Effect of Grain Moisture Content on Popping Yield of Sorghum Genotypes

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Abstract
This paper aimed at providing popping characteristics of different red and white sorghum genotypes according to different moisture content at traditional methods of popping using high temperature for a short time (HTST). To increasing grain moisture level, seven sorghum genotypes - mutant and hybrid lines (M1(6282), 16113, 16121, 1641, 1643, 1651, 1673) were soaked to 0, 60, 120 and 180 min in distilled water. The popping rate and expansion ratio were recorded. The results showed that conventional method of popping is a good main to produce pops sorghum after increasing moisture of grains. Moistening of grains from 13-16 % increased 5.3-10.2% popping rate of all sorghum genotypes. The mutant line M1(6282) with red coloration of pericarp had the highest popping rate and expansion ratio at 16% moisture i.e. 85% and 3.88 %, respectively. There was correlation between diameter of grains and parameters expansion ratio (from 0.604 to 0.724), popping rate (from 0.815 to 0.878) and moisture grains (from 0.815 to 0.878).

Keywords: expansion ratio, moisture, popping rate, popping, sorghum.

Introduction
Sorghum (Sorghum bicolor) is the fifth in importance among the world cereals, after wheat, rice, maize and barley according to data of FAO. In Bulgaria, the areas with sorghum were over 66000 ha in 2014, according to data from the Department of Agrostatistics at the Ministry of Agriculture, Food and Forestry (MAFF, 2014). The uses of sorghum depend mainly on genetic characteristics. It can be used both for human, animal consumption as well as in industry, for uses ranging from the paper industry, adhesives, mineral processing, and even the production of sausages (Bragachini et al., 2012; Ratnavathi and Komala, 2016).

Popping sorghum developed into an industry of commercial importance. Sorghum is a cereal grain culture that is becoming more popular in the United States because it’s gluten free, nutritious and healthy snack food. The sorghum have application in ready-to-eat (RTE) foods, health-promoting products, breakfast cereals and snacks, precooked pasta, unleavened flatbreads, beers and nonalcoholic malt drinks, other onalcoholic fermented or powder-based beverages. The wholegrain sorghum flour is antioxidant-rich. These innovative applications point toward a gradual mainstreaming of sorghum and millets against the background of increasing demand for alternative grains and other modern convenience-type foods and beverages (Alavi et al., 2018). The resulting demand for pop sorghum has given the stimulus necessary to the growing of the crop in a large way. The quality of pop
sorghum depends upon its palatability or flavor and upon its popping expansion. The popping quality of varieties of sorghum has been studied by various workers (Mishra et al. 2014; Mishra et al., 2015a; Raya et al., 2015; Tymchak and Kuianov, 2018). Puffing and popping are the old, simplest, inexpensive and quick traditional methods for preparation of functional foods and ready-to-eat snack products (Jaybhaye et al., 2014; Anithasri et al., 2018). Popping is a simultaneous starch gelatinization and expansion process, during which grains are exposed to high temperatures for short time (Mishra et al., 2014). The high temperature short time (HTST) treatment exploits the thermo-physical properties of starch and prepares expanded grains or flakes. During this process the Millard reaction takes place in which the sugars present in the aleurone layer react with amino acids of the millet and gives a pleasant and highly desired aroma to the puffed product. In also reduces anti-nutrients like phytates, tannins, etc., increase bio-availability of minerals, give pleasing texture to the product, and enhances protein and carbohydrate digestibility (Nirmala et al., 2000). For this reason, there exist scientific studies that investigate the methods of preparing pops from sorghum (Gaul and Rayas, 2008; Mirza et al., 2014). Many factors influence the popping process: moisture content, chemical composition, morphological and physical characteristics of the grain, types of endosperm, as well as the method of popping (Mishra et al., 2014; Kenghe et al., 2015). Great differences exist in the “poppability” of different varieties and in various lots of the same variety (Chavan et al., 2015). Although published studies (Kayode et al., 2007; Shen et al., 2018) have indicated the use of low polyphenolic white sorghum due to its non-intrusive flavour and colour, information on the use of coloured sorghum varieties is scarce.

Aim of the present study was to analyse popping of different red and white sorghum lines (M1(6282), 1641, 1643, 1673, 1651,16113, 16121) with different moisture by moistening for 0, 60, 120 and 180 min by conventional methods of popping using a hot-air.

