

Physicochemical characters of oilseeds from selected mustard genotypes

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Abstract

To evaluate the physicochemical characteristics of oilseeds, three varieties of mustard oilseeds were studied their seed weight, moisture, ash, carbohydrate, protein, fat, total energy and minerals composition of oil and cake. Among the varieties the highest thousand grain weight was found in BARI Sarisha-17 (4.24 g) and the lowest thousand grain weight was found in BARI Sarisha-15 (3.17 g). The highest moisture content was observed from BARI Sarisha-15 (4.52%); whereas the lowest moisture content was found in BARI Sarisha-17 (4.10%). The variety BARI Sarisha-17 contained significantly highest amount of oil (41.98%) whereas the variety BARI Sarisha-16 contained lowest amount of oil (40.95%). BARI Sarisha-16 contained highest amount of ash (14.20%). Significantly highest amount of protein was obtained from BARI Sarisha-15 (28.00%) and the lowest amount of protein obtained from BARI Sarisha-17 (22.57%). BARI Sarisha-17 contained highest amount of carbohydrate (18.85%), whereas BARI Sarisha-15 contained the lowest amount of carbohydrate (13.73%). BARI Sarisha-16 contained highest amount of Ca (2.52%) and Zn (66.80%). BARI Sarisha-15 contained highest amounts Cu (13.40%) and Fe (170.30%). Mustard varieties contained erucic acid (51.35-50.67%). Highest amount of total saturated fatty acid (TSFA) contained in BARI Sarisha-15 (9.02%) and the lowest amount contained BARI Sarisha-16 (8.28%). Highest amount of total unsaturated fatty acid (TUSFA) contained in BARI Sarisha-17 (90.26%) lowest amount contained in BARI Sarisha-16 (87.04%). The highest amount of gross energy found from BARI Sarisha-15 (543.60 kcal/g; while lowest amount of gross energy recorded from BARI Sarisha-16 (531.20 kcal/g). Highest saponification value found in BARI Sarisha-17 (159.40) and lowest saponification value was found in BARI Sarisha-15 (157.6). The result of this research work confirms the mustard varieties seed to be of good quality and can be used for food preparation. The knowledge of this study could be utilized for various food preparation and selection for breeding purpose.

Keywords: Mustard, Grain weight, Mineral content, Fatty acid, Iodine value

Introduction

Oilseed crops have occupied an important place in human nutrition as they remain the major sources of calories and proteins for a large proportion of the world population. Oilseeds are those seeds that contain considerably large amounts of oil. The most commonly known oilseeds (conventional oilseeds) are groundnut, soybean, palm kernel, cotton seed, olive, sunflower seed, rapeseed, sesame seed, linseed, safflower seed, etc (Ajala *et al.*, 2014; Aremu *et al.*, 2006). Generally, oils and fats from seeds and nuts constitute an essential parts of man's diet. The chief important of the vegetable oils lies in their food value. Vegetable oils derived from plant seeds have been playing vital roles to provide comfort in human lives in various aspects, they are essential in meeting global nutritional demands are utilized for many food and other industrial purposes (Idouraine *et al.*, 1996). In a balanced diet for human health 20–25% of calories should come from oils and fats. Herbal oils are the main sources of fats and fat-soluble vitamins, which have a substantial role in the human diet (Stuchlik *et al.*, 2002). After cereals, oily seeds are the second food sources throughout the world, whose oil is of rich fatty acid types (Siavash *et al.*, 2005).

Mustard seeds have been highly prized medicinal as well as culinary spice being in use since ancient times. The seeds are obtained from mustard plant (*Brassica spp.*) which also include cabbage, broccoli, brussels sprouts, etc. Mustard seeds have high energy content, having 28–32% oil with relatively high protein content (28–36%). Well refined mustard oil has a yellow to brown color and its smell and taste are enjoyable. Mustard oil has a special fatty acid composition: 20–28% oleic acid, 10–12% linolic, 9.0–9.5% linolenic acid and 30–40% erucic acid (Abul-Fadl *et al.*, 2011). The protein quality and quantity of *B. campestris* obtained oil cake is high (Chowdhury *et al.*, 2014). Mustard seeds contain 28-32% protein by weight, although these values can vary slightly between varieties, growing regions and crop years. The amino acid composition of mustard protein is well balanced; it is rich in essential amino acids. Rapeseed

and mustard contain relatively lower amount carbohydrate. It consists mainly glucose, sucrose and fructose crude fiber, dry mustard seeds contained 20–23% carbohydrate. Mustards seed are rich source of many health benefiting minerals such as calcium, manganese, copper, iron, selenium, and zinc (Sarwar *et al.*, 2009). Mustard seeds act as a laxative, stimulant to gastric mucosa and increase intestinal secretion (Sarwar *et al.*, 2009; Sarwar *et al.*, 2004). These crops, including rape (*B. campestris L.*, and *B. napus L.*) and mustard (*B. juncea*) are the third major source of edible vegetable oils in the world, after soybean and oily palm. The residue left after oil extraction (i.e., oil cake or meal) being rich in protein can be used as livestock feed (Durrani *et al.*, 1990).

Oilseed is critically needed in many developing countries where protein-energy malnutrition remains a major health hazard, especially among children. The protein quantity and quality, caloric value, and overall nutrient content of oilseeds are quite good. Some oil seed cultivars viz. BARI Sarisha-15, BARI Sarisha-16, BARI Sarisha-17, is widely cultivated throughout the country. If the nutritional status of oil seed is known, their consumption and multipurpose uses will be increased. The characteristics of oils from different sources depend mainly on their compositions and no oil from a single source can be suitable for all purposes, thus the study of their constituents is important. Hence the physicochemical properties of these popular selected varieties was undertaken to ensure their nutritional status. The main purpose of our present study is to determine the oil content, protein, carbohydrate and minerals content of different genotypes groundnut seed.

