Drying and quality features of selected maize varieties dried in commercial processing complexes

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Abstract: The drying status and quality aspects in terms of physical, nutritional, functional properties and microbial status of three common maize varieties (900M gold, pioneer 92 and kavri) dried in different drying complexes are presented in this paper. Total drying varied from18-20 h for drying of freshly harvested maize varieties in the complexes where sun drying method was used. The overall calculation reveled that drying cost in the mills ranged from US$11.5 to US$14.75 per ton of fresh maize (1 US$ equals 80 BDT). The dimensions of the maize varieties as length, width and thickness were found to be ranged from 12.62±0.34 to 14.54±0.32, 9.56±0.24 to 10.60±0.35, 6.38±0.28 to 7.3±0.41 mm, respectively. The 900M gold variety gave the highest bulk density of 575.84±3.8 kg m^{-3}. The highest crude protein (8.75%±0.10%) and water solubility index (1.90±0.02 gm gm^{-1} of gel) were found in the dried samples of 900 M gold variety at 14% moisture content. The highest ash, fat and starch content were 2.01%±0.02%, 3.97%±0.09% and 76.33%±0.88%, respectively in pioneer 92 varieties at 14% moisture content. The highest microbial load was found at higher moisture dried grain (14%) than lower moisture dried samples. The quality of dried grain was found to be affected with the variation in final moisture content during storage. Therefore, maize should be dried at moisture content less than 14% to maintain quality and to keep free from microbial infestation for its future use as food and feed.

Keywords: maize drying, drying cost, physical properties, nutritional quality, moisture content, microbial load

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1 Introduction

Drying and management of maize is an important issue in the present world. Because, it's increased production and versatile usage in food and feed industries are increasing day by day whole over the world. The average yield of this crop is higher than other crops (Farnham et al., 2003). The world production was 1,014.02 million metric ton in 2014 to 2015 (USDA, 2016). It is extensively cultivated in several Asian countries of the world including Thailand, China, India, Pakistan and Bangladesh. The maize production was 2.23 million metric tons in Bangladesh during 2013-2014 (Bangladesh Bureau of Statistics [BBS], 2014).

Several varieties of maize including hybrid are cultivated in this country. Maize is a good source of important nutrients. It contains 11.2% protein, 66.2% carbohydrate, 3.6% fat, 1.5% minerals and 2.7% fiber (Gopalan et al., 1981). Additionally it contains carotene, niacin, thiamine and riboflavin. Maize grain makes 60% boiler feed where whole grain is used as non-ruminants

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feed (Dalhke et al., 2001). The grain of maize gives the highest conversation ratio to meat and eggs when compared with other cereal grain because of its high starch and low fiber content. In tropical countries greater portion of yellow maize is more preferable for livestock feed. Maize is an important industrial raw material in the starch, feed and food industry. Maize provides greater nutritional value when it is used as an ingredient in the food processing and feeding industry (Ullah et al., 2010).

Sun drying (natural air drying) is the most common farming and agricultural process in many countries like Bangladesh, particularly where the open-air temperature reaches 30°C or higher. Natural air drying is a method used to dry maize by passing unheated (natural) air through the grain mass until its moisture content reaches equilibrium moisture content (EMC). The advantage of drying grain in the sun is that it is an inexpensive and easily manageable method. Open air natural sun drying on mud-plastered or concrete floors is the conventional method of drying grain. Unfavorable weather conditions are likely to occur during the harvesting and drying period thus quality degradation and microbial infestation of the final product become common. The safe moisture content for cereal grains is usually 12% to 14% on wet basis (Bala, 1997).

