maize were indigenous varieties, collected from Chattogram division. Pericarp color of deep red maize kernel was identified as deep red to black. The pericarp color of multi colored maize kernel varied from yellow to deep red. Endosperms of the both samples were white. Whole grain red rice was collected from Jessore. Image of samples are shown in Figure-3

3.2. Sample preparation and storage:

Maize kernels were removed from cob, sundried and cleaned. Rice was cleaned and dried. 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 −20 ºC till analysis.

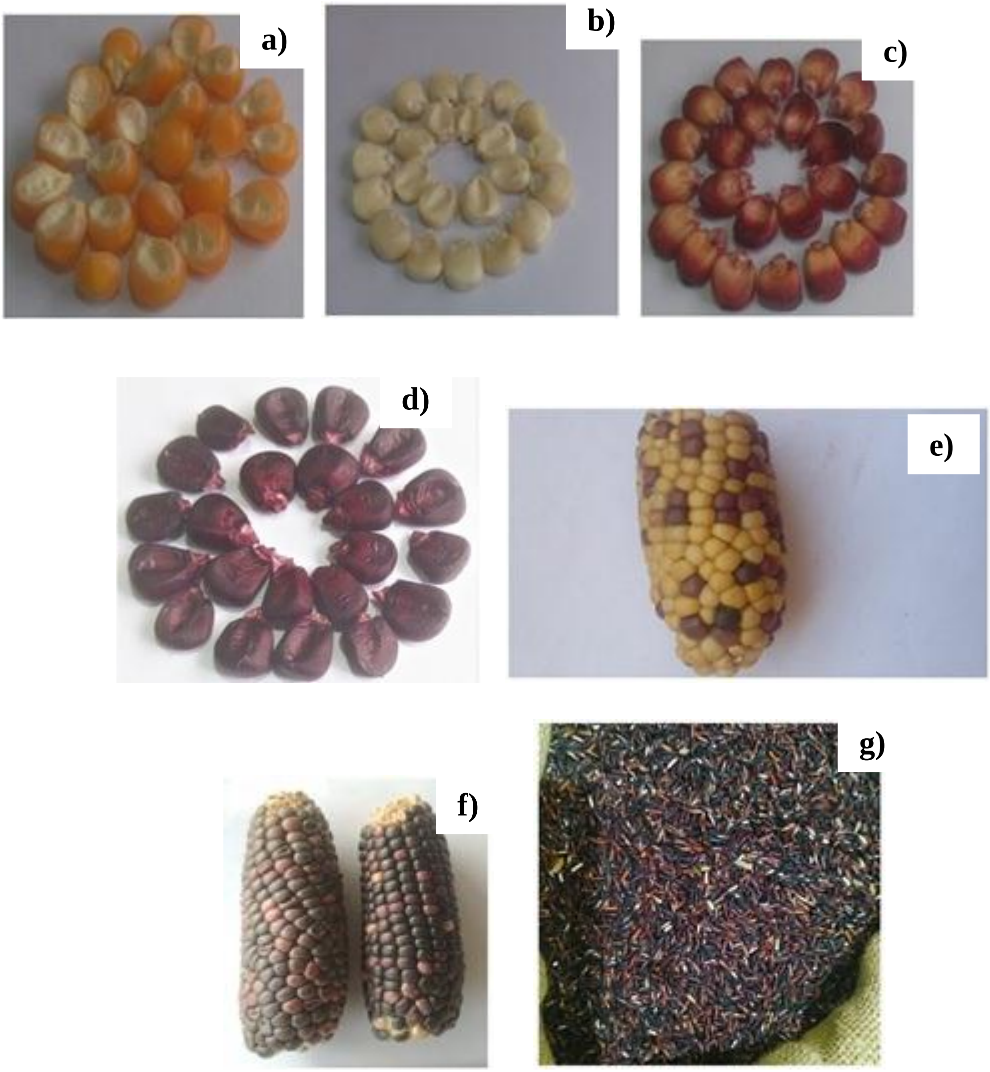

Figure 3. Whole grain maize and rice sample (a)Yellow maize, b) White maize, c) Red maize, d) Purple maize, e) Mixed colored maize, f) Deep colored maize and g) Red Rice)

3.3. Materials

i. Atomic absorption spectrophotometer
ii. Beaker
iii. Burette
iv. Cotton

v. Desiccator

vi. Filter paper

vii. Forceps

viii. Grease

ix. Heat proof hand gloves

x. Kjeldahl apparatus and flasks

xi. Magnetic stirrer with hot plate

xii. Measuring cylinder

xiii. Moisture dish

xiv. Muffle Furnace

xv. Oven

xvi. Petroleum ether

xvii. Pipette

xviii. Reagent bottle

xix. Round bottom flask

xx. Silica Crucible

xxi. Soxhlet apparatus

xxii. Spatula

xxiii. Test tubes

xxiv. UV/Vis spectrophotometer

xxv. Volumetric flask

xxvi. Weighing machine

3.4. Chemicals

i. Acetic acid (CH_3COOH)

ii. Acetone ($(CH_3)_2CO$)

iii. Barium chloride ($BaCl_2.2H_2O$)

iv. Boric acid (H_3BO_3)

v. Bromo-cresol green ($C_{21}H_{14}Br_4O_5S$)

vi. Copper sulphate ($CuSO_4$)

vii. Ethyl alcohol (C_2H_5OH)

viii. Ferrous ammonium sulphate ($(NH_4)_2Fe(SO_4)_2 \cdot 6H_2O$)

ix. Hydrochloric acid (HCl)

x. lanthanum oxide (La_2O_3)

xi. Litmus paper

xii. Methyl red ($C_{15}H_{15}N_3O_2$)

xiii. Nitric acid (HNO_3)

xiv. Perchloric acid ($HClO_4$)

xv. Petroleum ether (b.p. 60–80° C)

xvi. Polyvinyl pyrolidone (PVP K_{30})

xvii. Potassium persulphate ($K_2S_2O_8$)

xviii. Potassium sulphate (K_2SO_4)

xix. Potassium thiocyanate (KSCN)

xx. Selenium dioxide (SeO_2)

xxi. Sodium hydroxide (NaOH)

xxii. Sulphuric acid (H_2SO_4)

3.5. Color Test:

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. The ‘L’ indicates brightness or whiteness, positive ‘a’ value indicates redness while a negative value indicates greenness of the sample. The positive ‘b’ value indicates yellowness and negative ‘b’ indicates blueness.

3.6. Determination of moisture content

Moisture content in samples was determined following the method by AACC (2000). Dried and cleaned moisture cup were taken and weighed the empty moisture cup (W1). Then sample was taken (2 g) in the moisture cup and weighed for total weight (W2). The sample was kept in the oven at 130 ^{o}C for 2 hours. After heating, the samples were cooled to room temperature in desiccator and weighed after at least 30 min (W3). The final moisture content of sample was determined following the equation given below.

$$\text{Moisture}(\%) = \frac{(W2 - W3)}{(W2 - W1)} \times 100$$

3.7. Determination of bulk density

Bulk density of maize flour was determined following the method described by Earlier, Edema *et al.*, (2005). A known weight of sample (2 g) was taken to a 20 mL measuring cylinder and the volume of sample was recorded in mL. The bulk density was measured by using the following formula.