Material and Methods

Materials and Measurement

The experiment was carried out at the Biochemistry laboratory of the Department of Biochemistry, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh and Post Harvest Technology Division BARI Joydebpur, Gazipur, Bangladesh. Three varieties of mustard (*Brassica spp.*) namely BARI Sarisha-15 (grain properties is yellow in color, oval in shape and small in size), BARI Sarisha-16 (grain properties is brownish in color and round in shape and large size), BARI Sarisha-17 (grain properties is brownish in color, round in shape and large size) were collected from the Oilseeds Research Centre of BARI, Gazipur, Bangladesh. Seed were cleaned sun dried and stored into plastic container in a cool place until used for the chemical analysis. The nutritive value of a food-grain is indicated by its composition shown by chemical analysis. The degree to which the chemical analysis indicates the nutritive value is dependent on the constituents determined. All the chemicals used were collected from Merck (Germany), Wako Pure Chemicals Industries Ltd. and JHD (China). These chemicals were used analytical and spectroscopic grade without further purification.

Determination of Physical Properties of Mustard Varieties

Determination of grain weight: Grain weight was determined by randomly selecting thousand seed sample weighted by electric balance (KEY: JY-2003; China).

Determination of moisture: Moisture content of mustard sample was determined by a thermostat controlled oven. Empty aluminum moisture dish was weighted (W_1) and 2.5 g sample was taken in a moisture dish and weighted (W_2). The sample was spread evenly and placed without lid in oven and dried samples overnight at 100 °C temperature. The dishes were transferred to desiccators to cool. Aluminum dish was weighed after cooling (W_3). The percentage of the moisture was then calculated by the following formula.

$$\% \text{Moisture} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Determination of ash: The sample is ignited at 600 °C by muffle furnace (Nebetherm: Mod-L9/11/c6; Germany) to burn off all organic material. The inorganic material which does not volatilize at that temperature is called ash. The temperature of the muffle furnace was fixed to 600 °C and crucible was heated for 1h and transferred into desiccators; cooled them to room temperature and weighted (W_1).

About 2 g sample was put into the crucible weighted (W_2). The sample was burned in a muffle furnace at 600 °C for about 2 h. The crucibles were transferred into the desiccators and cooled them to room temperature and weighted (W_3). It was done immediately to prevent moisture absorption. The incineration repeated until constant weight was obtained. The percentage of the ash was then calculated by the following formula (Ranganna *et al.*, 1986).

$$\% \text{ Ash} = \frac{(W_3 - W_1)}{(W_2 - W_1)} \times 100$$

$W_3 - W_1 = \text{Weight of the ash obtained}$
 $W_2 - W_1 = \text{Weight of the sample taken}$

Determination of Chemical Constant of Mustard Varieties

Estimation of fatty acid composition: Fatty acid composition was determined by gas-liquid chromatographic method (Uppstrom *et al.*, 1978). About 12 mg of oil or equivalent amount of oil seeds was taken (seed was crushed in an oil paper and then transferred into a test tube). The sample was extracted and transesterified at the same time with 5 ml ethylated reagent (petroleum ether/0.02M sodium hydroxide in ethanol (2/3) and shake. The samples were kept for overnight at room temperature. 10 ml salt solution (80 g NaCl and 3 g sodium hydrogen sulphate in 1 liter water) was added and shake. As soon as the two layers were separated, the benzene phase was transferred to small test tubes. A Philips PU 4500 chromatograph instrument was used with flame ionization detector (FID). A glass column (1.5m x 4mm) was packed with BDS. With this column the injection post, column and detector temperature was set at 220 °C, 185 °C and 240 °C, respectively. Nitrogen flow (used as carrier gas) rate was 22 ml/min, the injection volume was 2 µl. Peak areas were measured with an electronic digital integrator (Shinadzu C-R6A chromatopac).

Saponification value: At first, 2 g fat was taken in 250 ml round bottom flask and 25 ml, 0.5 N alcoholic potassium hydroxide solution added in same flask. The flask was fitted with a long air condenser and heated solution at reflux temperature about 30 minutes. Finally, the flask was cooled and added 1 ml of 1% phenolphthalein solution and titrate the excess of the alkali against standard 0.5 N HCl acid. At the same time and under similar conditions carry out a blank titration without fat (25 ml, 0.5 N same alcoholic KOH solution was taken in another round bottom flask and heated in a similar way and titrated, against 0.5 N acid). 1 ml of 0.5 N HCl acid was equivalent to 0.02805 g of KOH.

$$\text{Saponification value} = \frac{(b - a) \times 0.02805 \times 1000}{\text{Wt. of substance in g}} \times 100$$

Where, a = mL of 0.5 N acid required in sample solution titration

b = mL of 0.5 N acid required in blank solution titration

Iodine value: 5 g of oil or fat was taken into 200 ml a glass stoppard bottle. 5 ml of CCl_4 was added to dissolve this oil after 25 ml of Wij's solution was added and to allow it at least 1 hour in a dark place. Then 5 ml of 10% potassium iodide solution and 50 ml water were added to each bottle and titrated against 0.1 N $\text{Na}_2\text{S}_2\text{O}_3$ solution using starch solution as the indicator, near the end point of titration the color of solution becomes pale yellow. Blue color disappears which indicates the end point. At the same time and under similar conditions carry out a blank titration without oil or fat.

$$\text{Iodine value} = \frac{100}{\text{Wt. of oil}} \times 10.0127 \times (v_1 - v_2)$$

Where, a = mL of 0.1 N $\text{Na}_2\text{S}_2\text{O}_3$ used in blank titration

b = mL of 0.1 N $\text{Na}_2\text{S}_2\text{O}_3$ used in the case of oil titration

Estimation of carbohydrate: Total carbohydrate estimation method was described by Raghuramulu *et al.*, 2003. The content of the available carbohydrate was determined by the following equation:

$$\text{Carbohydrate} = 100 - [(\text{Moisture} + \text{Protein} + \text{Ash} + \text{Oil/Fats}) \text{ g}/100 \text{ g}]$$

Chemical analyses

Estimation of oils/fats: The oil content was determined by the ether soluble extract method. Dried sample was weighed out into an extraction thimble. Weight of thimble and sample were recorded in laboratory book. The thimble was placed into the soxhlet. 100 ml ethyl ether was added to the soxhlet flask then it was connected to holder and condenser. Soxhlet flask was placed on hot plate and distilled at low temperature for 20 hours. After extraction it was turned off and allowed to cool. When distillation was ceased, the extraction thimble was removed and allowed to air dry for 40 minutes the thimble was weighed out. The fat determined by the above procedure contains usual lipids including waxes pigments, certain gums and resins (Thiex *et al.*, 2003). A better name for these constituents would be “ether soluble extract.”