Improper drying affects quality of dried grains. Drying is practiced to maintain the quality of grain during storage to prevent the growth of bacteria, fungi, insects and mites. If grain is dried at high temperature, discoloration and other kinds of heat damage may occur (Foster, 1982). Maize kernel weight and germination decreased if air temperature increased from 25°C to 100°C (Peplinski et al., 1994). During high temperature drying, maize grains quality undergo alterations such as stress crack (Gustafson et al., 1979) and protein denaturation (Malumba et al., 2008). In addition to stress cracking and breakage, the change in colour of the kernel caused by thermal effects is also important, particularly when drying involves very high temperatures. Stress-cracking is the major quality problem caused by high temperature drying and rapid cooling of grain. Fractures in the maize endosperm lead to problems in both storage and processing.

To ensure high quality during storage, maize should be protected from weather, growth of microorganisms, and insects (Oyekale et al., 2012). Lynch and Morey (1989) investigated that ambient air maize drying offers advantages in maize quality compared to high temperature drying but the drying process takes place over a much longer period of time. Mechanical drying of maize requires high initial costs. Mechanical dryers is faster and gives a better quality product but they are expensive and requires substantial quantities of fuel or electricity to operate, leading to high cost of drying (Ajay et al., 2009).

Most of the commercially available dryers are designed to suit the needs of the processing industry and their output capacity is therefore far above the needs of individuals, or even of farmer groups. Sun drying methods are followed by the most of the maize farmers and millers in Bangladesh which must be assessed for suggesting efficient drying operation. Limited reviews are found where the effect of final moisture content of dried maize on grain quality during storage is reported. There is inadequate information on the effect of varieties of maize on quality of dried grain used for food and feed. This study is important to find out the facts and figure of commercial drying of maize so as to suggest for future improved drying practices.

2 Materials and methods

2.1 Site selection and data collection

Five major maize growing areas of Dinajpur namely Basher hat, Khesalpur, Dashmile, Teromile, and Birganj were selected for data collection of this study. 10 maize processing complexes from the above areas were selected for data collection. A comprehensive questionnaire was prepared to collect necessary data on maize drying. Data were collected based on verbal report, interview and some physical observations.

2.2 Moisture content determination

AOAC method 7.045 (2000) was used to determine the moisture content of maize sample. 5 g grind sample was taken in a clean, dry and pre-weighed crucible. Then the powder was transferred to an oven and dried at 105°C for 16 h. After that it was cooled in a desiccator and weighed. Again it was transferred to an oven and dried until a constant weight was obtained. Finally it was cooled and weighed.

Moisture content weight basis (w_b) was calculated by the following Equation (1):

$$\text{Moisture (\%)} = \frac{W_1 - W_2}{W} \times 100 \quad (1)$$

where, W_1 = weight of sample with crucible, g; W_2 = weight of dried sample with crucible, g, and W = weight of wet sample, g.

2.3 Drying time and drying cost calculation

Total drying time, number of labour required to accomplish whole drying process for a batch were recorded based on verbal report and physical observation. Unit drying cost in Tk ton^{-1} was then calculated as Equation (2): (Hellevang and Reff, 1987).

$$\text{Cost/ton} = \frac{\text{Cost of drying for one batch (Tk)}}{\text{Amount of raw maize in one batch (kg)}} \times 1000 \quad (2)$$

While cost included (labour cost, drying floor cost, packaging cost, transportation cost ,blowing cost and others related to drying). The unit of cost was then converted to US$/ton. It is noted that the drying cost was similar in case of all varieties of raw maize.

2.3 Determining physical properties of maize

2.3.1 Sample collection

Three varieties of sun dried maize (900M gold, pioneer-92, kavri-50) were collected from different drying complexes. Because, these varieties are extensively grown and covering large area.

2.3.2 Grain dimensions

25 kernels were selected randomly for determination of kernel dimensions (Length, width and thickness) with a vernier calliper according to the method of Martinez-Herrera and Lachance (1979). All the dimensions were taken in mm.

2.3.3 Bulk density

Bulk density was determined by weighing the amount of grain in 50 cm^3 calibrated beaker based on a modification of the method used by Kikuchi et al. (1982). An average of 5 measurements represented one determination. Test Bulk density was expressed as mass per unit volume (kg m^{-3}).