$$\text{Bulk density} = \frac{Weight\ in\ g}{Volume\ in\ mL}$$

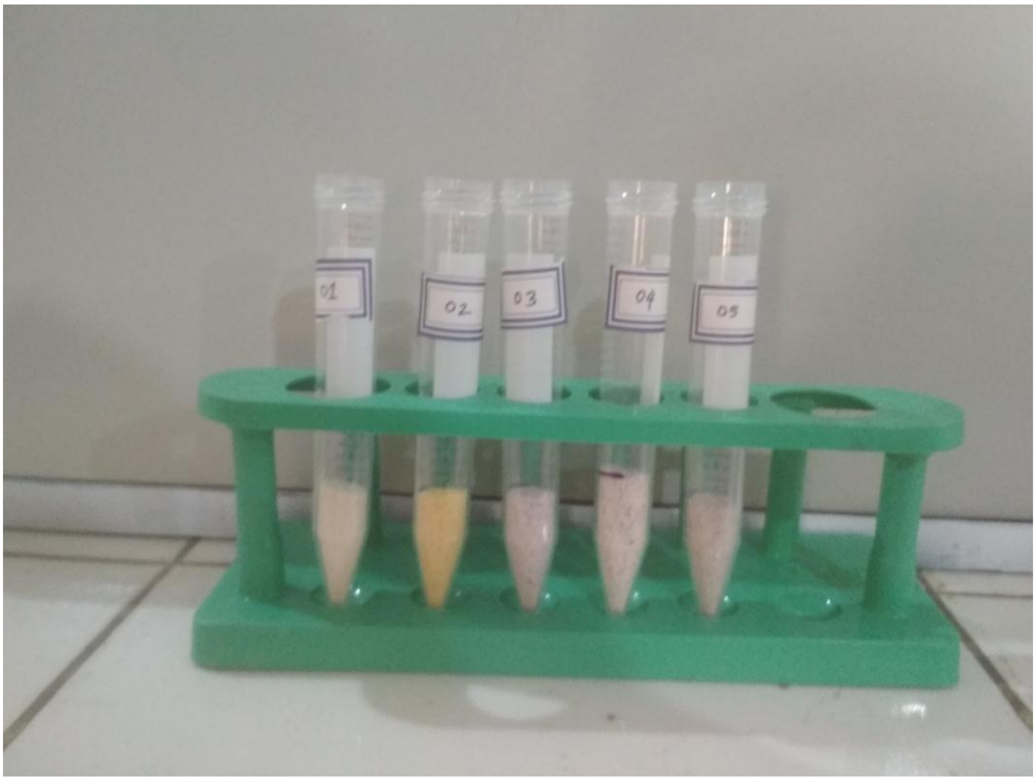

Figure 4. Determination of bulk density

3.8. Sedimentation Test

Sedimentation value was determined according to Ali & Bhattacharya, (1976). Finely grind grain flour (2 g) was taken in a 20 mL glass stoppered measuring cylinder, tapped 3 times and the initial volume occupied by the flour was noted down. Then distilled water was added up to 10 mL mark. The measuring cylinder was capped and the slurry mixed further by invasion and the cylinders were left undisturbed for 4 hours. Final volume of the sample was recorded and percentage change in the volume was calculated following the formula given below.

$$\text{Change (\%)} = \frac{(Final\ volume - initial\ volume)}{initial\ Volume} \times 100$$

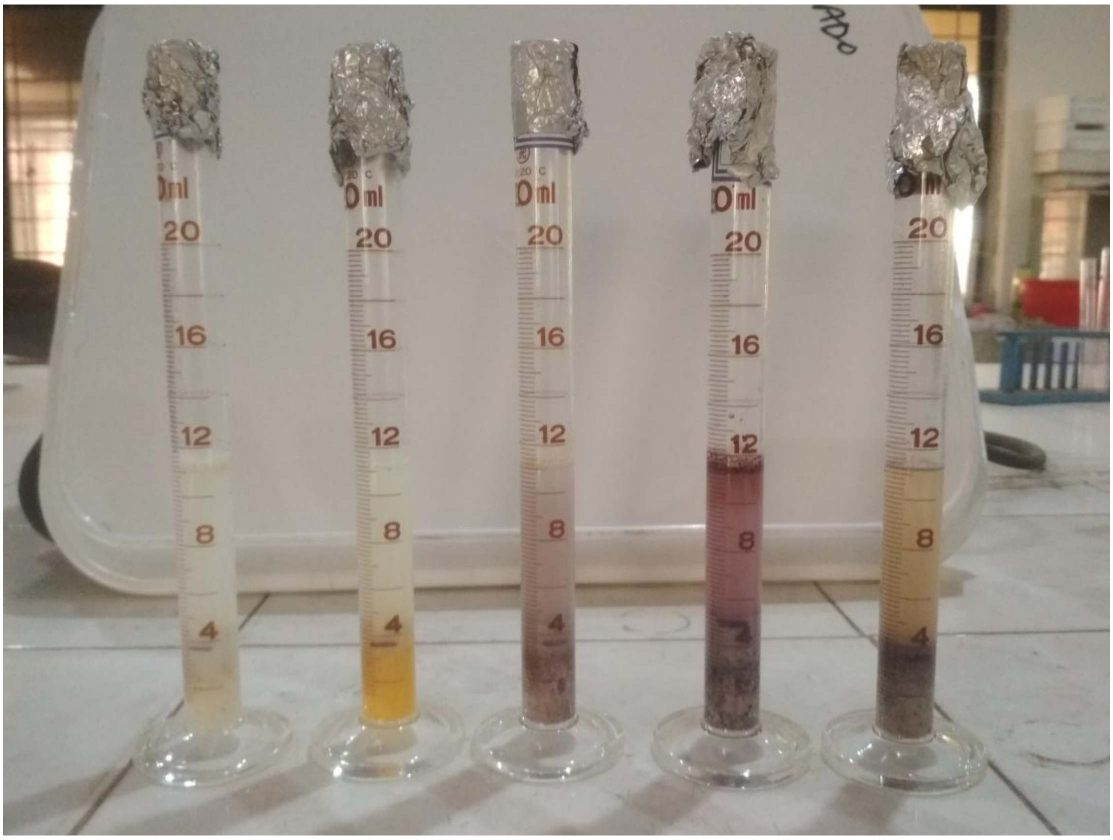

Figure 5. Determination of sedimentation test

3.9. Determination of fat

Fat was extracted by petroleum ether (b.p. 60–80° C) employing a Soxhlet apparatus according to AOAC (2000). Fat was estimated as crude ether extract of the dry material. The dried sample (2 g) was weighed accurately into a thimble and plugged with cotton. The thimble was placed in a Soxhlet apparatus and extracted with petroleum ether (b. p 60-80 °C) for 16 hours. The ether extract was collected into a pre weighed round bottom flask. The excess ether was removed by evaporation and the flask was dried with residue at 80 ^{o}C to 100 ^{o}C, cooled in a desiccator and weighed. Fat content in sample was estimated following the equation given below.

$$\text{Fat contain } (\%) = \frac{Wt\ of\ ether\ extract}{Wt\ of\ the\ sample} \times 100$$

Figure 6. Fat extraction by Soxhlet apparatus

3.10. Determination of ash content

Ash content was determined according to AOAC (2000). To determine the ash content of samples, cleaned crucibles were heated in muffle furnace at 600 ^{o}C for 1 hour. After heating it was transferred into a desiccator, cooled them to room temperature and their weight was recorded (W1). About 2 g of sample was taken into the pre-weighed crucible and the final weight of the sample and crucible was recorded (W2). The sample was burned in a muffle furnace at 600 ^{o}C till it turned to ash completely. The crucible was transferred into the desiccator and cooled them to room temperature and the final weight of the crucible and ash was recorded (W3). It was done immediately to prevent moisture absorption. The ash content of sample was calculated following the equation given below.

Weight of the sample taken = W2 – W1

Weight of the ash obtained = W3 – W2

$$\% \text{ Ash} = \frac{\text{Weight of the ash}}{\text{Weight of the sample taken}} \times 100$$

$$= \frac{(W3 - W2)}{(W2 - W1)} \times 100$$

Figure 7. Determination of ash content

3.11. Determination of nitrogen

Protein content was determined from the total nitrogen (N × 6.25) using the micro Kjeldahl method (AOAC 2000).

