Physico-chemical, engineering and functional properties of two soybean cultivars

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ABSTRACT

Information on the physico-chemical, engineering and functional properties of soybean is pertinent to design equipment for the grading, pretreatments and processing. It will also help to decide the right end-use of the valuable crop as it has various diverse applications. This study evaluated these properties of two popular cultivars of soybean grown in Punjab, India viz. SL-744 and SL-958 and the investigations revealed that the grains of SL-958 are bolder and heavier than SL-744 with lighter color, greater hydration capacity, swelling capacity and volume making it more suitable for applications which require soaking and heat processing. SL-744 exhibits higher water absorption and oil absorption capacities as well as foaming capacity hence it can be used in baking industry where these properties are desirable for improving the texture, consistency and flavor of the prepared products.

Key words: Frictional properties, Functional properties, Geometric properties, Physico-chemical properties, Soybean

INTRODUCTION

We are celebrating the year 2016 as the ‘International year of Pulses’ the world over. Soybean (Glycine max) is often called ‘golden bean’ or ‘miracle bean’ and it is conceived as an oilseed crop. Due to its high protein content (40%), it is now being promoted to be used as a pulse as well. It belongs to family Fabaceae and is one of the most important sources of proteins and is used for both food and feed purposes. The protein content in soybean is the highest among the pulses (Verma et al., 2014) and its quality is comparable with animal protein due to the presence of all nine essential amino acids required for human health. Soybean is probably the world’s most valuable crop, used as feed by billions of livestock, as a source of dietary proteins and oil by millions of people, and in the industrial manufacture of thousands of products (Fabiyi, 2006). Now a day, soybean is gaining popularity in the food section owing to its functional properties as it is most abundant source of isoflavones (up to 3 mg/g dry weight) in the nature (Dixit et al., 2011). The health benefits associated with soybean consumption are numerous and they are supported by various clinical studies (Setchell and Lydeking-Olsen, 2003; Spence et al., 2005; Messina et al., 2006; Zhang et al., 2005). Its fortification in cereal products is being adopted to complete the amino acid balance and increase the protein quality of the product (Singh et al., 2009).

The largest soya bean producer of the world is the USA. India stands fifth in the production of soybean in the world with a production of 10.5 million tons (Anonymous, 2014) with Madhya Pradesh being the leading state followed by Maharashtra and Rajasthan. Soybean has many diverse applications as it is used for its oil, feed purposes, food uses and industrial products. The physical properties of grains are important for designing of equipment and machines required for storage, grading, sorting, dehulling, processing etc. of the grains. Soybean has different varieties varying in shape, color, size, physical properties and chemical composition and since it has varied applications, both food and industrial, so the knowledge of the physical, mechanical and functional properties of its varieties is pertinent. There has been an increase in the utilization of legumes in composite flours for various food formulations and so a knowhow of their functional properties is of significance (Singh, 2001). Since no work is done to assess these properties of these two cultivars of soybean viz. SL-744 and SL-958, hence the present work was carried out to determine the same.

MATERIALS AND METHODS

Two varieties of soybean viz. SL-958 and SL-744 were procured from the Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, India for the year 2015 (Fig. 1).

The grains were cleaned manually to remove its dirt and other foreign materials and packed in ziplock packets and stored in clean, dry place for further studies. The physicochemical and functional properties of the grains were determined on the basis of their ‘as is’ moisture content which