Materials and Methods

Seeds materials:
Seed materials of seven lines Sorghum bicolor (L) Moench (of various origins - mutant and hybrid lines) for conducting investigation on puffing is from work collection (different breeding programs in direction productivity) from Institute of Forage Crops, Pleven, Bulgaria (Table 1) harvested in 2018 year. The experiment was conducted 5 to 6 months after harvesting.

Sample preparation
Averaged samples of 500 g seeds (manually cleaned from impurities, damaged and broken grains) of each sorghum genotype (Sorghum bicolor (L) Moench) were prepared to determine some grain characteristics in eight replications (seeds diameter, mm; 1000-grain weight, g; moisture, % (AOAC, 2000) and grain pericarp coloration). For this reason, there exist scientific studies that investigate the methods of preparing pops from sorghum (Gaul and Rayas, 2008; Mirza et al., 2014). Many factors influence the popping process: moisture content, chemical composition, morphological and physical characteristics of the grain, types of endosperm, as well as the method of popping (Mishra et al., 2014; Kenghe et al., 2015). Great differences exist in the “poppability” of different varieties and in various lots of the same variety (Chavan et al., 2015). Although published studies (Kayode et al., 2007; Shen et al., 2018) have indicated the use of low polyphenolic white sorghum due to its non-intrusive flavour and colour, information on the use of coloured sorghum varieties is scarce.

Table 1. Description of the studied genotypes of sorghum (Sorghum bicolor (L) Moench)

<table>
<thead>
<tr>
<th>№</th>
<th>Genotype</th>
<th>Origine</th>
<th>Method of creates</th>
<th>Color of grain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M1(6282)</td>
<td>Mutant line</td>
<td>0,3% DES (Diethyl sulfate purum &gt; 99% C4H10O4S – Fluka)</td>
<td>deep brown</td>
</tr>
<tr>
<td>2</td>
<td>16113</td>
<td>Hybrid line</td>
<td>Hybridizations</td>
<td>deep brown</td>
</tr>
<tr>
<td>3</td>
<td>16121</td>
<td>Hybrid line</td>
<td>Hybridizations</td>
<td>red</td>
</tr>
<tr>
<td>4</td>
<td>1641</td>
<td>Hybrid line</td>
<td>Hybridizations</td>
<td>white</td>
</tr>
<tr>
<td>5</td>
<td>1643</td>
<td>Hybrid line</td>
<td>Hybridizations</td>
<td>white</td>
</tr>
<tr>
<td>6</td>
<td>1651</td>
<td>Hybrid line</td>
<td>Hybridizations</td>
<td>white</td>
</tr>
<tr>
<td>7</td>
<td>1673</td>
<td>Hybrid line</td>
<td>Hybridizations</td>
<td>white with brown spots</td>
</tr>
</tbody>
</table>
1000 grains with different moisture (by soaked to 0, 60, 120 and 180 min in distilled water) was popping by traditional methods using high temperature for a short time (HTST). The small cooking pan with a lid on top was heated by using LPG burner. The flame was adjusted so that popping would commence in about one minute, which time had previously been found to give the best results. The heating was continued until complete popping took place. All popping trials were repeated thrice. The samples were analysed for popping rate and expansion ratio.

**Analysis of popped sorghum:**

The popping percentage was calculated on the basis of number of grains popped.

\[
Popping\ rate\ (%) = \frac{\text{Number}\ of\ popped\ grains}{\text{Total}\ number\ of\ grains\ used\ in\ popping} \times 100
\]

Expansion ratio is the ratio of final diameter of pops (mm) to that of diameter of grains (mm).

\[
\text{Expansion ratio} = \frac{\text{Final}\ diameter\ of\ pops\ (mm)}{\text{Diameter}\ of\ grains\ (mm)}
\]

**Statistical analysis**

In order to determine the significant differences of the experimental data Statistica Software Package version 10 (StatSoft, Inc., 2011) was used. Fisher’s Least-Significant-Difference (LSD) test was used at the p<0.05 probability level. Relationships between some parameters and characteristics of sorghum grains were examined by Pearson correlation coefficients.