A) Preparation of reagents:

i) Preparation of 2% boric acid:

Twenty gram of boric acid was taken to a small beaker. Few drops of ethyl alcohol were added just to dissolve the powder. It was transferred to a 1L volumetric flask and 750 mL distilled water was added to it. Another 220 mL of ethyl alcohol and 10 mL of mixed indicator were added to it. The pH of the solution was adjusted to near neutral by adding diluted N/10 NaOH solution.

ii) Preparation of mixed indicator:

In a 100 mL volumetric flask, 0.66 g of methyl red and 0.33 g of bromo-cresol green were taken. About 80 mL of ethanol was added to it and mixed well. After completely dissolve, the final volume was made up to 100 mL with ethanol.

iii) Preparation of digestion mixture:

In a beaker, 46 g of potassium sulphate (K_2SO_4), 3.5 g of copper sulphate and 0.5 g of selenium dioxide were taken and mixed well. It was used as a digestion mixture for the analysis.

iv) Preparation of 40% NaOH:

In a beaker 40 g of NaOH was weighed accurately and 100 mL of distilled water was added slowly to it. It was stirred continuously to dissolve NaOH properly. The solution was transferred in a reagent bottle.

v) Preparation of N/70 HCL acid solution

B) Digestion of sample:

About 0.5 – 1 g of weighed sample was transferred to a long neck kjeldal flask carefully. A small amount of digestion mixture (0.2 g – 0.4 g) was added to the flask. After that 20 mL of conc. H_2SO_4 was taken in each flask. Then the samples were kept on a gas burner for digestion until the solution became clear. The complete digestion was transferred into a 100 mL volumetric flask. The final volume was made up to 100 mL with distilled water.

C) Distillation:

A volume of 5 mL digested sample was transferred to a distillation flask and 10 mL of 40% NaOH. Five mL of 2% boric acid solution was taken in each 100 mL conical flask which was placed at the bottom of distillation flask. The tube was dipped into boric acid solution. The distillate was collected in a 100 mL conical flask containing boric acid. After collecting 50 mL of distillate, the heater was switched off and the conical flask was removed from the apparatus**.** The collected distillate was titrated against N/70 HCL until the color turned to pink. Nitrogen content in sample was calculated following the equation given below. Protein was calculated from nitrogen multiplying by the conversion factor 6.25.

$$\%\ \mathrm{N} = \frac{(sample\ reading\ - blank\ reading) \times Normality\ of\ HCL \times 0.014}{sample\ weight} \times 100$$

$$\%\ \mathrm{Protein} = \%\mathrm{N} \times conversion\ factor\ (6.25)$$

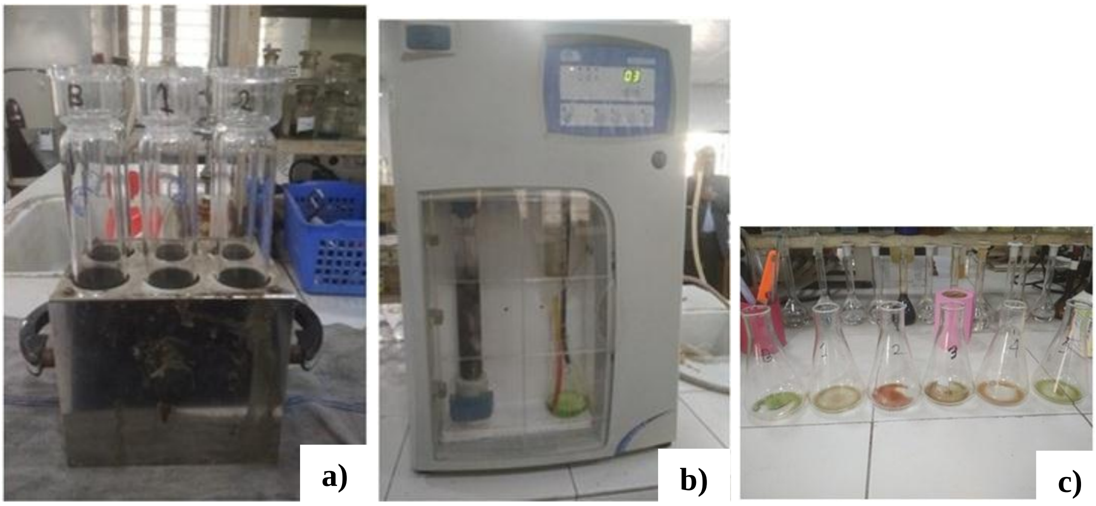

Figure 8. Estimation of protein (a): Digestion of sample, b): Distillation of sample and c): Titration of sample)

3.12. Determination of crude fiber

A) Preparation of reagents:

i) H_2SO_4 solution (0.255 N): In a 2 L volumetric flask, about 1L distilled water taken and 13.2 mL of H_2SO_4 was added to it. It was mixed well and the final volume was made up to 2 L using distilled water.

ii) NaOH solution (0.313 N):

In a 2 L volumetric flask containing about 1 L distilled water 25 g of NaOH was added. It was mixed well and the final volume was made up to 2 L with distilled water.

B) Procedure:

Crude fibre was determined from fat free sample according to the AOAC methods (2000). About 10 g of fat free dried sample was taken in a 500 mL flask. About 200 mL of H_2SO_4 was added to flask and placed on a hot plate of a digestion apparatus for 30 minutes with occasional rotation The content of the flask was filtered after completing digestion through a linen cloth and washed with boiling water. The residue was washed with hot water until the washings were free from acid (tested with Litmus paper). The washed residue was transferred back carefully to the flask by spatula. After that 200 mL of NaOH was added and boiled for 30 minutes with occasional rotation in the same digestion chamber. After 30 minutes, the content of the flask was filtered through the same cloth and washed with boiling water. The sample was washed until the washings were free from alkali (tested with Litmus paper). The residue was transferred to a silica crucible and dried at 110 ^oC to a constant weight. The crucible containing dried residue was transferred to a muffle furnace and burned at 600 ^oC for 20 minutes. The weight of the burned sample was noted down for calculation. Crude fibre was calculated from the equation given below.

$$\% \text{ Crude Fiber} = \frac{(weight\ after\ dring\ at\ 110oC\ ) - (\text{weight after buring at600oC }) }{weight\ of\ sample\ taken\ for\ fat\ extraction} \times 100$$

Figure 9. Determination of crude fibre

3.13. Estimation of minerals (Ca, Mg, S, Cu, Fe, Mn, Zn)

Minerals such as-P, K, and S were determined using spectrophotometer; Ca, Mg and micro minerals such as-Fe and Zn were determined by atomic absorption spectrophotometer following the procedure described by Hunter (1984).

A) Preparation of reagents

a) Reagents for Ca and Mg determination

i) Preparation of 1% Lanthanum solution:

In a 5 L beaker, 59 g of lanthanum oxide (La_2O_3) was taken and about 50 mL of distilled water was added with it. Slowly and carefully, 250 mL of conc. HCl was added in it to dissolve the La_2O_3. The final volume was made to 5 liters with distilled water.

b) Reagents for S determination

i) Mixed acid seed solution:

In a one litter flask, 65 mL of conc. HNO_3 and 250 mL of glacial acetic acid were taken and about 500 mL of distilled water was added in it. It was mixed properly. Then 3 mL of 1000 ppm S standard solution was added and final volume was made up to a liter with distilled water.

ii) Turbidimetric reagent

In a conical flask, 10 g of polyvinyl pyrolidone (PVP K30) was dissolved in 100 mL of hot water. In a separate conical flask, 150 g of $BaCl_2.2H_2O$ was dissolved in 500 mL of distilled water. Then PVP and barium chloride solutions were mixed and final volume was made up to 1liter with distilled water.

c) Preparation of standards

The mixture of standards of Cu, Fe, Mn and Zn were prepared together in water. The concentration for the elements was 2 µg Cu/mL, 10 µg Fe/mL, 4 µg Mn/mL, and 2 µg Zn/mL. Concentration of sulpher was 20 µg /mL. Ca and Mg were prepared in the same solution and the concentration 100 µg Ca/mL, 40 µg Mg/mL respectively.

d) Digestion solution

i) Nitric-perchloric solution: Concentrated perchloric acid (100 mL) was added to 500 mL concentrated HNO_3 to prepare nitric-perchloric solution.