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Physico-chemical properties: The crude fat and protein (using factor of 6.5 X N) content of the soybean cultivars were also determined as per the standard AOAC procedures whereas the total carbohydrate content were obtained by difference. Total calories were determined by multiplying protein, carbohydrate and fat content by 4, 4 and 9/each g of nutrients respectively (Singh et al., 2013). A total number of 100 seeds of each cultivar of soybean were weighed individually and reported as average grain weight. The total numbers of seeds present in 100 g of each sample were counted to determine the hydration capacity, hydration index, swelling capacity and swelling index of the seeds by the method given by Acuna et al. (2012). Color of soybean seed was measured using a Hunter Laboratory Instrument Model CIE 1996 (Hunter Associates Laboratory, Inc., Reston, Virginia, U.S.A.) and expressed in terms of the ‘L’ (lightness (100) or darkness (0)), ‘a’ (redness (+) or greenness (–)), and ‘b’ (yellowness (+) or blueness (–)). A white calibration plate (L = 91.08, a = –1.25 and b = 1.43) was used as a standard for the measurements. ΔE, which signifies the total color difference, was calculated (Kaur et al., 2015) as:

$$\Delta E = \sqrt{[(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]/2}$$

where, ΔL = $L_{\text{sample}} - L_{\text{standard}}$, Δa = $a_{\text{sample}} - a_{\text{standard}}$, Δb = $b_{\text{sample}} - b_{\text{standard}}$

Geometric properties: To determine the shape and size of the grains i.e. length (l), width (w), and thickness (t) were measured with the help of a digital Vernier caliper (Mitutoyo, Model Absolute Digimatic, Japan) with an accuracy of 0.01mm. The length (l) was defined as the longest dimension of the grain, width (w) was the distance from the micropyre to the ridge, and thickness (t) was the measurement of the two cotyledons faces parallel to each other. Based on these readings the various calculations were done by using the following equations (Mohsenin, 1980):

Geometric Mean Diameter, $D_g = (lwt)^{1/3}$ ………… (1)

Arithmetic Mean Diameter, $D_a = (l+w+t)/3$ ………… (2)

Harmonic Mean Diameter, $D_h = n/(1/l+1/w+1/t)$ ………… (3)

The sphericity ($\phi$) of the sample was evaluated using the equation

$$\phi = \frac{D_g}{l}$$ ………… (4)

The surface area of soybean grain was found by analogy with a sphere of the same geometric mean diameter, using the following relationship (Altuntas et al., 2005):

$$S = \phi D_g^2$$ ………… (5)

Where, S is the surface area in mm$^2$.

The volume of grain (V) was calculated by the equation as described by Jain and Bal (1997):

$$V = \frac{\pi Bl^2}{6(2L-B)}$$ ………… (6)

Gravimetric properties: The Bulk density of the soybean grains was determined by filling a 1000 ml cylinder with seeds to a set height, tapping it twice and weighing the contents. True density was measured by using the toluene displacement method as it is not absorbed by the grains. The porosity of seed was calculated from the values of true density and bulk density using an established relationship given by (Mohsenin, 1980). For each cultivar, the mass of randomly selected 100 grains were weighed and results multiplied by 10 to get 1000 grain weight. The estimation of bulk density, true density and 1000 seeds mass was carried out in triplicates and average values were reported.

Frictional Properties: The angle of repose is the angle compared to the horizontal at which the material will stand
2.6 Statistical analysis: Data was analyzed using analysis of variance (Sheron et al., 1998). Means with significance were tested using least significant difference (LSD) test. Significance was accepted at pd”0.05. STATPAC (OPSTAT) was used to analyze the data.

RESULTS AND DISCUSSION

Physico-chemical properties: The results tabulated under Table 1 show the physico-chemical properties of the soybean cultivars. The SL-744 cultivar showed higher protein and carbohydrate content than its counterpart. The average grain weight of SL-958 was more than SL-744. It is less than the average weight of soybean available in colombia as assessed by Acuna et al. (2012). The 1000 grain mass of SL-958 was greater than that of SL-744 as apparent from its dimensions values which were also greater. But both these varieties are lighter than other varieties of soybean as studied by Wandkar et al. (2012); Tavakoli et al. (2009); Krishna et al. (2003); Ramteke et al. (2010). The hydration capacity and swelling capacity of SL-958 is more than SL-744 which means it is more permeable than the latter and may require shorter processing time for soaking or heat treatment. These properties are known to directly influence the characteristics of a food system as concluded by McWatters (1983). The Hunter color values L, a, b of both the cultivars do not show much variation and are at par with each other. SL-958 has lower ΔE value which signifies that it is closer to the standard.

