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

Adnan Amjad[1,*], Muhammad Atif Randhawa[1], Masood Sadiq Butt[1], Muhammad Asghar[2], Rickey Y. Yada[3] and Reena Pinhero[4]

[1]National Institute Food Science and Technology, University of Agriculture, Faisalabad, Pakistan; [2]Department of Biochemistry, University of Agriculture, Faisalabad, Pakistan; [3]Food Science, Faculty of Land and Food System, University of British Columbia, Canada; [4]Department 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 fries/chips 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 use 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; Sadia, 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 (Blenkinsop *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 160th 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 NH_2 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, Santé and Kuroda. Upon frying at higher temperature the cultivars Kuroda and Santé 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.

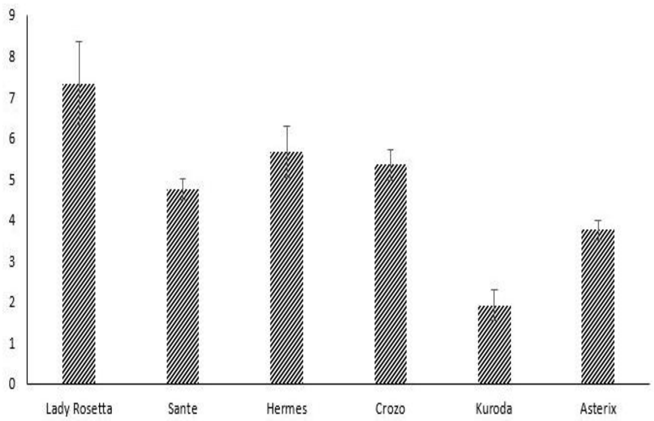

Figure 1. Hedonic scale (means± standard deviation) for chips color of six potato cultivars 1: Dark. 2: Dark Brown, 3: Brown, 4: Yellow-Brown. 5: Yellow. 6: Slightly Yellow. 7: Golden Yellow. 8: Very golden Yellow. 9: Extremely golden Yellow

The data indicated that low temperature stimulates the activity of enzymes related to the degradation of the starch to sugars, however it is also a time dependent mechanism. Brown *et al.* (1990) had determined the high accumulated sugar levels in different 22 potato clones after low temperature (4°C) storage than at higher temperature (10°C). Edwards *et al.* (2002) examined the sugar contents in yellow fleshed tubers stored at 3.3°C, 8.3°C and 10°C. Lower concentrations of reducing sugars (glucose, fructose) and non-reducing (sucrose) were investigated in tubers stored at 10°C as compared to those stored at 3.3 and 8.3°C.

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

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

Cultivars	Temperature (°C)	Reducing sugars				Non-reducing sugar	
		Glucose		Fructose		Sucrose	
		Before storage	After storage	Before storage	After storage	Before storage	After storage
Lady Rosetta	3	29.03±1.5l-m	176.55±2.3 d-f	26.78±1.3i-l	174.28±2.4e	55.33±2.6l-o	92.33±2.6f-j
	7	32.37±0.8 i-m	101.60±10.1k-q	32.37±0.8g-l	103.70±7.1lm	52.37±0.8k-m	101.60±4.7cd
	11	30.42±2.8k-m	64.67±2.7r-j	28.17±2.7f-m	62.40±2.6u-z	53.40±2.8mn	66.40±2.6b-g
Santé	3	41.23±3.1d-m	153.91±4.8e-h	30.12±0.5h-l	151.63±4.2f	72.87±3.7u-a	78.87±2.75q-x
	7	39.23±3.1f-m	136.91±6.3g-j	38.98±3.1b-i	134.64±6.3h-i	74.90±2.39v-a	98.90±2.39c-f
	11	40.23±1.8g-m	88.42±2.7n-u	38.15±1.8c-j	86.15±2.7n-r	73.83±1.75w-a	86.83±1.7j-p
Hermes	3	32.45±3.9i-m	189.07±2.8c-d	30.2±3.9h-l	186.80±2.9de	45.37±1.2q-r	82.37±1.72m-u
	7	33.67±4.6h-m	122.1±3.4h-m	21.91±1.3l	119.83±3.4i-k	59.07±1.85g-l	84.08±1.3k-s
	11	30.96±1.1k-m	78.23±3.9o-a	28.71±4.1f-m	75.96±3.9p-v	42.63±1.2r	55.63±1.2k-o
Crozo	3	24.71±2.9mn	198.22±5.2cd	22.45±2.3k-l	195.17±5.2d	59.43±0.6g-l	96.45±0.6d-g
	7	22.16±1.3m	135.70±8.9g-j	31.18±2.6h-m	133.43±2.9g-i	64.3±1.9e-i	89.33±1.9h-m
	11	23.83±1.7l	58.76±3.3t-l	22.58±1.7j-l	56.49±3.4w-a	59.33±1.7h-m	72.31±1.7x-c
Kuroda	3	54.66±3.2v-m	255.38±2.7a	52.41±3.4x-d	253.11±2.7ab	77.43±2.8r-z	114.45±1.8cd
	7	54.53±2.4v-m	185.78±6.3de	52.28±2.1x-c	113.92±5.6j-l	75.13±0.93w-a	102.16±0.9ef
	11	54.75±1.2v-m	96.03±3.7l-r	52.50±1.4x-d	93.76±3.7m-o	74.63±1.9v-a	90.61±1.7g-k
Asterix	3	31.64±1.9j-m	214.26±3.2bc	29.39±1.9g-m	211.99±3.2c	66.07±3.9c-h	103.08±1.4de
	7	33.43±2.6h-m	135.70±1.9g-j	31.18±2.6ij	133.43±2.9g-i	64.13±1.6e-i	89.33±2.7g-m
	11	34.40±2.7h-m	87.90±4.1o-v	32.15±2.7g-l	84.73±4.1n-s	65.23±2.7di	78.21±2.6q-y

