SCREENING POTATO CULTIVARS FOR LOW SUGAR ACCUMULATION DURING STORAGE AT VARIOUS STORAGE TEMPERATURES

Adnan Amjad¹,*, Muhammad Atif Randhawa¹, Masood Sadiq Butt¹, Muhammad Asghar², Rickey Y. Yada³ and Reena Pinhero⁴

¹National Institute Food Science and Technology, University of Agriculture, Faisalabad, Pakistan; ²Department of Biochemistry, University of Agriculture, Faisalabad, Pakistan; ³Food Science, Faculty of Land and Food System, University of British Columbia, Canada; ⁴Department of Food Science, Ontario Agricultural College, University of Guelph, Canada

*Corresponding author’s e-mail: adnanft01@gmail.com

Low sugars and light frying color are key traits to be observed during storage while assorting the potatoes for chips/fries preparation. Selecting the best cultivars reflects an important element for effective and economical processing by the industry. Six commercial potato cultivars were selected to evaluate their behavior and chipping potential regarding sugar accumulation during storage for a period of 160 days at various temperatures (3, 7 and 11 °C). All the temperatures posed significant effect on sugar contents during storage however, high sugar accumulation was noticed at 3°C for all the cultivars ranged from 29.03 to 255.38 for glucose, 26.78 to 253.11 for fructose and 55.33 to 114.45 mg100⁻¹ g fresh weight for sucrose. Storage at 11°C had least effect on sugar accumulation than 3°C and 7°C. Chips color was used as an index to evaluate the processing quality as well as sugar accumulation. At the end of storage, sugar accumulation and chips color were found in order of (low to high) Lady Rosetta < Hermes < Crozo < Asterix < Santé < Kuroda. Consequently, significant variability among the cultivars was observed whereas Lady Rosetta (golden yellow), Hermes (slightly yellow) and Crozo (yellow) were found to be the most suitable cultivars for chips/fries preparation.

Keyword: Potato cultivars, chips, storage temperature, sugars accumulation, reducing sugars, Maillard reaction, chipping quality

INTRODUCTION

Potato (Solanum tuberosum) is grown on almost 20 million hectares worldwide and the annual consumption of potato tuber by an average citizen is approximately 33 kg (FAO, 2014). In Pakistan, the estimated total annual domestic production of potatoes is 1.8 million metric ton (MT) of which 280000 MT used for seed production. Potato tuber is considered as a rich in calories food having carbohydrates comprised of 75% of total dry matter. The key nutrient in potato tubers is starch, a principal carbohydrate source in the human diet (Jansen et al., 2001; Sadiq, 2015). Potato is a balanced food containing essential vitamins and minerals with high energy and nutritional quality protein (Ek Brand-Miller and Copeland, 2012). In recent years, great attention has been found in developing the potato cultivars suitable to be processed into chips and fries with adequate frying color taken directly from low-temperature storage (Mehdi et al., 2008). To fulfil the increasing demand of potatoes by processing industry throughout the year, storage is an obligatory requirement. Choice of suitable variety, storage temperature and conditions always remained a challenge for commercial cold stores. Therefore, potato varieties with no or low reducing sugars are always required to meet the growing demands of the chip processing industry. Low temperature storage includes the benefits of delaying tuber’s dormancy, fresh weight loss and water evaporation as well as reduces the risk of fungal and bacterial diseases (Blenkingsop et al., 2002). The ability of storing potato cultivars (at low temperature) for prolong time would be helpful in alleviating the consumer and environmental concerns. It also discourages the use of anti-sprouting chemicals to prevent sprouting. The principal drawback associated with low temperature storage is the accumulation of sugars while the tubers with high concentration of sugars are usually not suitable for processing into chips. Potatoes sweet in taste are also not favored by the consumers as they turn into dark brown to black color products upon frying at higher temperature along with bitter taste and flavor (Singh et al., 2008).