Geometric properties: The mean value of three major dimensions viz. length, width and thickness were determined and are tabulated in Table 2. The minimum and maximum values for length, width and thickness for SL-958 were 5.46 and 7.66 mm; 4.05 and 6.20 mm and 4.05 and 5.93mm respectively, whereas the minimum and maximum values for SL-744 for length were 5.10 and 7.68 mm, for width 4.31 and 6.14mm and 3.60 and 5.53mm for thickness. The average weight of soybean available in colombia as assessed by Acuna et al. (2012); Tavakoli et al. (2009); Krishna et al. (2003); Ramteke et al. (2010). The hydration capacity and swelling capacity of SL-958 is more than SL-744 which means it is more permeable than the latter and may require shorter processing time for soaking or heat treatment. These properties are known to directly influence the characteristics of a food system as concluded by McWatters (1983). The Hunter color values L, a, b of both the cultivars do not show much variation and are at par with each other. SL-958 has lower ΔE value which signifies that it is closer to the standard.

Table 1: Physico-chemical characteristics of soybean cultivars

<table>
<thead>
<tr>
<th>Parameters</th>
<th>SL-958</th>
<th>SL-744</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Grain Weight(g)</td>
<td>0.119</td>
<td>0.097</td>
</tr>
<tr>
<td>Hydration Capacity (g/seed)</td>
<td>0.087</td>
<td>0.053</td>
</tr>
<tr>
<td>Hydration Index</td>
<td>0.73</td>
<td>0.55</td>
</tr>
<tr>
<td>Swelling Capacity (ml/seed)</td>
<td>0.17</td>
<td>0.11</td>
</tr>
<tr>
<td>Swelling Index</td>
<td>0.0012</td>
<td>0.0008</td>
</tr>
<tr>
<td>1000 seed mass (g)</td>
<td>81.36(0.83) a</td>
<td>61.08(0.91) b</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>6.54</td>
<td>8.31</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>41.7</td>
<td>42.3</td>
</tr>
<tr>
<td>Oil (%)</td>
<td>20.2</td>
<td>21.0</td>
</tr>
<tr>
<td>Carbohydrates (%)</td>
<td>31.53</td>
<td>28.51</td>
</tr>
<tr>
<td>Calories (kcal.)</td>
<td>475.14</td>
<td>471.56</td>
</tr>
<tr>
<td>l (color)</td>
<td>54.27(0.97) p</td>
<td>52.85(1.01) p</td>
</tr>
<tr>
<td>a (color)</td>
<td>6.69(0.69) p</td>
<td>8.25(0.34) p</td>
</tr>
<tr>
<td>b (color)</td>
<td>28.75(1.27) p</td>
<td>30.66(0.90) p</td>
</tr>
<tr>
<td>ΔE</td>
<td>46.55(0.65) p</td>
<td>49.07(0.51) p</td>
</tr>
</tbody>
</table>

Values in parenthesis are standard deviation; values with same superscript in a column do not differ significantly (p<0.05)
grains of SL-958 were observed to be bolder than that of SL-744 showing higher mean values for all the three principle dimensions. The varieties differed significantly in their Geometric mean diameter as well with SL-958 having a greater GMD than SL-744.

The sphericity values of both varieties were at par with each other significantly. These were also in agreement with the sphericity values of soybean at initial moisture contact as reported by Shirkole et al. (2011). The surface area and volume of both the varieties differed significantly. The minimum and maximum values for surface area of SL-958 were 72.73 to 125.30 mm\(^2\) whereas for SL-744 these were 65.98 to 120.72 mm\(^2\). Similarly for volume of the grain showed a range of 10.58 to 18.99 mm\(^3\) for SL-958 and 9.63 to 18.34 mm\(^3\) for SL-744.