% Crude fats/oil (on a dry weight basis) =

$$\frac{\text{Wt. of thimble \& sample before extraction} - \text{Wt. of thimble \& sample after}}{\text{Weight of sample before extraction}} \times 100$$

Estimation of total protein content by microkjeldhal method: The protein content of food stuff is obtained by estimating the nitrogen content of the material and multiplying the nitrogen value by 5.5 (according to the fact that nitrogen constitutes on average 18% of a protein molecule). The estimation of nitrogen is done by Kjeldhal method (AOAC, 2010) which depends upon the fact that organic nitrogen when digested at 380 °C temperature with sulphuric acid in the presence of catalyst selenium oxide, mercury or copper sulfate is converted into ammonium sulphate (AOAC, 2010). Ammonia liberated by making the solution alkaline is distilled into a known volume of a standard acid which is then back titrated. A known quantity of the finely ground sample (100 mg) weighted out in an Mkj digestion flask. About 2 g digestion mixture (100 g of K₂SO₄ was thoroughly mixed with 20 g of CuSO₄.5H₂O and 2.5 g selenium dioxide was added with it) was added with it 2 ml of concentrated sulphuric acid was dispensed into the flask. Then it was digested for about 2 hrs at 380 °C temperature in Mkj digestion set and was cooled the clear digest. The digest was dissolved in minimum amount of distilled water and carefully transferred to an Mkj distillation set 60%, 10 ml of NaOH solution was added and distilled it. The distillate was collected for 5 min into 4%, 5 ml boric acid containing 2 drops of mixed indicator (methyl red and bromocresol green) in a 50 ml conical flask, till the color of solution was changed. The distillate was titrated against a standard 0.02 N HCl acid and noted the titer value (TV).

$$N\% = \frac{(14.007) \times (\text{Normality of the Acid, 0.02}) \times (\text{Titer volume})}{\text{Weight of sample (mg)}} \times 100$$

Where, 14.007 is the equivalent weight of nitrogen

Nitrogen % is converted into protein by multiplying with a factor 5.5 for cereals and pulses.

$$\text{Crude protein (\%)} = \% N \times 5.5$$

Estimation of minerals

Mineral content was determined using absorption spectrophotometer.

Reagent for Ca and Mg determination: 1% lanthanum solution: 59 g of lanthanum oxide (La₂O₃) were added with about 50 ml of water. Slowly and cautiously, 250 ml concentrated HCl was added to dissolve the La₂O₃. It was made to 5 liters with water.

Preparation of standards solution: For convenience the Cu, Fe and Zn were prepared together in water. The high concentration for these elements was as follows: 2 µg Cu/ml, 10 µg Fe/ml, 4 µg and 2 µg Zn/ml. Ca and Mg were prepared in the same solution with high concentrations as follows; 100 µg Ca/ml, 40 µg Mg/ml.

Digestion solution: Nitric-perchloric solution. Concentrated perchloric acid (100 ml) was added to 500 ml concentrated HNO₃ to prepare nitric-perchloric solution.

Digestion of oilseed cake for determination of Ca, Mg, Fe and Zn

Digestion procedure: Weighted 500 g dry seed sample and put into a 50 ml boiling flask. 5 ml of nitric-perchloric solution was allowed on cool hot plate and turned temperature to 375°C. It was allowed to digest for 1 hour and 30 minutes. The flask was removed from digestion chamber and was cooled and 15 ml water was added. The flask was agitated and heated to dissolve the ash and filter.

Analytical procedure: By using a combination diluter-dispenser, 1 ml aliquot was taken from filtrate and 19 ml water (dilution 1) was added. The other dilutions were made in the following order. For P, K and Na determination, 1 ml aliquot from dilution 1, 9 ml of water and 10 ml of color reagent were mixed together. It was allowed to stand about 20 minutes and reading was taken of spectrophotometer at 680 nm. For Ca and Mg determination, 1 ml aliquot from dilution 1, 9 ml of water and 10 ml of 1% lanthanum solution were mixed together. It was analyzed by absorption spectrophotometer. For Fe, Mn and Zn determination, the original filtrate was used to analyze these elements by absorption spectrophotometer.

Estimation of energy

The chemical energy content of food ingredients is usually expressed in terms of heat units (since all forms of energy are convertible into heat energy). The gross food energy was estimated by multiplying the crude protein, crude fat and total carbohydrate by at water factors 4, 9 and 4 respectively (Onimawo *et al.*, 1998; Osborne *et al.*, 1998).

Statistical analysis

The recorded data for each character from the experiments was analyzed statistically find out the variation resulting from experimental treatments using MSTAT package program. The mean for all the treatments were calculated and analysis of variance of characters under the study was performed by F variance test. The mean differences were evaluated by least significance difference test.

Results and Discussion

Three varieties of mustard seed were collected for the determination of physical and chemical characteristics.

Physical characteristics of mustard varieties

Grain weight: Seed weights were determined at 13% moisture level. Seed weight varied with their size and shape (Table 1). BARI Sarisha-17 seed size is higher than the other two varieties mustard. Among different mustard varieties highest thousand grain weight was found in BARI Sarisha-17 (4.24 g), followed by BARI Sarisha-16 (3.620 g) and BARI Sarisha-15 (3.17 g). Our studies mustard seed grain weight are consistent with the results reported by Chowdhury *et al.*, (2014) Banga *et al.*, (2013), Siddiqui *et al.*, (2004), Andarhennadi *et al.*, (1991), Biswas (1989), Chowdhury *et al.*, (1987) and Kaul *et al.*, (1986). Banga *et al.*, (2013) and Siddiqui *et al.*, (2004) found that the highest amount of 1000 seed weight were 5.15 g and 3.95 g, respectively. Our studies mustard seed grain weight values are higher than the reported value of Mandal *et al.*, (2002); who found that thousand seed weight varies from 2.50–2.65 g.