B) Digestion of sample for determination of Ca, Mg, S, Cu, Fe, Mn, and Zn

Dried plant sample (500 mg) was taken into a 50 mL boiling flask. Five mL of nitric-perchloric acid solution was added in it. Flask was placed on a hot plate and turned the temperature to 375 °C. It was allowed to digest for 1 and half hour. The flask was removed from digestion chamber and allowed to cool. Then 15 mL distilled water was added to it. The flask was agitated and heated to dissolve the ash and the total content was filtered for further analysis.

C) Analytical procedure

One mL aliquot was taken from filtrate using a combination diluter-dispenser and 19 mL water was added to it (dilution 1). The other dilutions of sample were also made. For S determination, 7 mL of dilution 1, and 9 mL of acid seed solution and 4 mL of turbidimetric solution were mixed together properly. It was allowed to stand for 20 minutes. The data was recorded in turbidimeter or in colorimeter at 535 nm using a cuvette with 2 cm light path. For Ca and Mg determination, 1 mL aliquot from dilution 1, and 9 mL of water and 10 mL of 1% lanthanum solution were mixed together. It was analyzed following AA procedure. For Cu, Fe, Mn and Zn determination, the original filtrate was used to analyze the elements following AA procedure.

3.14. Statistical analysis:

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).

Chapter IV

RESULTS AND DISCUSSIONS

4.1. Physico-functional properties

4.1.1. Color parameters

Color of a grain influences acceptance of a grain and food as well. Color study in terms of Brightness or whiteness (L*), redness (a*), and yellowness (b*) of different pigmented and non-pigmented maize and rice is shown in the Table 3. Redness of the samples ranged from 13.16 ± 0.67 to 1.37. ± 0.47. The highest redness (a*) (13.16 ± 0.67) observed in yellow maize (BHM 9) followed by deep red maize, red rice and mixed maize. The lowest value of redness was observed in purple maize (1.37 ± 0.47). Low redness in the SAU red maize might be due to dominance of yellowness in both sides of kernel while the top of the kernel was red. The value of yellowness was ranged from 27.92 ± 3.3 to 0.52 ± 0.22 in grain samples. The highest value of yellowness was observed in mixed maize which has yellow kernel dominant on the cob. The second highest b* value was observed for yellow maize and the lowest b* was recorded for purple maize. Brightness of whiteness of colored grains ranged from 83.25 ± 0.47 to 38.62 ± 2.0. The highest lightness was recorded for white maize and the lowest lightness was in red rice. Among maize the lowest lightness was recorded for deep red maize, purple maize and SAU red maize. The lowest brightness indicates deepness of color of the grain. Amador-Rodriguez *et al.*, (2019) reported lightness of white and blue corn flour. They have reported higher lightness for three white maize flour (86.15, 88.17 and 80.93) than blue corn flour (62.34). Redness of blue corn was less than white corn flour and yellowness was higher in white corn flour than blue corn flour. Shen *et al.,* (2009) reported lower L*, a*, and b* value for red rice than white rice. The present findings for L*, a*, and b* were similar to the value reported by Shen *et al.,* (2009). Pandey *et al.,* (2016) reported 33.18 ± 0.04, 11.11 ± 0.04, and 8.44 ± 0.02 for L*, a*, and b* for a whole grain red rice named Jyothi. The present findings were similar to the reported value.

Table 3. Color properties of whole grain pigmented and non-pigmented maize and rice

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 ± 2b[c]	83.25 ± 0.47[a]
Purple maize	1.37 ± 0.47[c]	0.52 ± 0.22[e]	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[b]	15.48 ± 0.58[cd]	45.6 ± 2.9[cd]
Red Rice	9.4 ± 0.2[b]	11.12 ± 0.87[d]	38.62 ± 2[d]

Values are mean ± SD presented as dry weight basis; different alphabets in each column shows the significant difference (p<0.05). Here, a* = redness, b* = yellowness and L* = brightness.

4.1.2. Bulk density

Bulk density of grain flour is presented in the Table 2. The bulk density of grain flour was ranged from 0.565 ± 0.005 g/mL to 0.747 ± 0.023 g/mL. There was no significant difference in bulk density among all grain samples except the purple maize. Purple maize showed the lowest bulk density (0.565 ± 0.005 g/mL). Ikujenlola *et al.,* (2014) reported bulk density 0.73 g/mL for QPM which was similar to present study.

Compared to the present study, Edema *et al.*, (2005) reported less bulk density (0.46 g/mL and 0.47 g/mL) in maize in their finding. Chen *et al.*, (2015) reported bulk density of red rice flour with the particle size varied from 156. ± 12.43 g/mL to 10.68 ±0.89 g/mL. The bulk density of 4 different size particle ranged from 0.624 ± 0.021 g/mL to 0.745 ± 0.009 g/mL for higher to lower particle sized particles. The present value of bulk density of red rice flour similar to the reported value.

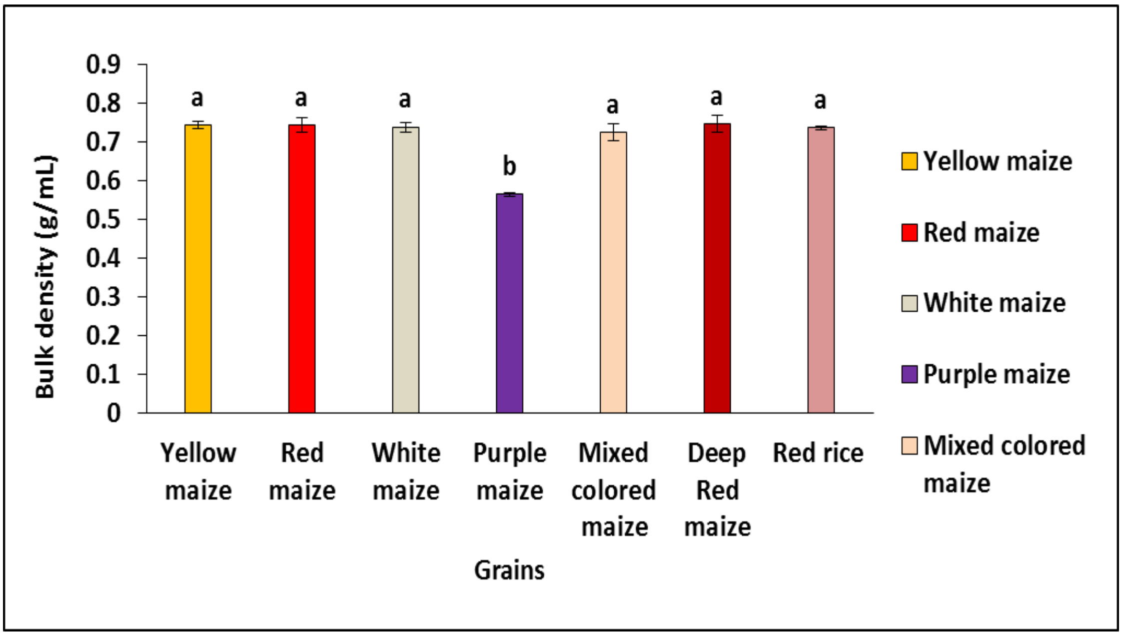

Figure 10. Bulk density (g/mL) of grains flour

4.1.3. Sedimentation value

Sedimentation value of different colored maize and rice flour is shown in the Table 3. Percentage change in sedimentation value indicates gelatinization of starch. The sedimentation value of the flours ranged from 15.05 ± 0.31 % to 35.43 ± 0.59 %. Among all the grain sample, white maize flour showed the highest sedimentation value (35.43. ± 0.59 %) followed by yellow maize. The purple maize flour showed the lowest sedimentation value (15.05 ± 0.31 %). Red maize, Mixed colored maize, Deep Red maize shown the similar sedimentation value.