2.4 Nutritional analysis

2.4. 1 Sample preparation

Dried maize of the three varieties at different moisture content (14% and 12%) were used in this study. Samples were initially grounded by a mortar and pestle and passed through a 60 mesh sieve. The powdered samples of particular moisture content were packed in high density polyethylene (HDPE) package at room temperature until further analysis.

2.4.2 Crude protein content determination

Crude protein content was determined by AOAC official method (2000). Three stages were used to determine protein content such as digestion, distillation and titration.

i) Calculation for N_2 content:

% of N_2 = Burette reading × Normality of H_2S0_4 × mL equivalent of N2

Here, Normality of $H_2S0_4 = 0.2$; mL equivalent of N2 = 1.4.

ii) Calculation for protein content:

% Protein = % of N_2×Protein factor

Here, Protein factor = 6.25.

2.4.3 Ash content determination

Ash content of maize sample was analyzed by AOAC official method (2000). 5 g powdered sample was taken in pre weighed crucible. Then it was placed in muffle furnace at 550°C to 600°C for 5-6 h. After ashing, the crucible was cooled and kept for some time in a desiccator and weighed. From the weighs recorded the present ash content was calculated by the following Equation (3):

$$\text{Ash (\%)} = \frac{A_1 - A_2}{A} \times 100 \quad (3)$$

where, A_1 = weight of ash with crucible, g; A_2 = weight of empty crucible, g, and A = weight of sample, g.

2.4.4 Fat content determination

AOAC method 7.045 (2000) was used to determine the fat content of the grounded maize flour. Five grams sample was taken into thimble. The thimble was attached to the Soxhlet apparatus which was attached with a round bottom flask containing 200 ml ether. The fat was extracted for 5-6 h. After that ether was evaporated at 80°C until the flask completely dried.

Fat content was calculated by following Equation (4):

$$\text{Fat (\%)} = \frac{F_1 - F_2}{F} \times 100 \qquad (4)$$

where, F_1 = weight of evaporated flask with sample, g; F_2 = weight of empty flask, g, and F = weight of sample in g.

2.4.5 Starch determination

One gram of oven dried powdered sample was taken in an erlenmeyer flask and 50 mL of cold water was added. The content of flask was allowed to stand for one hour with occasional stirring. It was then filtered and the residue was washed with 50 mL distilled water. The sample was hydrolyzed with 10% HCl for 2.5 h under reflux. The hydrolysate was neutralized with dilute sodium hydroxide solution and filtered. The filtrate was collected in a 100 mL volumetric flask and the volume was made up to 100 mL.

The reducing sugar in the filtrate was determined by Fehling's titration method and the amount of glucose was calculated as following Equation (5):

$$\text{Starch (\%)} = \text{glucose (\%)} \times 0.9 \qquad (5)$$

2.5 Functional properties

2.5.1 Water adsorption index (WAI)

WAI was determined according to the method reported by Asaduzzaman et al. (2013). Powdered sample (0.83 g) was suspended with 10 mL of water into a 30 mL of tared centrifuge tube. The mixture was centrifuged for 30 min at 4000 rpm and the supernatant was poured carefully into a tared dish. The residue was weighed.

Water absorption index was determined by following Equation (6):

$$\text{WAI (gel g}^{-1}\text{)} = \frac{X_1 - X_2}{X} \times 100 \qquad (6)$$

where, X_1 = weight of tube with residue, g; X_2 = weight of the tube, g, and X = weight of sample, g.

2.5.2 Water solubility index (WSI)

WSI was also determined according to the method reported by (Asaduzzaman et al., 2013) .Dried flour (0.83 g) was suspended with 10 mL of water into a 30 mL of tared centrifuge tube. The mixture was centrifuged for 30 min at 4000 rpm and the supernatant was poured carefully into a tared dish. The supernatant was dried at 70°C until obtained a constant weight. Then it was cooled and weighed.

WSI was finally calculated by following Equation (7):

$$\text{WSI (\%)} = \frac{S_1 - S_2}{S} \times 100 \qquad (7)$$

where, S_1 = weight of dish and dried sample, g; S_2 = weight of dish, g, and S = weight of dried sample, g.