Moisture: The moisture content of different released varieties of mustard was ranged from 4.10% to 4.52% (Table 1). The results of the moisture content were significantly lower than Sarker *et al.*, (2015), Mahmud *et al.*, (2012), BARI annual report (1987-88). According to Sarker *et al.*, (2015) moisture content of mustard cakes were $9.20 \pm 0.5\%$; and the moisture content $8.3 \pm 0.2\%$ reported in literature by Mahmud *et al.*, (2012).

Table 1. Weight of 1000 seeds and moisture of different varieties of mustard oilseed varieties

Name of the Varieties (Treatments)	Weight of 1000 Seeds (at 13% Moisture Level) (g)	Moisture (%)
BARI Sarisha-15	3.17	4.52 a
BARI Sarisha-16	3.62	4.20 b
BARI Sarisha-17	4.24	4.10 b
LSD _(0.05)	2.627	0.3285
CV (%)	1.33 %	3.36 %

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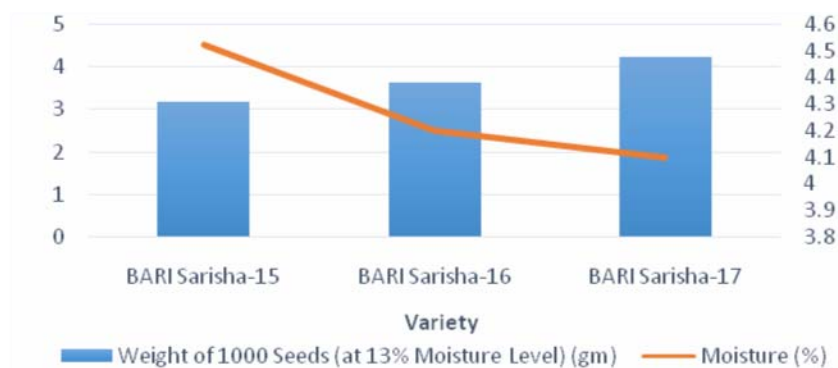


Fig.1. Relation between weight of 1000 seeds in g (at 13% moisture level) and moisture of different varieties of mustard oilseed.

Oil content: The oil content of different varieties of mustard varied from 40.95% to 49.51% (Table 2). Mustard variety BARI Sarisha-17 contained highest amount of oil (41.98%), followed by BARI Sarisha-15 (41.85%) and BARI Sarisha-16 (40.95%). The results clearly indicated that mustard variety can be considered as better source of oil. Present studies values of oil content mustard seed are higher than the reported value of Gadei *et al.*, (2012) and B. R. Moser *et al.* (2009), who found that oil content ranges from 28-32%; whereas Arif *et al.* (2012), Bhowmik (2003), Novoselov *et al.*, (1994) reported that oil content of rapeseed ranges from 45.67–43.87%, 42–46% and 45–46% respectively, which are slightly higher than present results. On the other hand, the present investigations were more or less similar the reported values of Vijay *et al.*, (1992), Rathore (1999–2000), BARI report (2001), Sengupta *et al.*, (2003), Mandal *et al.*, (2002). These variations might be due to biological factor, environmental factor, soil and crop management practices.

Oil cake: The BARI Sarisha-16 contained significantly highest amount of oil cake (59.05%), followed by BARI Sarisha-15 (58.15%) and BARI Sarisha-17 (58.02%) (Table 2). The present studies values of mustard oil cake were supported by the reported values of Chowdhury *et al.*, (2014) and Appelqvist *et al.*, (1992). Chowdhury *et al.*, (2014) found that percentage of oil cake range from 58.14 to 59.95% and Appelqvist *et al.*, (1992), reported that typically rape seed oil (kind of mustard seed) contain 58% cake.

Dry weight of cake

The highest value was obtained from BARI Sarisha-16 (54.85%), followed by BARI Sarisha-17 (53.92) and BARI Sarisha-15 (53.63%) (Table 2).

Table 2. Proximate analysis of oil content, oil cake and dry wt. of cake of the different oilseed varieties

Name of the Varieties (Treatments)	Oil Content (%)	Oil Cake (%)	Dry Wt. of Cake (%)
BARI Sarisha-15	41.85c	58.15b	53.63c
BARI Sarisha-16	40.95d	59.05a	54.85a
BARI Sarisha-17	41.98c	58.02b	53.92b
LSD (0.05)	0.1726	0.1726	0.1908
CV (%)	0.21%	0.17%	0.21%

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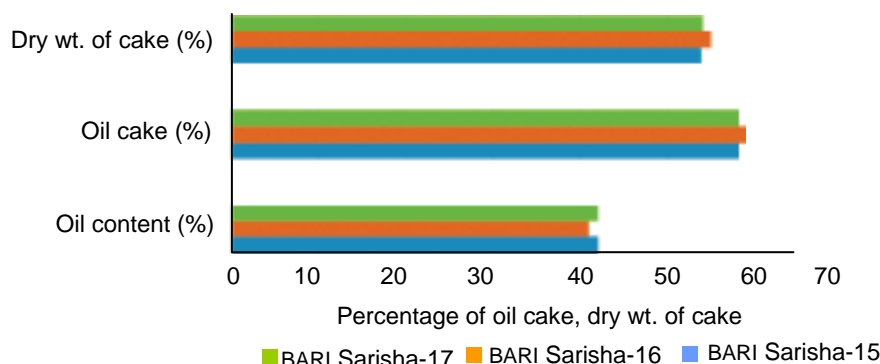


Fig. 2. Relation between oil content, oil cake and dry wt. of cake of different mustard oilseed varieties.