Reducing sugars (glucose, fructose) of potato are of great concern in relation to processing, especially for the fried products. The chip color is mainly dependent on ‘Maillard reaction’ between free amino acids of carbohydrates and reducing sugars. In this regard, a positive correlation between the intensity of chip color to the reducing sugar has been reported (Roe et al., 1990; Marwaha, 2002). Potatoes
having sugar contents in the range of 100-150 mg100^1 g fresh weight (0.1%) usually produce chips with good frying color (Marwaha et al., 2005). There is a dire need to investigate the potato cultivars having low sugar accumulation during prolong storage. While maintaining a favorable storage temperature as well as the sprout control with minimum fresh weight loss during storage is another challenging task for growers and food technologists. The present research work was aimed to characterize the levels of sugar accumulation in commercial potato cultivars (Lady Rosetta, Santé, Hermes, Crozo, Kuroda, Asterix) after storage at different temperatures (3, 7 and 11°C) for the period of 160 days. Screening of potato cultivars based on the variations in their sugar contents during prolong storage and to investigate the chips processing potential of each cultivar was another objective of this study.

**MATERIALS AND METHODS**

**Sample procurement:** Potato cultivars *i.e.* Lady Rosetta, Santé, Hermes, Crozo, Kuroda and Asterix were collected from the field. All the samples were washed and their dust/dirt was removed. Initially, sugar analysis (in triplicate) of all the cultivars were conducted at harvest or fresh level.

**Storage at controlled conditions:** Samples were dried properly at room temperature and stored in laboratory scale controlled chambers (Memmert, ICH 110-260 Germany) at different temperatures (3, 7 and 11°C) with 85% relative humidity for 160 days. Analysis were conducted at intervals of 40, 80, 120, and 160^th^ day of storage to estimate the varietal behavior for sugar accumulation.

**Sample preparation and sugar extraction:** A 100 g peeled and chopped sample of potato tuber was obtained in triplicate individually from each cultivar, mixed and homogenized in methanol (80 mL) for 2 min in a commercial scale laboratory blender. The homogenate was treated with 5 g of activated carbon (70-200 mesh) and subjected to shaking for 20 min at room temperature on a benchtop orbital shaker (IRMICO, OS 10 Instruments, Germany). The homogenates were stored for 1.5 h at 4°C following the vacuum filtration (Rocker, 400 Gottingen Sartorius, Germany). The filtrate was then incubated at 37°C for 16 h to precipitate protein contents and again stored at 4°C until analyzed by HPLC.

**Chromatographic analysis:** Sample cleanup was consisted of passing through 0.22 μm nylon filter (Minisart, Sartorius). After filtration, the samples were sonicated for 15 minutes in ultrasonic water bath at 35°C to remove air bubbles. The estimation of reducing (fructose, glucose) and non-reducing (sucrose) sugar was carried out by HPLC (Perkin Elmer series 200) equipped with polar bonded phase NH2 column (25 cm x 4.6 mm id) and refractive index detector (RID) set at 214 nm wavelength. The mobile phase of acetonitrile:water (80:20) was used with 1.5 mL min⁻¹ flow rate and column temperature maintained at 40°C (Kyriacou et al., 2009).

**Chips preparation and sensory evaluation:** Five tubers per each cultivar were taken out, hand washed, abrasive peeled and cut longitudinally into uniform 1.5 mm thick slices by using an automatic slicer. Potato slices were rinsed at room temperature under tap water to remove the surface starch and dewatered by centrifuging (PPM No. 824, Sweden) for 3 min at 3000 rpm. The dried slices were fried for 4 min in corn oil maintained at temperature of 170°C in a deep fryer till the bubbling stopped. After frying, slices were removed and oil was drained off for 1 min, cooled and placed on plates for sensory evaluation. The chips color was scored on Hedonic scale of 1 to 9 (1 being the darkest and 9 lightest) under the fluorescent tube light (Abong et al., 2010).