**Results and Discussion**

The data of moisture, 1000-grain weight, and diameter of grains was presented in Table 1. The 1000-grain weight varied from 28.30 to 29.80 g at red coloration genotypes and from 24.85 to 27.95 g at white coloration genotypes. Seed moisture is one of the main factors an also plays a significant role for obtaining high quality popped grain with better popping characteristics. It is known that sorghum seed moisture is in the range of 9-12% and particle size of 0.60-1.40 mm (Mishra et al., 2015b; Chávez et al., 2017). Effect of grain moisture content on popping quality of sorghum was studied at different red and white sorghum. Sorghum can be tempered to optimum moisture content and coated with different ingredients as pretreatments in order to increase the number of popped kernels and improve their popping quality (Mishra et al., 2015b; Gely and Pagano 2017; Anithasri et al., 2018).

Diameter of genotype with red pericarp is larger (from 0.73 to 1.04 mm) than genotypes with white pericarp (from 0.65 to 0.83 mm). There were differences in the grain moisture within the individual genotypes, which ranged from 8.53 to 9.75% at red coloration genotypes and from 8.27 to 8.52 g at white coloration genotypes. The moisture was highest after 180 minutes soaking of seeds at all genotypes. Genotype differences in water absorption capacity were observed. The least water absorption after 180 min is at line 1643 (1.70%) and most strongly at line 16121 (7.05%).

As a whole grain, this cereal has the highest level of antioxidants and phenolic compounds, regardless of the color of the grain (Chávez et al., 2017).

Effect of moistening of sorghum grains were analyzed on popping characteristics (popping rate and expansion ratio) using traditional process of popping and presented in Figure 1 and 2. Moisture content has been considered the most critical factor in popping, because it affects the rate and extent of pressure build up in starch granules (Maisont and Narkrusga, 2010). The observed differences within sorghum varieties can be explained by genetic differences, because the
comparisons were made under equal conditions. The mutant line M1(6282) with red coloration of pericarp had the highest popping rate (85%) and expansion ratio (3.88) at 16.07% moisture. Line 1621 also had shown higher popping rate (79%) but lower expansion ratio (2.23). Lines 1651 (white pericarp) had higher popping rate (79.5%) and height expansion ratio (3.24).

The popping quality of the millet and sorghum grains varies with variety, grain hardness, and the moisture content of the grains (Alavi et al., 2018). A number of studies have contributed toward understanding the popping process in millets and sorghum (Mishra et al., 2015a; Gely and Pagano, 2017). Kernels with medium to thick pericarp, hard endosperm, and conditioned to a typical grain moisture content of 15% - 18% are critical for obtaining maximum popping yield. Correlation coefficients was determined between quality parameters (1000-grain weight

**Figure 1.** Popping rate of different sorghum popped grains

**Figure 2.** Expansion ratio of different sorghum popped grains
and diameter of grains) and physical characters of pops (moisture level, popping rate and expansion ratio) (Tables 3). There was a high correlation between diameter of grains and parameters popping rate (from 0.815 to 0.878), expansion ratio (from 0.604 to 0.724), and moisture (from 0.815 to 0.878). The correlations of the studied parameters and 1000-seed weight are low and unproven.

Preferred grain composition varies depending on end-use but grain quality and productivity dependent of genetic constitution of the variety. The studies of genes regulating grain quality and relation between them traits will help to maintain and improve the characteristics of the varieties. Positive correlation between two desirable traits makes the job of the plant breeder easy for improving both traits simultaneously. Knowledge on heritability helps plant breeder to decide suitable method for improving the variety. (Boyles et al., 2017).

**Conclusion**

The results showed that conventional method of popping is a good main to produce pops sorghum after increasing moisture of grains. Moistening of grains from 13-16 % increased 5.3-10.2% popping rate of all sorghum genotypes. The mutant line M1(6282) with red coloration of pericarp had the highest popping rate and expansion ratio at 16% moisture level i.e. 85% and 3.88 %, respectively. This study demonstrated one of the qualities of sorghum grain and the ability to make gluten-free popcorn. The conventional method of popping is a quick method of assessing the poppability of grains of a large number of breeding materials and enriching the genetic diversity of this species.

Other moisture level should be a subject of our future studies for betterment poppability of sorghum.

**References**