Chemical characteristics of mustard varieties

Chemical constant of oil

Saponification value: Saponification values of different varieties of mustard varied have been presented in Table 3. The highest saponification values of mustard variety was found in BARI Sarisha-17 (159.40), the lowest value was found in BARI Sarisha-15 (157.60) and BARI Sarisha-16 was found 157.90. These values are supported by Chowdhury *et al.*, (2014) study. Our present studies saponification values found in mustard varieties are lower than the various reported studies as Khan *et al.*, (2013), Martin *et al.*, (1995) and Richet *et al.* (1987). They were found saponification value of the extracted mustard oils >170, 170 and 182.4 respectively.

Iodine value: The iodine values of different varieties of mustard varieties have been presented in Fig. 3. In case of mustard varieties, the all iodine values are statistically similar BARI Sarisha-15 (72.50), BARI Sarisha-16 (70.60) and BARI Sarisha-17 (73.44) (Table 3). The observed values were supported by the reported values of Chowdhury *et al.*, (2014), Khan *et al.*, (2013), Richet *et al.*, (1987), Martin *et al.*, (1995) and Chowdhury *et al.*, (2015).

Table 3. Chemical constant of oil of different mustard oilseed varieties

Name of the varieties (Treatment)	Saponification Value	Iodine Value
BARI Sarisha-15	157.60	72.50
BARI Sarisha-16	157.90	70.60
BARI Sarisha-17	159.40	73.44
LSD _(0.05)	2.35	3.28
CV (%)	0.66 %	2.00 %

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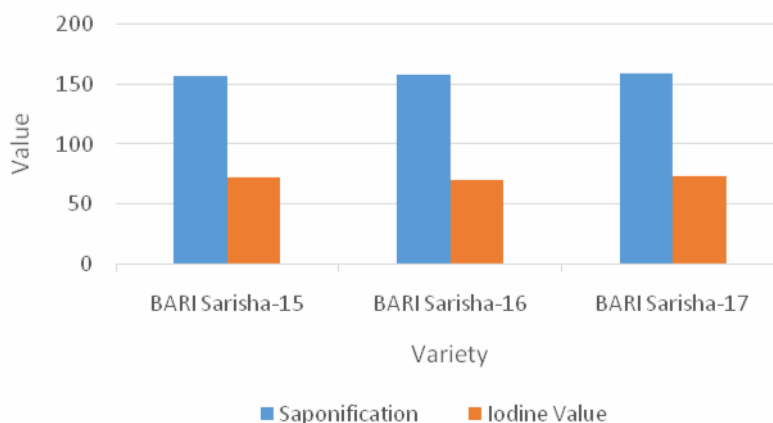


Fig. 3. Saponification value and iodine value of different mustard oilseed varieties.

Fatty acid composition: There was a significant difference between the studied mustard varieties in terms of their fatty acid composition (Table 4). Significantly the highest amount of palmitic acid was observed in BARI Sarisha-17 (3.22%). Lowest amount of palmitic acid content was observed in BARI Sarisha-16 (2.09%) and BARI Sarisha-15 was observed in 2.88% palmitic acid. Highest amount of stearic acid content found in BARI Sarisha-15 (1.40%) and the lowest amount found in BARI sarisha-17 (1.19%). BARI Sarisha-17 contained the highest amount of oleic acid 18.69% followed by BARI Sarisha-15 (16.16%) and BARI Sarisha-16 (14.72%). The BARI Sarisha-15, BARI Sarisha-16, BARI Sarisha-17, contained 4.74%, 4.96%, 4.02% of arachidic acid respectively; these three varieties contained statistically similar amount of arachidic acid. Highest amount of linoleic acid was found in BARI Sarisha-15 (15.11%) which was significantly highest among all the varieties and lowest amount was found BARI Sarisha-17 (14.38%). The linoleic acid content is important from the stand point of utilization of oil for food products. Mustard variety BARI Sarisha-17, BARI Sarisha-16, BARI Sarisha-15 contained 51.35%, 50.67% and 50.67% of erucic acid respectively. Concentration of linoleic acid varied from 0.240% to 7.10%. Analytical data indicated that the highest amount of total saturated fatty acid (TSFA) contained in BARI Sarisha-15 (9.02%) and the lowest amount contained BARI Sarisha-16 (8.28%). Highest amount of total unsaturated fatty acid (TUSFA) contained in BARI Sarisha-17 (90.26%) lowest amount contained in BARI Sarisha-16 (87.04%). The highest amount of gross energy found from BARI Sarisha-15 (543.60 kcal/g); while lowest amount of gross energy recorded from BARI Sarisha-16 (531.20 kcal/g). From the present data, it might be suggested that the mustered oil seeds are suitable for edible purpose as they contained higher amount of protein, oil and gross energy. These findings are in conformity with the results by Chowdhury *et al.*, (2014), Moser *et al.*, (2009), Appelqvist (1980), Chowdhury *et al.*, (2015), Mubashir (2012), Abul-fadl *et al.*, (2011), Chauhan and Kumar (2011). Mubashir, (2012) stated that mustard oil possess 42% erucic acid and 12% oleic acid, it has also 6% omega-3 alpha-linolenic acid and 15% omega-6 linoleic acid along with 12% saturated fats.

Chauhan and Kumar, (2011), observed that the concentration of oleic acid (18:1), a beneficial monounsaturated fatty acid, ranges from 3.6–32.2% in rapeseed-mustard oil. Abul-fadl *et al.*, (2011) reported that, erucic acid was in yellow and brown mustard seeds oils were represented about 37.89% and 23.90%, respectively. Oleic acid was ranged from 19.08% to 20.24% of total fatty acid profiles in both yellow and brown mustard oilseeds. Moreover, linoleic acid was recorded from 12.37 to 21.36 both yellow and brown mustard oilseeds. Moser *et al.*, (2009) observed that, mustard oil has a special fatty acid composition, it contains about 20–28% oleic acid, 10–12% linoleic, 9.0–9.5% linolenic acid, and 30–40% erucic acid. Moreover, Appelqvist (1980) found that fatty acid composition of mustard varieties i.e., 3.0%, 0.8%, 9.9%, 13.5%, 9.8%, 6.3% and 52.3% for palmitic acid, stearic acid, oleic acid, linoleic acid, linolenic acid, eicosenoic acid and erucic acid, respectively.