Gravimetric properties: The gravimetric properties of soybean cultivars are presented in Table 3. The results revealed that the bulk density of both varieties is at par with each other while true density, porosity and 1000 grain weight varies significantly (p<0.05). Porosity and density of grains are important parameters that affect the kernel hardness, milling, drying rate and breakage susceptibility (Chang, 1988). Porosity is a property of grain that depends on its bulk and kernel densities.

Frictional Properties: Frictional properties as depicted in Table 4 are important in determining the pressure of grain and silage against bin wells and silos. The static coefficient of friction is used to determine the angle at which chutes must be positioned to achieve consistent flow of materials through the chute. Such information is useful in sizing motor requirements for grain transportation and handling (Ghasemi, 2012). The least coefficient of friction was observed on glass surface for varieties and maximum on the plywood surface.

The values were significantly different for both the cultivars for all four surfaces under study.

Functional properties: Table 5 shows the various functional properties of soybean flour. The Water Absorption Capacity (WAC) of the flours of the two cultivars was ranged between 2.44 and 2.82 ml/g. Among them, were SL-744 showed higher WAC for (2.82 ml/g) than SL-958 (2.44 ml/g) which might be due to the presence of polar amino acid residues in the proteins that have high affinity for water molecules (Yusuf et al., 2008). Similarly the high Oil Absorption Capacity (OAC) of SL-744 might be due to the presence of hydrophobic amino acids in the proteins which show greater binding towards lipids (Lawal and Adebowale, 2004). This functional property of the flour are desirable as they help in enhancing the flavor and mouth feel of food preparations and find wide application in foods such as cakes, whipped toppings, sausages etc. The WAC and OAC of both these cultivars are greater than the Nigerian variety of soybean (Akubor and Onimawo, 2003) as well as Colombian variety (Acuna et al., 2012).

Foaming Capacity (FC) of SL-744 was greater than SL-958 and there was an inverse relationship between FC and Foaming Stability (FS). The greater FC is due to the large air bubbles surrounded by thinner protein film which collapse easily and hence lower FS (Jitngramkusol et al., 2008). This property finds application in baking industry where foams provide improved texture and consistency to the product. SL-958 formed a firm gel at the concentration of 12% whereas SL-744 gave a firm gel at 14%. Legume flours contain high protein as well as starch which influence the gel capacity as both protein gelation and starch gelatinization compete for water (Kausal et al., 2012). The least gel concentration of green gram was found to be 18% (Chandra and Samsher, 2013) and 12-16% for different varieties of soybean (Acuna et al., 2012).
chickpea cultivars (Kaur and Singh, 2005). Food systems which require thickening such as sauces, custards and puddings utilize this property as the gel structure provides a matrix for retaining moisture, fat and other ingredients.

The Water Absorption Index (WAI) and Water Solubility Index (WSI) of both the cultivars do not vary significantly from each other. The WAI is an indication of the flours ability to absorb moisture to deliver an optimum consistency in food system. WSI explains the starch degradation and indicates the amount of free polysaccharide released from the granule on the addition of excess water (Osundahunsi et al., 2003). SL-958 has higher WAI of 3.86 (g/g) and can be used in products where the main concern is a high viscosity as suggested by Bryant et al. (2001).

CONCLUSION
The analysis of various physico-chemical, engineering and functional properties of the two soybean cultivars revealed that:

1. The sizing, grading or dehulling machines for both the cultivars should have different specifications as the grains of SL-958 are bolder and with more average weight than their counterpart.

2. Since the hydration capacity and swelling capacity of variety SL-958 is found to be greater than SL-744 hence it will be more suitable for processing conditions which require soaking and heat processing like the soy milk industry. Moreover its color values, (ΔE) also signifies that the product obtained will be of lighter color which is a desirable feature.

3. The flour of SL-744 has higher WAC, OAC and FC which makes it a better choice for application in baking and meat industry as a functional ingredient.

**REFERENCES**