sedimentation value in maize and rice obtained in present study was similar to the sedimentation value (15.0 ± 0.08 %) reported by Edema *et al.*, (2005) who have analyzed commercially available maize flour and quality protein maize flour. Sapna and Jayadeep (2021) reported sedimentation value of red rice flour, commercial rice flour and black rice flour ranged from 50.0 ± 2.9% to 87.5 ± 0.10%. Sedimentation value of red rice in present study was lower than reported value by Sapna and Jayadeep (2021).

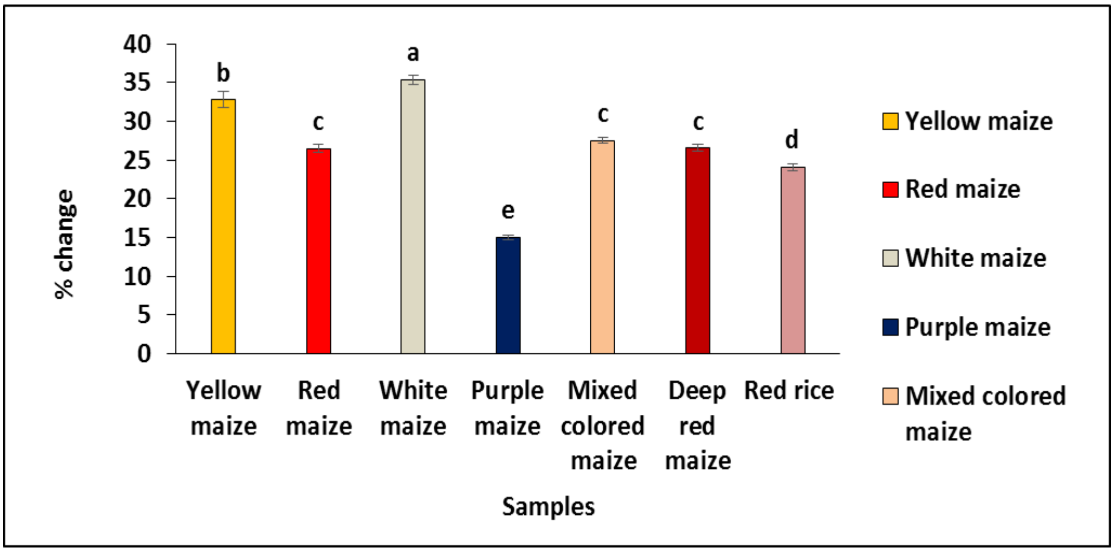

Figure 11. Change (%) in sedimentation of grains flour

4.2. Nutritional composition

4.2.1. Proximate composition

Heinemann *et al.*, (2005) carried out a comparative study of nutrient composition of 20 commercial brown, parboiled and milled rice from Brazil. Author have reported 12.60 ± 0.54% mean value of moisture content in brown rice which found higher than the present findings.

Proximate composition of whole grain pigmented and non-pigmented maize and rice was determined. The values are presented in the Table 4. The ash content in samples ranged from 1.22 ± 0.09% to 2.27 ± 0.059%. Among the samples, red maize and purple maize contained the highest ash content (2.27 ± 0.059% and 2.27 ± 0.05%) and the mixed colored maize contained the lowest ash content (1.22 ± 0.09%). There was no significant different in ash content in yellow maize, white maize, deep red maize, and red rice. Ash content in the maize samples in present study was 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 present finding. Heinemann *et al.*, (2005) carried out a comparative study of nutrient composition of 20 commercial brown, parboiled and milled rice from Brazil. Author have reported 1.21% mean value of ash content in brown rice which found lower than the present findings.

The fibre content in samples ranged from 3.31 ± 0.06% to 4.17 ± 0.049%. Among the maize sample, mixed colored maize contained the highest fibre content (4.17 ± 0.049%) which was similar to its content in red rice. The White maize contained the lowest fibre content (3.31 ± 0.06%). Furthermore, yellow maize, red maize, and purple maize showed the similar fibre content in them. Ikya *et al.*, (2013) and Edema *et al.*, (2005) reported less (1.92% and 1.48% to 1.09%) fibre content in maize than the present finding.

Table 4. Proximate composition of whole grain pigmented and non-pigmented maize and rice (%) dry weight basis

Sample name	Moisture	Ash	Crude fibre	Carbohydrate	Protein	Oil
Yellow maize	10.87 ± 0.06^{ab}	1.69 ± 0.009^{b}	3.58 ± 0.029^{c}	67.69 ± 0.52^{b}	11.77 ±0.45^{ab}	4.37 ± 0.09^{c}
Red maize	10.63 ± 0.36^{ab}	2.27 ± 0.059^{a}	3.54 ± 0.05^{c}	65.76 ± 0.57^{c}	12.6 ± 0.5^{a}	4.97 ± 0.1^{abc}
White maize	10.82 ± 0.33^{ab}	1.68 ± 0.009^{b}	3.31 ± 0.06^{d}	67.18 ± 0.44^{bc}	11.36 ± 0.29^{b}	5.63 ± 0.15ab
Purple maize	10.57 ± 0.22^{ab}	2.27 ± 0.050^{a}	3.55 ± 0.029^{c}	72.38 ± 0.33^{a}	7.4 ± 0.26^{c}	3.9 ± 0.18c
Mixed maize	10.31 ± 0.22^{a}	1.22 ± 0.09^{c}	4.17 ± 0.049^{a}	73.59 ± 0.09^{a}	5.58 ± 0.18^{d}	4.9± 0.04abc
Deep Red maize	11.39 ± 0.28^{a}	1.69 ± 0.009^{b}	3.97 ± 0.097^{b}	72.71 ± 0.24^{a}	5.89 ± 0.23^{d}	4.7 ± 0.16bc
Red Rice	10.08 ± 0.28^{b}	1.66 ± 0.018^{b}	4.06 ±0.056^{ab}	66.21 ± 1.16^{bc}	11.33 ± 0.24^{b}	6.1 ± 0.9a

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 ± 0.57% to 73.59 ± 0.09%. There was no significant difference observed in carbohydrate content in purple maize, mixed colored maize, deep red maize. Red maize contained the lowest carbohydrate (65.76 ± 0.57%) among samples. Carbohydrate content in rice was comparable with its content in maize. Carbohydrate content in maize flour in present study was similar to the carbohydrate content (66.2%) reported by CIMMYT report (1998). However, Ramírez-Jiménez *et al.*, (2018) and Edema *et al.*, (2005) reported higher carbohydrate content in maize than present finding.