Table 4. Fatty acid composition of the different oilseed varieties

Name of the Varieties (Treatments)	Percentage of Fatty Acids						
	Saturated Fatty Acid (SFA)			Unsaturated Fatty Acid (USFA)			
	Palmitic Acid (C _{16:0})	Stearic Acid (C _{18:0})	Arachidic Acid (C _{20:0})	Oleic Acid (C _{18:1})	Linoleic Acid (C _{18:2})	Linolenic Acid (C _{18:3})	Erucic Acid (C _{22:1})
BARI Sarisha-15	2.88 e	1.40 d	4.74 a	16.16 e	15.11 c	7.14 a	50.6b
BARI Sarisha-16	2.09 f	1.23 e	4.96 a	14.72 f	14.88cd	6.84 b	50.6b
BARI Sarisha-17	3.22 d	1.19 e	4.02 a	18.69 d	14.38 d	5.84 c	51.35a
LSD (0.05)	0.1409	0.09965	1.987	1.005	0.6904	0.2573	0.5548
CV (%)	1.12%	2.99%	39.33%	1.52%	1.62%	3.59%	1.20%

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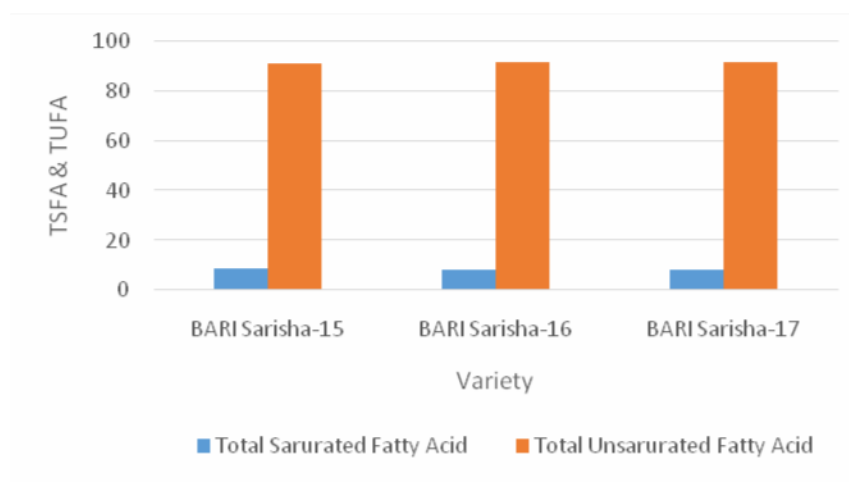


Fig. 4. Percentage of total saturated and unsaturated fatty acid of oil of the different varieties of oilseed.

Analysis of oil cake

After extraction of oil, the seeds gave the defatted cakes of varying amounts. The results of cake analysis were presented in Table 5.

Ash: Ash content of different released varieties of mustard oilseeds were variable and ranged from 11.90% to 14.20% (Table 5). BARI Sarisha-16 contained the highest amount of ash (14.20%) followed by BARI Sarisha-17 (12.50%) and BARI Sarisha-15 (11.90%). Our studies values of mustard varieties were significantly higher than the reported value of Sarker *et al.*, (2015), Abul-Fadl *et al.*, (2011), Sosulski *et al.*, (1991) and Kaul *et al.*, (1986).

Protein: Protein content of different varieties of mustard has been presented in Table 5. Significantly highest amount of protein was obtained from BARI Sarisha-15 (28.00%), the lowest amount of protein content found in BARI Sarisha-17 (22.57%). The present studies values are more or less similar with the reported values of Sarker *et al.*, (2015), Chowdhury *et al.*, (2010), Sosulki *et al.*, (1991), and Mirza *et al.*, (1998), Chowdhury *et al.*, (2015). These results are lower than those reported by many other authors. Prapakornwiriya and Diosady (2004) determined the protein 45.0% and 34.0% respectively. Sengupta *et al.* (2003) revealed that protein content of rapeseed were ranges from 44.2–44.7%. However our studies result is higher than the reported value of many other authors of Asibuo *et al.*, (2008), Ingale *et al.*, (2011), Ayoola *et al.*, (2012). This might be due to the nitrogen fertilizer application, ecology and agronomics practices.

Carbohydrate: Carbohydrate content of different released varieties of oil seed were determined moisture free basis. The data have been presented in Table 5. The amount of carbohydrate contained found in BARI Sarisha-17, BARI Sarisha-16, BARI Sarisha-15 were 18.85%, 14.05%, 13.75% respectively. Agronomics practices, environmental factors as well as variation among the species and varieties might be influenced the carbohydrate content. Our studies carbohydrate content are slightly lower than the reported values of Ayoola *et al.*, (2012), Bachheti *et al.*, (2012) and Gopalan *et al.*, (1981). Bachheti *et al.*, (2012) found that mustard seeds contain 23.8% carbohydrate and Gopalan *et al.*, (1981) stated that dry mustard seeds contained 20-23% carbohydrate.