2.6 Microbial load calculation

The dried maize samples were collected from three mills. Then the samples were surface sterilized with 70% ethanol and rinsed in peptone water according to the methods of (Böltner et al., 2008). The samples were then mashed with mortar and pestle to expose the microbes inhabiting. One gram of the maize sample was dissolved in 99mL distilled water and further serial dilution 10^{-5} to 10^{-7} for bacterial colonizers, using the pour plate methods according to Orole and Aedjumo (2011). One gram of bruffed peptone was dissolved in 999 mL of distilled water. From the prepared peptone water serial dilution was made 10^{-5} to 10^{-7} for bacterial isolation. 1ml of each dilution was placed into petri dishes, using the pour plate technique. The petri dishes were incubated at 37°C, 18 to 24 h for bacterial colony according to the method of (Zinniel et al., 2002).

2.7 Statistical analysis

All measurements were carried out in triplicate for each of the sample except particle dimensions (25 times) for calculating average. Results are expressed as mean values standard error mean. Data were analyzed using statistical software (SPSS windows version 20). Mean comparisons were performed using Duncan's multiple range tests for significant effect at least of p<0.05.

3 Results and discussion

3.1 Drying cost of maize in commercial processing complexes

Drying cost was found to be ranged from US$11.5 to US$ 14.75. The highest cost was obtained by Styles & Brothers mill as shown in Figure 1. Similar drying cost was exhibited by Taimur husking mill. The results slightly varied with other mills such as Faria traders, Hamid enterprise, and Janata husking mills respectively. The lowest cost was obtained by Chowdury mills. The drying cost varied between different grain processors due to the variation of individual drying operation related cost and area of drying complexes. Transportation of products generally contributes a significant portion of overall harvest and drying cost variability (Curtin et al., 1980).

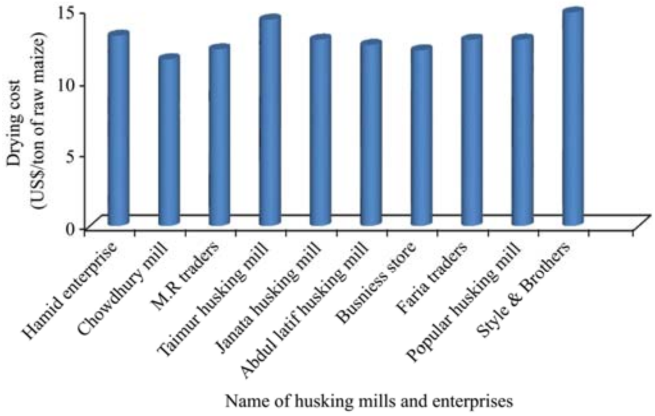

Figure 1 Drying cost of maize in different millers of Dinajpur district

3.2 Physical properties of maize

The grain dimensions (Length, Width, and Thickness) are presented in Table 1. The highest frequency was obtained at 12 mm length of pioneer variety as shown in Figure 2 and the kernel length of this variety significantly varied with the other varieties. Kernel length of 900M gold was found in lowest frequency. Width of 900M gold and pioneer maize varieties showed almost similar result compared to the kavri variety as shown in Figure 3. The thickness of maize kernel also varied with their varieties as shown in Figure 4. Kernel (length, width and thickness) ranged from 9mm to 17 mm, 7mm to 13 mm and 4mm to 10 mm respectively as shown in Figure 2, Figure 3 and Figure 4. The knowledge of physical properties is necessary to optimize the design of equipment's for post-harvest handling and processing of agricultural products (Aviara et al., 1999).