Protein content in samples ranged from 5.58 ± 0.18% to 11.77 ± 0.45%. Red maize contained the highest protein content (11.77 ± 0.45%) although no significant difference observed for yellow and red maize for protein content. The mixed colored maize and deep red maize contained the lowest protein content (5.58% and 5.89% respectively), which were local maize sample. Protein content in maize obtained in present study was similar to the protein content (5.58 ± 0.18% to 11.77 ± 0.45%) in blue and white maize reported by Camelo-Méndez *et al.*, (2017); Ikya *et al.*, (2013), Edema *et al.*, (2005), and Ramírez-Jiménez *et al.*, (2018). Heinemann *et al.*, (2005) carried out a comparative study of nutrient composition of 20 commercial brown, parboiled and milled rice from Brazil. Author have reported 6.85 ± 0.34% mean value of protein content in brown rice which found lower than the present findings.

The oil content in samples ranged from 3.9 ± 0.18% to 6.1 ± 0.9%. Among all the sample, red rice contained the highest oil content (6.1 ± 0.9%) and white maize, red maize, and mixed maize had comparable to whole grain rice for oil content. The purple maize contained the lowest oil content (3.9 ± 0.18%). Oil content in samples in present study was similar to the oil content in maize reported by Ikya *et al.*, (2013); Edema *et al.*, (2005); and Ramírez-Jiménez *et al.*, (2018). However, CIMMYT (1998)) reported less oil content in maize than present finding. Heinemann *et al.*, (2005) carried out a comparative study of nutrient composition of 20 commercial brown, parboiled and milled rice from Brazil. Author have reported 2.65% mean value of crude fat content in analyzed brown rice which found lower than the present findings. Yankah *et al.*, (2020) reported nutritional composition of local brown rice, maize (obaatanpa), and millet. Authors reported 12.31 ± 0.14% of moisture, 0.79 ± 0.00% of ash, 4.67 ± 0.01% of fat, 4.28 ± 0.19% of protein, and 77.94 ± 0.32% of carbohydrate in brown rice collected from Ghana. The authors reported higher content of moisture and carbohydrate in brown rice than the present finding and lower ash, protein and oil content in their analyzed brown rice than the present finding.

4.2.2. Mineral content in whole grain pigmented and non-pigmented maize and rice

4.2.2.1. Macro minerals

Macro minerals such as calcium (Ca), magnesium (Mg), and sulphur (S) content was determined in maize samples and presented in the Table 5. The Ca content of different colored maize and rice ranged from 140.16 ± 10.8 mg/100 g to 317.39 ± 16.3 mg/100 g. Among all the samples, purple maize contained the highest Ca content (317.39 ± 16.3 mg/100 g) and the white maize contained the lowest Ca content (140.16 ± 10.8 mg/100 g). In present study, Ca content in maize found much higher than the value (5.96 mg/100 g) reported by Gallego-Castillo *et al.*, (2021). The values of Ca content were 93.65 mg/100 g to 233.0 mg/100 g in 12 maize samples reported by Hossain *et al.,* (2008). Bressani *et al.*, (2004) reported more Ca content in maize than present finding.

Table 5. Minerals content (macro) whole grain pigmented and non-pigmented maize and rice (mg/100 g) dry weight basis

Sample name	Ca	Mg	S
Yellow maize	251.7 ± 18.4^{cd}	240.48 ± 14.3^{a}	82.28 ± 23^{a}
Red maize	216.72 ± 6.4^{d}	245.49 ± 17.9^{a}	70.99 ± 13^{a}
White maize	140.16 ± 10.8^{e}	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^{ab}	245.06 ± 18.3^{a}	67.03 ± 18.2^{a}
Deep Red maize	290.01 ± 2.7^{abc}	241.43 ± 14^{a}	90.39 ± 18.5^{a}
Red Rice	272.22 ± 12.8^{bc}	244.07 ± 18.2^{a}	88.88 ± 18.1^{a}

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

The Mg content of different colored maize and rice ranged from 214.81 ± 6.8 mg/ 100g to 245.06 ± 18.3 mg/ 100g. There was similarity ($p > 0.05$) in Mg content in all the samples. Hossain *et al.,* (2008) reported 646.9 mg/ 100 g to 263.6 mg/100 g of Mg in 12 maize samples which found much higher than the present findings.

The S content of different colored maize and rice ranged from 37.37 ± 13.9 mg/ 100g to 90.39 ± 18.5 mg/ 100g. There was no significant difference among yellow, red, mixed, deep red maize and red rice sample. However, white maize contained the lowest S content (37.37± 13.9 mg/ 100g) which was comparable to the S content in purple maize. The S content in the samples found within the range of S content (72.87 mg/100 g to 179.5 mg/100 g) reported by Hossain *et al.,* (2008). Heinemann *et al.,* (2005) carried out a comparative study of nutrient composition of 20 commercial brown, parboiled and milled rice from Brazil. Author have reported 16.88 ± 0.57 mg/100 g of Mg, and 6.85 ± 0.43 mg/100 g of Ca, mean value of five brown rice which found much lower than the present findings. Yankah *et al.,* (2020) reported nutritional composition of local brown rice, maize (obaatanpa), and millet. Authors reported 16.60 ± 0.16 mg/100 g of Ca in brown rice collected from Ghana. The authors reported lower Ca content in their analyzed brown rice than the present finding.

4.2.2.2. Micro minerals

Micro minerals such as Cu, Fe, Mn, and Zn were determined and presented the in the Table 6. The Cu content of different colored maize and rice ranged from 0.13 ± 0.011 mg/100 g to 0.28 ± 0.02 mg/100 g. Among the samples, red rice contained the highest Cu content (0.28 ± 0.02 mg/100 g) and the yellow maize and mixed colored maize contained the lowest Cu content. The Cu content in 12 maize ranged from 3.81 mg/ 100 g to 0.41 mg/ 100 g as reported by Hossain *et al.*, (2008).

Table 6. Minerals content (micro) in whole grain maize and rice (mg/100 g) dry weight basis

Sample name	Cu	Fe	Mn	Zn
Yellow maize	0.14 ± 0.01[d]	4.99 ± 0.37[a]	0.83 ± 0.06[cd]	5.64 ± 0.13[e]
Red maize	0.26 ± 0.017[ab]	2.57 ± 0.22[b]	0.90 ± 0.04[c]	18.0 ± 0.23[b]
White maize	0.24 ± 0.011[ab]	1.39 ± 0.19[c]	0.51 ± 0.05[e]	19.75 ± 0.1[a]
Purple maize	0.21 ± 0.009[bc]	1.31 ± 0.13[c]	0.72 ± 0.03[d]	9.55 ± 0.2[c]
Mixed maize	0.13 ± 0.011[d]	1.60 ± 0.14[c]	1.34 ± 0.02[b]	8.62 ± 0.21[d]
Deep Red maize	0.18 ± 0.014[cd]	1.36 ± 0.04[c]	1.38 ± 0.02[b]	5.14 ± 0.14[e]
Red Rice	0.28 ± 0.02[a]	0.61 ± 0.14[d]	3.41 ± 0.03[a]	4.02 ± 0.13[f]

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

The Iron content in samples ranged from 0.61 ± 0.14 mg/100 g to 4.99 ± 0.37 mg/100 g. Among all the samples, yellow maize contained the highest iron content (4.99 ± 0.37 mg/100 g) followed by red maize. Whole grain red rice contained the lowest iron content (0.61 ± 0.14 mg/100 g). Fe content in samples in present study found similar to the Fe content reported by Gallego-Castillo *et al.*, (2021) and Bressani *et al.*, (2004). CIMMYT (1998) reported less Fe content in maize than present finding. The Mn content of samples ranged from 0.51 ± 0.05 mg/100 g to 3.418 ± 0.03 mg/100 g. There was significant variation in the samples for Mn content. Among the samples, red rice contained the highest Mn content (3.418 ± 0.03 mg/100 g) while the white maize contained the lowest Mn content (0.51 ± 0.05 mg/100 g). Mixed colored maize and Deep Red maize showed the similar Mn content value. The values of Mn found more or less similar with the value (0.48 mg/100 g) reported by Hossain *et al.,* (2008) who found that Mn content ranged from 0.55 mg/ 100 g to 1.35 mg/ 100 g in 12 maize varieties grown in Bangladesh.