Table 5. Proximate analysis of protein, ash and carbohydrate content of the different oilseed varieties (dry weight basis)

Name of the varieties (Treatments)	Ash (%)	Protein (%)	Carbohydrate (%)
BARI Sarisha-15	11.90 c	28.00 c	13.73 b
BARI Sarisha-16	14.20 a	26.60 c	14.05 b
BARI Sarisha-17	12.50 b	22.57 d	18.85 a
LSD (0.05)	0.2636	1.661	1.953
CV (%)	1.29%	3.10%	10.10%

Figure in a column followed by a common letter do not differ significantly at 5% level by DMRT

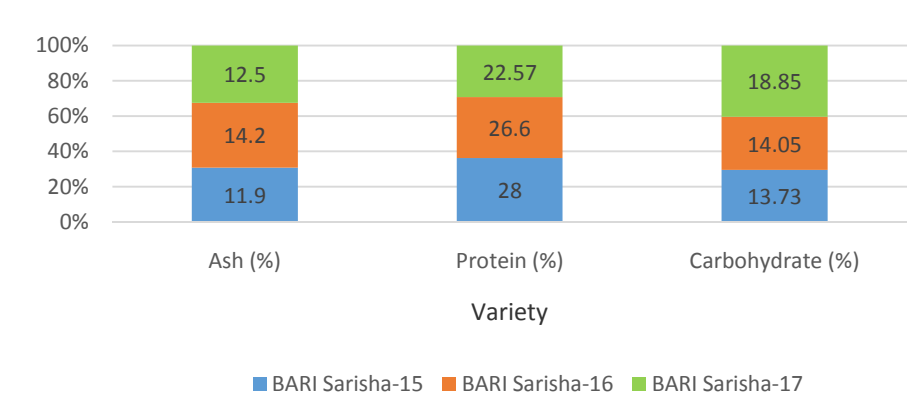


Fig. 5. Proximate analysis of protein, ash and carbohydrate content of the different oilseed varieties (dry weight basis).

Proximate analysis of minerals content of the different oilseed varieties

Different major and minor minerals were analyzed this work. The amounts of major minerals content of rapeseed have been illustrated in Table 6. It is well known that rape seed contained small amount of minerals.

In case of calcium content of different released varieties of mustard was ranged from 2.58% to 1.10% (Table 6). Significantly highest amount of calcium (Ca) content was observed in BARI Sarisha-16 (2.52%), followed by BARI Sarisha-15 (2.15%); these varieties are statistically similar in respect to calcium content. The lowest amount of calcium content was obtained from BARI Sarisha-17 (1.10%). The present investigations were supported by reported value of Sarker *et al.*, (2015), Sengupta *et al.*, (2003), Chowdhury *et al.*, (2015), Bachheti *et al.*, (2012), Josefson (1988), and Pathak *et al.*, (1973). Sengupta *et al.*, (2003) and Bachheti *et al.*, (2012), reported that mustard contains 492.1 mg and 490 mg calcium respectively, while Josefson (1988) stated that mustard contain 0.7% Ca.

Magnesium is the major minerals for human nutrition. Magnesium content of different released varieties of oil seed have been presented in Table 6. There is no significant variation in magnesium content among the varieties. Magnesium content of different varieties was ranged from 0.64% to 0.740%. The present investigations were supported by reported value of Sarker *et al.*, (2015), Sengupta *et al.*, (2003), Chowdhury *et al.*, (2015), Bachheti *et al.*, (2012), Josefson (1988), and Pathak *et al.*, (1973).

Percentage of nitrogen is influenced by nitrogen fertilizer application, ecology and agronomies practices. Significantly highest amount of nitrogen content was obtained from BARI Sarisha-15 (4.48%), the lowest amount of nitrogen content found in BARI Sarisha-17 (3.67%) (Table-6). The present studies values are more or less similar with the reported values of Sarker *et al.*, (2015), Sosulki *et al.*, (1991), Chowdhury *et al.*, (2010), and Mirza *et al.* (1998).

Copper contained of different varieties of mustards were ranged from 6.18-13.40 ppm (Table 6). Statistically similar amount of Cu content observed in BARI Sarisha-15 (13.40 ppm), BARI Sarisha-16 (13.26 ppm). Lowest amount of Cu contained observed in BARI Sarisha-17 (6.18 ppm). Our studies investigations were supported by reported value of Sarker *et al.*, (2015), Arif *et al.*, (2012), Bachheti *et al.*, (2012), Josefson (1988), and Pathak *et al.*, (1973).

Iron contained of different varieties of mustard was ranged from 75.70 ppm to 170.30 ppm (Table 6). Significantly highest amount of Fe contained was observed in BARI Sarisha-15 (170.30 ppm) which was followed by BARI Sarisha-17 (100.70 ppm). However these results were supported by the reported values of Chowdhury *et al.*, (2015). These might be influenced the different levels of Fe in soil, fertilizer and variation among the varieties. Our studies Fe values were higher than the reported values of Bachheti *et al.*, (2012) and Josefson (1988); who found that Fe content of mustard seed oil were 8.11 g/100 g and 18 ppm respectively.

The zinc content of different varieties of mustard was ranged from 51.45 to 66.80 ppm in (Table 6). Significantly highest amount of Zn contained was found in BARI Sarish-16 (66.80 ppm) which was followed by BARI Sarish-17 (51.91 ppm). The lowest amount was found in BARI Sarish-15 (51.45 ppm). The present values were supported by the reported value of Chowdhury *et al.*, (2015), Bachheti *et al.*, (2012) and Josefson (1988).

Table 6. Proximate analysis of minerals content of the different oilseed varieties

Name of the Varieties (Treatments)	Ca (%)	Mg (%)	N (%)	Cu (ppm)	Fe (ppm)	Zn (ppm)
BARI Sarisha-15	2.15 c	0.74 a	4.48 c	13.40 a	170.30 a	51.45 b
BARI Sarisha-16	2.52 ab	0.74 a	4.26 c	13.26 a	75.70 e	66.80 a
BARI Sarisha-17	1.10 d	0.64 a	3.66 d	6.18 c	100.70 d	51.91 b
LSD _(0.05)	0.1409	0.1286	1.661	1.226	6.084	0.7277
CV (%)	3.54%	6.96%	3.10%	5.90%	2.77%	0.71%

Figure in a column followed by a common letter do not differ significantly at 5% level of DMRT