Table 1 The physical properties of three maize varieties

Name of variety	Length, mm	Width, mm	Thickness, mm	Bulk density, kg m^{-3}
900M gold	14.54 ± 0.32^{b}	10.24 ± 0.21^{ab}	6.74 ± 0.28^{c}	575.84 ± 3.8^{c}
pioneer 92	12.98 ± 0.39^{c}	9.56 ± 0.24^{c}	7.3 ± 0.41^{c}	563.44 ± 6.52^{c}
kavri 50	12.62 ± 0.34^{c}	10.60 ± 0.35^{b}	6.38 ± 0.28^{c}	567.52 ± 12.61^{c}

Note: Values are mean ± Standard Error Mean of three replicates. $^{(a-c)}$ The test values along the same column carrying different superscripts for each composition are significantly different at least of (p<0.05).

The highest bulk density was found in 900M gold variety. Even though there is no significant difference in bulk density but slightly different results were obtained from pioneer and kavri varieties. The bulk density of grains is useful for the design of silos and storage bins (Nalladulai et al., 2002). Hybrids for 900M gold and kavri 50 would be more desirable for industrial dry milling based on our test weight results.

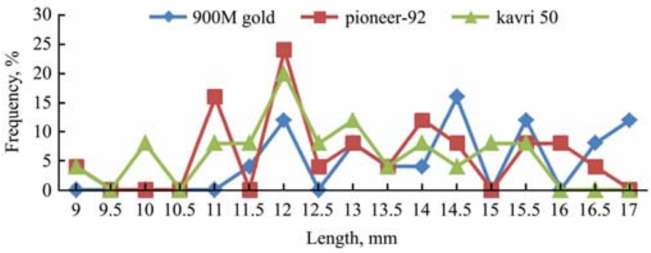

Figure 2 Length frequency distributions for three maize varieties

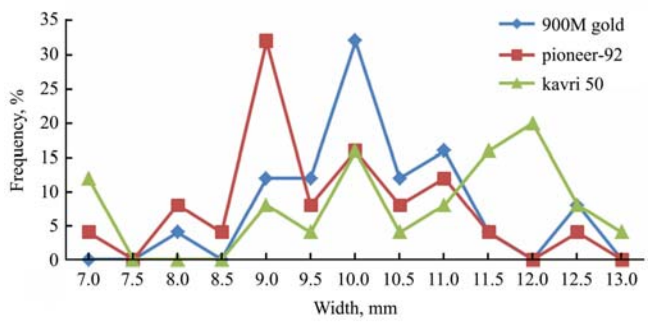

Figure 3 Width frequency distributions of three maize varieties

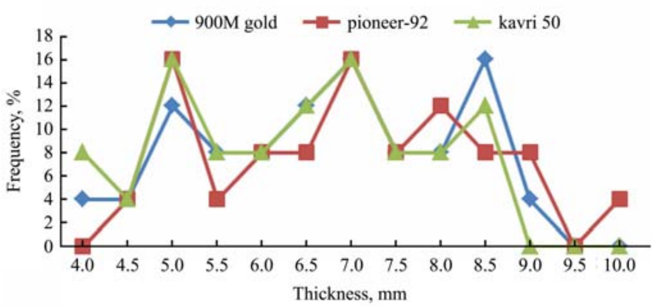

Figure 4 Thickness frequency distributions of three maize varieties

3.3 Nutritional quality of dried maize

3.3.1 Crude protein content

The protein content of the three maize varieties was found to be 8.75%, 7.99% and 7.72% (w_b) at 14% moisture content Table 2. The crude protein content for 12% moisture grain was found 7.99%, 7.58%, and 8.2 2% on wet weight basis Table 3. The highest crude protein values were found in 900M gold variety for 14% moisture content. On the other hand the highest crude protein values obtained in kavri variety at 12% moisture content. Significant differences were observed between samples at different moisture content (Table 2 and 3). These values were also similar with (Rostagno, 1993). He reported that the average crude protein values were 8.1%

and 8.6% respectively. (D' Agostini et al., 2004) also found the minimum crude protein values of 7.3% wet weight basis. This variation could be occurred due to fertilizer application on maize field and environmental conditions (Lima et al., 2000).