The Zn content in samples ranged from 4.02 ± 0.13 mg/100 g to 19.75 ± 0.1 mg/100 g. Among the samples, white maize contained the highest Zn content (19.75 ± 0.1 mg/100 g) followed by red maize. The red rice contained the lowest Zn content (4.02 ± 0.13 mg/100 g). The obtaining values of Zn found more or less similar with the value (4.6 mg/100 g) reported by Hossain *et al.*, (2008), Iken *et al.*, (2002) and Bressani *et al.,* (2004). Zn content in maize sample was 3.48 mg/100 g to 7.77 mg/100 g respectively as reported by Hossain *et al.,* (2008). Gallego-Castillo *et al.,* (2021) reported less and Zn content 23.91 μg/g and 33.02 μg/g in regular and zinc bio-fortified maize respectively.

Heinemann *et al.,* (2005) carried out a comparative study of nutrient composition of 20 commercial brown, parboiled and milled rice from Brazil. Author have reported 1.98 ± 0.11 mg/100 g of Zn, 0.57 ± 0.35 mg/100 g of Fe, 0.36 ± 0.05 mg/100 g of Mn, and 0.16 ± 0.07 mg/100 g of Cu, mean value of five brown rice. Fe content in red rice found similar to the Fe content as reported by authors, and the content of Cu, Mn, and Zn was lower than the present findings. Yankah *et al.,* (2020) reported nutritional composition of local brown rice, maize (obaatanpa), and millet. Authors reported 12.15 ± 0.21% of Zn in brown rice collected from Ghana. The authors reported absence of Fe in the brown rice and higher Zn content in their analyzed brown rice than the present finding.

Chapter V

SUMMARY AND CONCLUSION

Present study was conducted to evaluate physico-functional and nutritional properties of six pigmented and non-pigmented maize and one pigmented rice available in Bangladesh. The major parts of the study were carried out in Sher-e-Bangla Agricultural University and IFST (Institute of Food Science and Technology), BCSIR (Bangladesh Council of Scientific and Industrial Research, Dhaka).

Physico-functional properties help to understand quality of flour for developing food. Color study, bulk density and sedimentation value were observed as physico functional properties. Brightness or whiteness (L*), redness (a*), and yellowness (b*) as the parameters of color study of different pigmented and non-pigmented maize and rice. The highest redness (a*) observed in yellow maize (BHM 9) followed by deep red maize, red rice and mixed maize. The lowest value of redness was observed in purple maize. The highest value of yellowness was observed in mixed maize. The second highest b* value was observed for yellow maize and the lowest b* was recorded for purple maize. The highest lightness was recorded for white maize and the lowest lightness was in red rice. Among maize the lowest lightness was recorded for deep red maize, purple maize and SAU red maize. There was no significant difference in bulk density among all grain samples except the purple maize. White maize flour showed the highest sedimentation value followed by yellow maize and the purple maize flour showed the lowest sedimentation value.

Moisture, ash, fibre, carbohydrate, protein and oil content were determined as proximate composition. Moisture content in all samples was below 12%. Red maize and purple maize contained the highest ash and the mixed colored maize contained the lowest ash. Mixed colored maize contained the highest fibre which was similar to its content in red rice. The white maize contained the lowest fibre. There was no significant difference observed in carbohydrate content in purple maize, mixed colored maize, deep red maize while red maize contained the lowest carbohydrate among samples. Carbohydrate content in rice was comparable with its content in maize. Red maize contained the highest protein although no significant difference observed for yellow and red maize for protein content. The mixed colored maize and deep red maize contained the lowest protein content respectively. Red rice performed better for oil content.

Calcium (Ca), magnesium (Mg), and sulphur (S) content was determined in samples. All most all samples performed equal for Mg and S. Purple maize, mixed maize and deep red maize performed better for Ca content. White maize had the highest amount of Zn while it had the lowest amount of Ca, and Mn. Yellow maize showed the highest amount of Fe and the lowest Cu content which was similar to mixed maize.

Considering all the aforementioned outcomes, it can be concluded that all maize samples were comparable and have similar nutrient like whole grain rice. However, Purple maize, mixed maize and deep red maize have less protein but high carbohydrate content than other sample. The red rice was poor in Zn and Fe content. Nonetheless whole grain maize and rice are rich in nutrients. Regular consumption of whole grain pigmented maize and rice might provide health benefits. Further research might be carried out to understand biochemical properties of other nutrients such as starch and its digestibility.

REFERENCES

Adiaha, M. S. (2017). The impact of Maize (Zea mays L.) and it uses for human development: A review.

Amador-Rodríguez, K. Y., Martínez-Bustos, F., and Silos-Espino, H. (2019). Effect of High-Energy Milling on Bioactive Compounds and Antioxidant Capacity in Nixtamalized Creole Corn Flours. *Plant Foods for Human Nutrition*, **74(2)**, 241-246.

Amador-Rodríguez, K. Y., Silos-Espino, H., Valera-Montero, L. L., Perales-Segovia, C., Flores-Benítez, S., and Martínez-Bustos, F. (2019). Physico-chemical, thermal, and rheological properties of nixtamalized creole corn flours produced by high-energy milling. *Food chem.*, **283**, 481-488.

AOAC.2004.Official methods of analysis. Association of official analytical chemists, Washington DC.

Bambaradeniya, C. N., and Amerasinghe, F. P. (2004). Biodiversity associated with the rice field agroecosystem in Asian countries: a brief review.

Bressani, R., & Scrimshaw, N. S. (1958). Effect of lime treatment on in vitro availability of essential amino acids and solubility of protein fractions in corn. *J. of agric. and food chem.*, **6**, 774-778.

Bressani, R., Turcios, J. C., Colmenares de Ruiz, A. S., and de Palomo, P. P. (2004). Effect of processing conditions on phytic acid, calcium, iron, and zinc contents of lime-cooked maize. *J. of agric. and food chem.*, **52(5)**, 1157-1162.

Brown, W. L., Zuber, M. S., Darrah, L. L., and Glover, D. V. (1986). Origins, adaptation, and types of corn. *EC-Cooperative Extension Service, University of Nebraska (USA).*

Camelo-Méndez, G. A., Agama-Acevedo, E., Tovar, J., and Bello-Pérez, L. A. (2017). Functional study of raw and cooked blue maize flour: Starch digestibility, total phenolic content and antioxidant activity. *J. of Cereal Science*, **76**, 179-185.

Chaudhari, P. R., Tamrakar, N., Singh, L., Tandon, A., and Sharma, D. (2018). Rice nutritional and medicinal properties: A. *J. of Pharmacognosy and Phytochem.*, **7(2)**, 150-156.

Chen, Q. M., Fu, M. R., Yue, F. L., and Cheng, Y. Y. (2015). Effect of superfine grinding on physicochemical properties, antioxidant activity and phenolic content of red rice (*Oryza sativa L.*). *Food and Nutrition Sci.*, **6(14)**, 1277.

Dewan. S. F. K., Salam M. A. and Mondal A. A. (1998). Prospects and Challenges of Maize Production in Bangladesh. CIMMYT Report 1998.

Dilip, K. and Aditya, N. (2013). Nutritional, Medical and Economic importance of Con: A mini review. *Research J. of Pharmaceutical sci..* **2(7)**, 7-8.

Edema, M. O., Sanni, L. O., and Sanni, A. I. (2005). Evaluation of maize-soybean flour blends for sour maize bread production in Nigeria. *African J. of Biotech.*, **4(9)**.