**Statistical analysis:** To analyze the experimental results, Analysis of Variance (ANOVA) was performed under Completely Randomized Design (CRD) with factorial arrangements by using SAS 9.1 (Statistical Analysis Software) statistical package (SAS Institute, Cary, NC, USA).

**RESULTS**

Significant variations (p<0.05) in sugar contents among all the cultivars during storage at different temperatures *i.e.* 3, 7 and 11°C were observed as indicated in Table 1. At 3°C, the cultivar Kuroda exhibited highest sugar accumulation than all other cultivars following Asterix, Santé, Crozo, Hermes and Lady Rosetta. The data revealed that the cultivars showed maximum accumulation of sugars during storage at 3°C. Whereas at 7°C, less sugar accumulation was recorded for all cultivars as compared to 3°C. However, the lowest sugar accumulation was noticed at 11°C for all cultivars. Cultivar Lady Rosetta showed the less sugar accumulation at 11°C as compared to the other cultivars. The order of low to high sugar accumulation at 11°C was observed as follows; Lady Rosetta < Hermes < Crozo < Santé < Asterix < Kuroda. Assessment of chips color is essential quality criteria for the judgment of product development and to fulfill the consumer requirements. The required product must provide satisfaction and pleasure to consumers as it is a part of their eating behavior. Potato crop is an important vegetable in Pakistan with a potential to use by the chips processing industry (Abbas et al., 2012). Therefore, chips prepared from different potato cultivars were assessed based on the sugar concentrations developed during prolong storage as shown in Table 1 and appraised with respect to their frying color as presented in Figure 1. The fried slices were removed and excess oil drained off for 1 min, placed on plates, cooled and taken for color evaluation by following the nine-point hedonic scale (1 being the darkest and 9 lightest) as adopted by Abong et al. (2010). The samples were coded, sensory analysis for the
color was scored by a panel of ten members with different age groups (20-30 year) and familiar with fries/chips. The results related to color quality of chips are described in Fig 1. Lighter color chips were presented by the cultivars i.e. Lady Rosetta, Hermes and Crozo following Asterix, Sánté and Kuroda. Upon frying at higher temperature the cultivars Kuroda and Sánté with high reducing sugars exhibited dark brown to black color which is not acceptable by the consumers. Besides color, it also imparts bitter taste and flavor to the end product. The decrease in the browning percentage or the improvement in chips color could be attributed to low reducing sugars since reducing sugars were the major component deciding the color of fried potato products.