Table 2 Nutritional characteristics of dried maize at 14% moisture content

Sample	Crude protein, %	Ash, %	Fat, %	Starch, %
900 M Gold	8.75±0.10[b]	1.48±0.01[c]	3.15±0.12[c]	59.67±0.88[c]
pioneer 92	7.99±0.21[c]	2.01±0.02[b]	3.97±0.09[b]	76.33±0.88[c]
kavri 50	7.72±0.10[c]	1.53±0.11[c]	3.96±0.02[b]	69.00±0.58[b]

Note: Values are mean ± standard error mean of three replicates. [(a-c)] The test values along the same column carrying different superscripts for each composition content are significantly different at least of (p<0.05).

Table 3 Nutritional characteristics of dried maize at 12% moisture content

Sample	Crude protein, %	Ash, %	Fat, %	Starch, %
900 M Gold	7.99±0.21[ab]	1.61±0.01[c]	3.18±0.04[c]	56.16±0.15[c]
pioneer 92	7.58±0.06[c]	1.10±0.01[c]	4.28±0.04[c]	67.4±0.89[c]
kavri 50	8.22±0.10[b]	1.24±0.02[b]	4.12±0.02[b]	60.68±0.36[b]

Note: Values are mean ± standard error mean of three replicates. [(a-c)] The test values along the same column carrying different superscripts for each composition content are significantly different at least of (p<0.05).

3.3.2 Ash content

The ash content was found to be 1.48%, 2.01% and 1.53% respectively in 900M gold, pioneer 92 and kavri 50 at 14% moisture content as shown in Table 2. The highest ash content was found in pioneer variety than others. The ash content found in the present study was 1.61%, 1.10% and 1.24% for 900M gold, pioneer 92 and kavri 50 for 12% moisture content respectively (Table 3). The highest value was obtained in 900M gold variety. These values are nearly similar to the value of 1.2% which was found by Watt and Merrill (1950). The variation in ash content in different varieties might be due to the locality (Ocloo et al., 2010).

3.3.3 Crude fat content

The highest fat content was found in pioneer variety compare to others as shown in Table 2. Maize sample of 12% moisture content found the fat content in the range of 3.18% to 4.28% (Table 2). The percent of crude fat obtained from dried maize in this study was consistent and in agreement with other researchers (Aseiedu et al., 1993).

3.3.4 Starch content

The amount of starch in different maize varieties varied from 56.16% to 76.44% as shown in Table 2 and Table 3. The highest starch percent was found in pioneer 92 varieties as mention in Table 2. So, it is found that percent moisture has an effect on starch content. The highest starch percent was found in pioneer 92 variety as shown in Table 3. The variety and percent moisture had an effect on starch content.

3.4 Functional properties

The functional properties of different varieties of dried maize at particular moisture content are shown in Figure 5 and Figure 6. The WAI in different varieties varied between 2.09 gel g^{-1} to 2.12 gel g^{-1} and 2.28 gel g^{-1} to 2.29 gel g^{-1} at 14% and 12% moisture content respectively. The highest value was found at 12% moisture content while the lowest value of WAI at 14% moisture content. Higher moisture content resulted in lower WAI because it is a usual phenomenon. Since a long period of drying breaks down the starch chains, which generates sort chains, these chain retain a large number of water molecule (Bello-Pèrez et al., 2002).These might be attributed to loss of starch crystalline structure (Asaduzzaman et al., 2013). WSI in different maize flour ranged between 1.63% and 1.90% at 14% moisture content whereas 1.85% to 2.45% at 12% moisture content. The highest value obtained from pioneer 92 at 12% moisture content and lowest value from 900M gold at 14% moisture content. Water solubility index can depend on the semi crystalline structure and disruption of starch granule and water molecules are bonded to the free hydroxyl groups of amylose and amylopectin by hydrogen bonds (Eliasson and Gudmundsson, 1996).