Kaul, J., Jain, K., and Olakh, D. (2019). An overview on role of yellow maize in food, feed and nutrition security. *International J. of Current Microbiology and Applied Sci.*, **8(2)**, 3037-3048.

Gallego-Castillo, S., Taleon, V., Talsma, E. F., Rosales-Nolasco, A., Palacios-Rojas, N. (2021). Effect of maize processing methods on the retention of minerals, phytic acid and amino acids when using high kernel-zinc maize. *Current research in food sci.*, **4**, 279-286.

Gopalan, C., Rama Sastri, B. V., and Balasubramanian, S. C. (1971). Nutritive value of Indian foods.

Gwirtz, J. A., and Garcia-Casal, M. N. (2014). Processing maize flour and corn meal food products. *Annals of the New York Academy of Sci.*, **1312(1)**, 66.

Heinemann, R. J. B., Fagundes, P. D. L., Pinto, E. A., Penteado, M. D. V., & Lanfer-Marquez, U. M. (2005). Comparative study of nutrient composition of commercial brown, parboiled and milled rice from Brazil. *J. of Food Composition and Analysis*, **18(4)**, 287-296.

Hossain, A., Shahjahan, M., Ahmed, K. U., Chowdhury, M. G. F., and Nuruddin, M. M. (2008).Study on carotene and mineral content of maize (Zea Mays, L) popularly grown in Bangladesh. *J. Subtrop. Agric,Res. Dev.* **6(2)**: 502-505.

Hossain, A., Shahjahan, M., Ahmed, K. U., Chowdhury, M. G. F., and Nuruddin, M. M. (2010). Biochemical composition of newly introduced maize (*Zea mays L*) vanities. *J. of Sci. and Tech.*, **8**.

Hu, Q. P., and Xu, J. G. (2011). Profiles of carotenoids, anthocyanins, phenolics, and antioxidant activity of selected color waxy corn grains during maturation. *J. of agric. and food chem.*, **59(5)**, 2026-2033.

Ikujenlola, A. V., and Adurotoye, E. A. (2014). Evaluation of quality characteristics of high nutrient dense complementary food from mixtures of malted quality protein maize (*Zea mays l.*) and steamed cowpea (Vigna unguiculata). *J. of food processing & tech.*, **5(1)**, 1.

Ikya, J. K., Gernah, D. I., and Sengev, I. A. (2013). Proximate composition, nutritive and sensory properties of fermented maize, and full fat soy flour blends for agidi production. *African J. of food sci.*, **7(12)**, 446-450.

Lee, I., We, G. J., Kim, D. E., Cho, Y. S., Yoon, M. R., Shin, M., and Ko, S. (2012). Classification of rice cultivars based on cluster analysis of hydration and pasting properties of their starches. LWT-*Food sci. and tech.*, **48(2)**, 164-168.

Mohanlal, S., Parvathy, R., Shalini, V., Mohanan, R., Helen, A., and Jayalekshmy, A. (2013). Chemical indices, antioxidant activity and anti- inflammatory effect of extracts of the medicinal rice "njavara" and staple varieties: a comparative study. *J. of food bioc.*, **37(3)**, 369-380.

Pandey, S., Asha, M. R., & Jayadep, A. (2016). Changes in physical, cooking, textural properties and crystallinity upon iron fortification of red rice (Jyothi). *J. of food sci. and tech.*, **53(2)**, 1014-1024.

Ramírez-Jiménez, A. K., Rangel-Hernández, J., Morales-Sánchez, E., Loarca-Piña, G., and Gaytán-Martínez, M. (2019). Changes on the phytochemicals profile of instant corn flours obtained by traditional nixtamalization and ohmic heating process. *Food chem.*, **276**, 57-62.

Ranum, P., Peña-Rosas, J. P., and Garcia-Casal, M. N. (2014). Global maize production, utilization, and consumption. *Annals of the New York academy of sci.*, **1312(1)**, 105-112.

Rui, M., Qian, J., Liu, L., Cai, Y., Lv, H., Han, J.and Xie, W. (2017). The neuronal protein Neurexin directly interacts with the Scribble–Pix complex to stimulate F-actin assembly for synaptic vesicle clustering. *J. of biol. Chem.*, **292(35)**, 14334-14348.

Sapna, I., & Jayadeep, A. (2021). Application of pulverization and thermal treatment to pigmented broken rice: insight into flour physical, functional and product forming properties. *J. of Food Sci. and Tech.*, **58(6)**, 2089-2097.

Shafie, B., Cheng, S. C., Lee, H. H., and Yiu, P. H. (2016). Characterization and classification of whole-grain rice based on rapid visco analyzer (RVA) pasting profile. *International food research J.*, **23(5)**.

Shao, Y., Jin, L., Zhang, G., Lu, Y., Shen, Y., and Bao, J. (2011). Association mapping of grain color, phenolic content, flavonoid content and antioxidant capacity in dehulled rice. *Theoretical and applied genetics*, **122(5)**, 1005-1016.

Shewry, P. R. (2007). Improving the protein content and composition of cereal grain. *J. of cereal sci.*, **46(3)**, 239-250.

Shen, Y., Jin, L., Xiao, P., Lu, Y., & Bao, J. (2009). Total phenolics, flavonoids, antioxidant capacity in rice grain and their relations to grain color, size and weight. *J. of Cereal Sci.*, **49(1)**, 106-111.

Sofi, P. A., Wani, S. A., Rather, A. G., and Wani, S. H. (2009). Quality protein maize (QPM): Genetic manipulation for the nutritional fortification of maize. *J. of plant breeding and crop sci.*, **1(6)**, 244-253.

Suri, D. J., and Tanumihardjo, S. A. (2016). Effects of different processing methods on the micronutrient and phytochemical contents of maize: from A to Z. Comprehensive Reviews in *Food sci. and food safety*, **15(5)**, 912-926.

Tensaout, H. A., Charrel, H., Mazid, M. A., Tomsett, A. B., and Mortimer, A. M. (2009). Molecular analysis of weedy rice in northwest Bangladesh. *In Limited Proceedings* (p. 41).

Tetens, I., Haraksingh Thilsted, S., Choudhury, N. H., Hassan, N., Biswas, S., Hansen, M., ... and Wahab, M. A. (1998). The rice-based diet in Bangladesh in the context of food and nutrition security. *Näringsforskning*, **42(1)**, 77-80.

Ullah, M. J., Islam, M. M., Fatima, K., Mahmud, M. S., and Islam, M. R. (2019). Yield and yield attributes of two exotic white maize hybrids at different agroclimatic regions of Bangladesh under varying fertilizer doses. *Adv Agr Environ Sci.*, **2**, 65-71.

Upadhyay, A., and Karn, S. K. (2018). Brown Rice: Nutritional composition and health benefits. *J. of food sci. and tech. Nepal*, **10**, 47-52.

Yankah, N., Intiful, F. D., and Tette, E. M. (2020). Comparative study of the nutritional composition of local brown rice, maize (obaatanpa), and millet—A baseline research for varietal complementary feeding. *Food sci. and nutrition*, **8(6)**, 2692-2698.

Zhu, F. (2018). Relationships between amylopectin internal molecular structure and physicochemical properties of starch. Trends in *Food sci. and tech.*, **78**, 234-242.

https://iimr.icar.gov.in/maize-biology/

https://en.wikipedia.org/wiki/Maize

https://www.shutterstock.com/image-vector/illustration-shows-part-corn-plants-673902061

https://www.dreamstime.com/illustration-showing-parts-rice-plant-beautiful-image129938988

https://www.researchgate.net/figure/The-corn-kernel-structure_fig1_49176833

https://www.researchgate.net/figure/Grain-structure-of-rice-kernel_fig2_266097223