**Figure 1. Hedonic scale (means± standard deviation) for chips color of six potato cultivars 1: Dark. 2:**

### Table 1. Pattern of sugar accumulation before and after storage among potato cultivars at different temperatures.

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Temperature (°C)</th>
<th>Glucose</th>
<th>Reducing sugars</th>
<th>Fructose</th>
<th>Non-reducing sugar</th>
<th>Sucrose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Before storage</td>
<td>After storage</td>
<td>Before storage</td>
<td>After storage</td>
<td>Before storage</td>
</tr>
<tr>
<td>Lady Rosetta</td>
<td>7</td>
<td>29.03±1.51-m</td>
<td>176.55±2.3 d-f</td>
<td>30.37±0.8 i-m</td>
<td>101.60±10.1-k-q</td>
<td>32.37±0.8 g-l</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>40.23±1.8 g-m</td>
<td>88.42±2.7 n-u</td>
<td>38.15±1.8 j</td>
<td>86.15±2.7 n-r</td>
<td>73.83±1.75 w-a</td>
</tr>
<tr>
<td>Santé</td>
<td>3</td>
<td>41.23±3.1 d-m</td>
<td>153.91±4.8 e-h</td>
<td>30.12±0.5 h-l</td>
<td>151.63±4.2 f</td>
<td>72.87±3.7 u-a</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>39.23±3.1 f-m</td>
<td>136.91±6.3 g-j</td>
<td>38.98±3.1 i-b</td>
<td>134.64±6.3 h-i</td>
<td>74.90±2.39 v-a</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>40.23±1.8 g-m</td>
<td>88.42±2.7 n-u</td>
<td>38.15±1.8 j</td>
<td>86.15±2.7 n-r</td>
<td>73.83±1.75 w-a</td>
</tr>
<tr>
<td>Hermes</td>
<td>3</td>
<td>32.45±3.9 i-m</td>
<td>189.07±2.8 c-d</td>
<td>30.2±3.9 h-l</td>
<td>186.80±2.9 d-e</td>
<td>45.37±1.2 q-r</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>33.67±4.6 h-m</td>
<td>122.1±3.4 h-m</td>
<td>21.9±1.3 l</td>
<td>119.83±3.4 i-k</td>
<td>59.07±1.85 g-l</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>30.96±1.1 k-m</td>
<td>78.23±3.9 o-a</td>
<td>28.71±4.1 f-m</td>
<td>75.96±3.9 p-v</td>
<td>42.63±1.2 r</td>
</tr>
<tr>
<td>Crozo</td>
<td>3</td>
<td>24.71±2.9 m</td>
<td>198.22±5.2 c-d</td>
<td>22.45±2.3 k-l</td>
<td>195.17±5.2 d</td>
<td>59.43±0.6 g-l</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>22.16±1.3 m</td>
<td>135.70±8.9 g-j</td>
<td>31.18±2.6 h-m</td>
<td>133.43±2.9 g-i</td>
<td>64.3±1.9 e-i</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>23.83±1.7 l</td>
<td>58.76±3.3 t-l</td>
<td>22.58±1.7 j-l</td>
<td>56.49±3.4 w-a</td>
<td>59.33±1.7 h-m</td>
</tr>
<tr>
<td>Kuroda</td>
<td>3</td>
<td>54.66±3.2 v-m</td>
<td>255.38±2.7 a</td>
<td>52.41±3.4 x-d</td>
<td>253.11±2.7 a-b</td>
<td>77.43±2.8 r-z</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>54.53±2.4 v-m</td>
<td>185.78±6.3 d-c</td>
<td>52.28±2.1 x-c</td>
<td>113.92±5.6 l-j</td>
<td>75.13±0.93 w-a</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>54.75±2.1 v-m</td>
<td>96.03±3.7 t-r</td>
<td>52.50±1.4 x-d</td>
<td>93.76±3.7 m-o</td>
<td>74.63±1.9 v-a</td>
</tr>
<tr>
<td>Asterix</td>
<td>3</td>
<td>31.64±1.9 j-m</td>
<td>214.26±3.2 b-c</td>
<td>29.39±1.9 g-m</td>
<td>211.99±3.2 c-e</td>
<td>66.07±3.9 c-h</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>33.43±2.6 h-m</td>
<td>135.70±1.9 g-j</td>
<td>31.18±2.6 j</td>
<td>133.43±2.9 g-i</td>
<td>64.13±1.6 e-i</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>34.40±2.7 h-m</td>
<td>87.90±4.1 o-v</td>
<td>32.15±2.7 g-l</td>
<td>84.73±4.1 n-s</td>
<td>65.23±2.7 d-i</td>
</tr>
</tbody>
</table>

*Values are means±standard deviation; means sharing similar letters are statistically non-significant at p<0.05.*

**DISCUSSION**

The results of the present study for variations in sugar contents revealed that each cultivar exhibited a different potential for sugar accumulation as indicated in Table 1. It can be suggested from the given findings that sugar accumulation during storage was cultivar specific; however, storage temperature has its own role in stimulating the biochemical conversion of starch to sugar. Cold induced sweetening (CIS) in stored tubers represents degradation of starch, primarily under the influence of starch phosphorylase enzyme and ultimately reducing sugars accumulate by the action of various enzymatic reactions (Sowokinos, 1990). On the other hand, quality of the raw tubers found to be vary between and within varieties, when grown under diverse conditions.