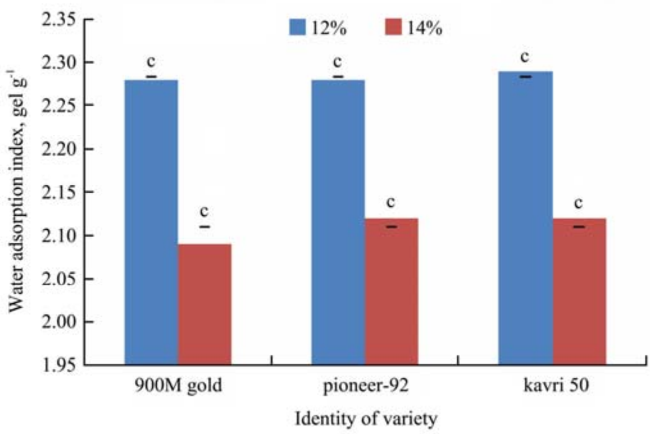

Figure 5 WAI of three maize varieties

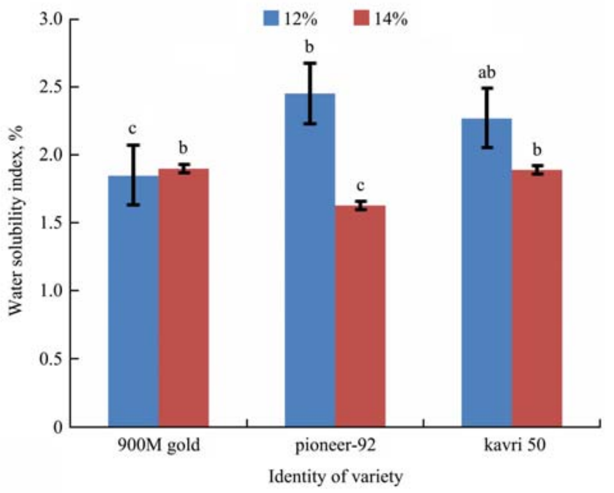

Figure 6 WSI of three maize varieties

3.5 Microbial status of dried maize

Microbial statuses of maize samples from selected mills were presented in Table 4.

The bacterial load varied from mill to mill and then variety to variety.

Table 4 Microbial status of dried maize

Name and location of drying unit	Variety of maize sample	Moisture content, %	Bacterial load, cfu g^{-1}
Hamid enterprise, Basherhat, Dinajpur	kavri 50	14	24×10^5
		12	2×10^5
Choudhury mills, Khesulpur, Dinajpur	900M gold	14	9×10^5
		12	8.2×10^5
M.R. traders Dashmail, Dinajpur	pioneer 92	14	62×10^5
		12	27×10^5

The higher bacterial load was found at 14% moisture content from 9×10^5 to 62×10^5 cfu g^{-1} whereas the lower bacterial load was found in the low range of 2×10^5 to 27×10^5 cfu g^{-1} at 12% moisture content as shown in Table 4. The bacterial load of different varieties fluctuated with each other (Table 4). Orole and Adejumo (2011) found bacterial count (cfu g^{-1}) of dried yellow grains was 2×10^5. The similar result was obtained by (Böltner et al., 2008). The variation of microbial growth occurred due to the effect of grain moisture, their storage condition and also drying floor. Reed et al. (2007) also reported that the higher the initial moisture contents the greater the infection of maize kernel. So, percent of moisture content has a significant effect for growth of microbes.

4 Conclusions

This study investigated drying characteristics and physical and nutritional quality of dried maize in commercial processing complexes. Drying time was 18 to 20h. Drying cost was higher for Style and Brothers mill and it was US$14.75. Significant differences were found in kernel dimensions and bulk densities and nutritional qualities among different varieties. The highest bacterial load was found at 14% moisture content. It can be recommended that dried maize of 900M gold can be used as raw material in food and feed industries of Bangladesh for preparing various value added products because of its high nutritional quality. The overall results showed that variety of pioneer 92 can be used as a good source of starch as well as thickening and binding agent in food system. Further work can be done to develop more efficient drying method or dryer for drying of maize at lower cost.

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