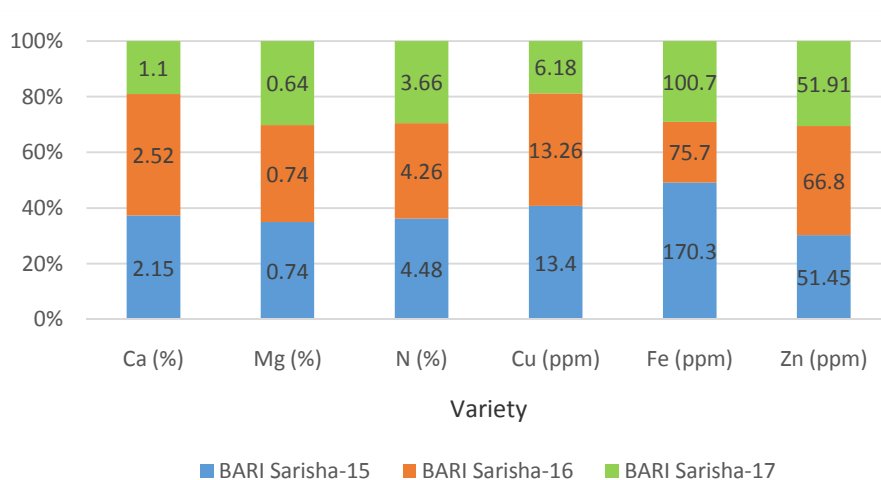


Fig. 6. Proximate analysis of mineral content of the different mustard oilseed varieties.

Gross energy

Significantly the highest amount of energy from carbohydrate found in BARI Sarisha-17 (75.41 kcal/g), followed by BARI Sarisha-16 (56.20 kcal/g), BARI Sarisha-15 (54.92) (Table 7). The highest energy from protein observed from BARI Sarisha-15 (112.00 kcal/g); whereas the lowest amount of energy from protein observed from BARI Sarisha-16 (90.27 kcal/g). The highest amount of energy from fat was observed in BARI Sarisha-17 (377.80 kcal/g), significantly same amount of energy obtained from BARI Sarisha-15 (376.60 kcal/g). The study found that Gross energy of different varieties of mustard ranged from 531.20 kcal/g to 543.6 kcal/g. The highest amount of gross energy found from BARI Sarisha-15 (543.60 kcal/g); while lowest amount of gross energy recorded from BARI Sarisha-16 (531.20 kcal/g). Our studies reports were supported by the reports of Chowdhury *et al.*, (2015), Hossain *et al.*, (2015).

Table 7. Proximate analysis of gross energy from carbohydrates, proteins and oils of the different varieties of oilseed

Name of the Varieties (Treatments)	Energy from Carbohydrate (kcal/g)	Energy from Protein (kcal/g)	Energy from Oil (kcal/g)	Total Energy (kcal/g)
BARI Sarisha-15	54.92 b	112.00 c	376.60 c	543.6 d
BARI Sarisha-16	56.20 b	106.40 c	368.50 d	531.2 e
BARI Sarisha-17	75.41 a	90.27 d	377.80 c	543.5d
LSD _(0.05)	7.811	6.445	1.554	1.549
CV (%)	10.10%	3.10%	0.21%	0.15

Figure in a column followed by a common letter do not differ significantly at 5% level by DMRT

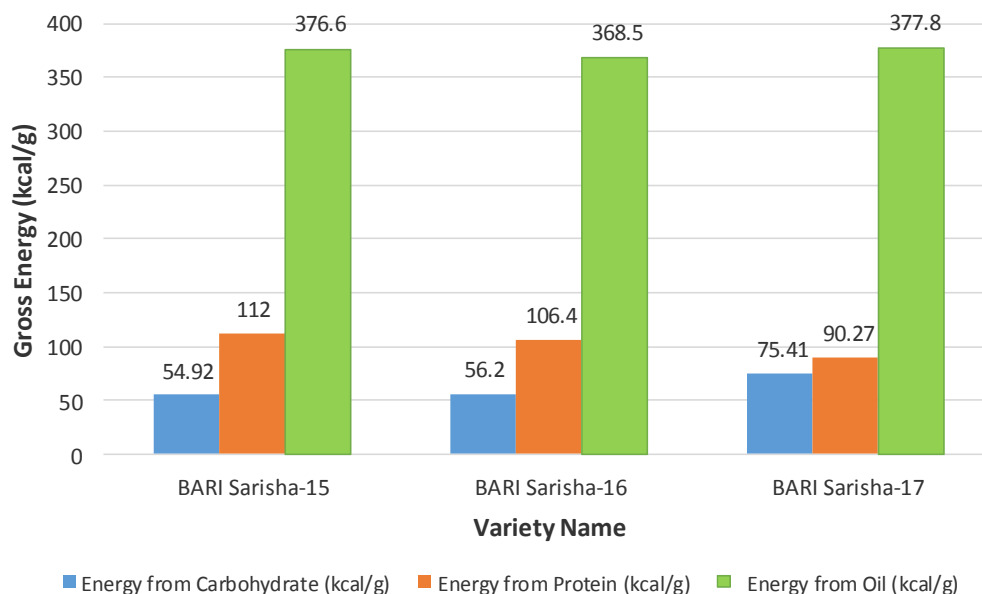


Fig. 7. Gross Energy of the different oilseed varieties

Conclusion

The physicochemical characteristics of three varieties of mustard oilseed were analyzed. Among those mustard varieties BARI Sarisha-17 contained highest amount of oil, saponification value, iodine value, carbohydrate contain and highest amount of total unsaturated fatty acid (TUSFA). It was observed that highest amount of gross energy found from BARI Sarisha-15 and it was also found that highest amounts protein, Mg, N, Cu, Fe and highest amount of total saturated fatty acid (TSFA). All mustard varieties contained good amount of erucic acid. BARI Sarisha-16 contained highest amount of Ca and Zn. It indicates that the BARI Sarisha-15 is a good candidate of most of the nutrient containing oil seed.

Farmers are cultivating different varieties of mustard in their field for the consumption oil and oilcake as food, feed and fertilizer. BARI Sarisha-15, BARI Sarisha-16, and BARI Sarisha-17 are grown in large scale as they contained the fair amount of nutrient contents.

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