**Dark Brown: 3; Brown, 4; Yellow-Brown: 5; Yellow: 6; Slightly Yellow: 7; Golden Yellow: 8; Very golden Yellow: 9; Extremely golden Yellow**
cultural and environmental conditions. At low temperature a number of enzymes responsible for carbohydrate splitting might get activated and contributed their role for potato sweetening. Karim et al. (2008) also proposed that activities of acid invertase, cellulose, β-galactosidase and amylase in all cultivars were found to be increased by 2-12, 1.1-3.7 and 1.9-4.5 and 1.2-4.1 folds, accordingly from harvesting or fresh level to prolong storage. CIS happens due to enlarge membrane permeability resulting in breakdown of starch. The starch is usually transformed into the glucose-1-phosphate in presence of starch synthase enzyme while this Glucose-1-Phosphate yields the UDP-glucose, it combines with fructose-6-phosphate and synthesize sucrose. Meanwhile, the invertase enzyme converts this sucrose into hexose; a respiratory substrate in glycolysis. Hence, gradual transformation of sucrose into its respective glucose and fructose occurs under the influence of storage temperatures (Kumar et al., 2004; Kaul et al., 2010). Various authors had tried to correlate the post storage accumulation of sugars to the level of sucro at harvest. No such association found with tubers stored at 5°C, whereas Sowokinos (2001) reported higher sucrose content in few potato cultivars and considered this to be associated with the accumulation of glucose and fructose during storage at an intermediate temperature. In a similar manner, Uri et al. (2014) suggested important correlation between total sugar contents measured at harvest stage and after cold storage. The color and taste of potato chips reflects as a major influential factor for consumer’s acceptability. In the current study, considerable results for chips color were obtained after warming of previously stored tubers at higher temperatures for a shorter period. Frying of potato tubers with high reducing sugars were negatively correlated with processing quality of tubers in terms of darkening/browning. The color of chips was based on sugar contents of the tubers as illustrated in Figure 1. Potatoes having high reducing sugar levels make dark fries which is not liked by the consumers. Pandey et al. (2004) had also found that the fries color is influenced by reducing sugar content and dry matter of potato. Genetic characters might be another reason for color variation among genotypes. Frying color always remained a prime measure of potato quality for processing. It has long been associated with reducing sugar content of stored tubers. Identification of compositional and metabolic factors that account for variability in chips color quality among different cultivars is an issue, addressed by various researchers. However, reducing sugars level may elucidate most of the variations in chips color development as illustrated in Figure 1. The variable that revealed the maximum significant correlation with chips color is the concentration of accumulated reducing sugars during storage (Blenkinsop et al., 2002). It may be concluded from the above discussion that, there always remains a need to investigate a suitable storage temperature to maintain a balance in sugar accumulation of the potato cultivars, ultimately lead to good frying color. The present work revealed that sugar contents were noticeably influenced (p<0.05) by the storage conditions at different temperatures (3, 7 and 11°C). Higher temperature seems to be the best in storing tubers as it developed low sugar accumulation as compare to the lower temperatures, however it is suitable only for short period of time since, as prolong storage also results in weight loss and sprouting. On the other hand, low temperature is associated with cold induced sweetening besides its benefits of controlling the fresh weight loss as well as sprouting. At the end of storage, sugar accumulation and chips color were found in the order of Lady Rosetta (golden yellow) < Hermes (slightly yellow) < Crozo (yellow) < Asterix (yellow brown) < Santé (brown) < Kuroda (dark brown). Consequently, significant (p<0.05) variability among the cultivars was recorded whereas Lady Rosetta, Hermes and Crozo were found to be the most suitable cultivars for low sugars and chips preparation.

REFERENCES


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