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

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 sucrose 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

Abbas, G., I.A. Hafiz, N.A. Abbasi and A. Hussain. 2012. Determination of processing and nutritional quality attributes of potato genotypes in Pakistan. Pak. J. Bot. 44:201-208.

Abong, G.O., W.O. Michael, K.I. Jasper and N.K. Jackson. 2010. Evaluation of selected Kenyan potato cultivars for processing into potato crisps. Agri. Biol. J. North Amer. 5:886-893.

Blenkinsop, R.W., L.J. Copp, R.Y. Yada and A.G. Marangoni. 2002. Changes in compositional parameters of tubers of potato (*Solanum tuberosum*) during low-temperature storage and their relationship to chip processing quality. J. Agri. Food Chem. 50:4545-4553.

Brown, J., G.R. Mackay, H. Bain, D.W. Griffiths and M.J. Allison. 1990. The processing potential of tubers of cultivated potato *Solanum tuberosum* L. after storage at low temperature sugars concentration. Potato Res. 33:219-227.

Edwards, C.G., J.W. Engler, C.R. Brown, J.C. Peterson and E.J. Sorensen. 2002. Changes in colour and sugar content of yellow-fleshed potatoes stored at three different temperatures. Am. J. Potato Res. 79:49-53.

Ek Brand-Miller, J. and L. Copeland. 2012. Glycemic effect of potatoes. Food Chem. 133:1230-1240.

FAOSTAT. 2013. Food and Agriculture Organizations of the United Nations, The Statistics Division. Availabale online with updates at http://faostat.fao.org

Jansen, G., W. Flamme, K. Schüler and M. Vandrey. 2001. Tuber and starch quality of wild and cultivated potato species and cultivars. Potato Res. 44:137-146.

Karim, M.R., M.M.H. Khan, M.S. Uddin, N.K. Sana, F. Nikkon and M.H. Rahman. 2008. Studies on the sugar accumulation and carbohydrate splitting enzyme levels in post harvested and cold stored potatoes. J. Bio-Sci. 16:95-99.

Kaul, A.D., K. Pradeep, H. Vandana and S. Anil. 2010. Biochemical behavior of different cultivars of potato tuber at different storage conditions. National Conference on Computational Instrumentation Chandigarh 19-20 March, India.

Kumar, D., B.P. Singh and K. Praveen. 2004. An overview of the factors affecting sugar content of potatoes. Ann. appl. Biol. 145:247-256.

Kyriacou, M.C., S.S. Anastasios, I.M. Ioannides and D. Gerasopoulos. 2009. The chip-processing potential of four potatoes (*Solanum tuberosum* L.) cultivars in response to long-term cold storage and reconditioning. J. Sci. Food. Agri. 89:758-764.

Marwaha, R.S. 2002. Chipping quality of potato cultivars during short term storage at warm temperatures. J. Food Sci. Technol. 39:489-95.

Marwaha, R.S., S.K. Pandey, S.V. Singh and S.M.P. Khurana. 2005. Processing and nutritional qualities of Indian and exotic potato cultivars as influenced by harvest date, tuber curing, pre-storage holding period, storage and reconditioning under short days. Adv. Hort. Sci. 19:130-140.

Mehdi, M., T. Saleem, H.K. Rai, M.S. Mir and G. Rai. 2008. Effect of nitrogen and FYM interaction on yield and yield traits of potato genotypes under Ladakh condition. Potato J. 35:126-129.

Pandey, S.K., S.V. Singh, P. Kumar, D. Kumar and P. Manivel. 2004. Sustaining potato chipping industry from Western and Central Uttar Pardesh: adoption of suitable varieties. Pot. J. 31:119-127.

Sadia, B. 2015. Improved isolation and culture of protoplasts from *S. chacoense* and potato: morphological and cytological evaluation of protoplast-derived regenerants of potato cv. desiree. Pak. J. Agri. Sci. 52:51-61.

Singh, B., R. Ezekiel, D. Kumar and S. Kumar. 2008. Reducing sugars content and chipping quality of tubers of potato cultivars after storage and reconditioning. Potato J. 35:23-30.

Sowokinos, J.R. 1990. Stress induced alteration in carbohydrate metabolism. In: M.E. Vayda and W. D. Park (eds.), The Molecular and Cellular Biology of the Potato, pp.137-158. Wallingford, UK: CAB International.

Sowokinos, J.R. 2001. Biochemical and molecular control of cold-induced sweetening in potatoes. Am. J. Potato Res. 78:221-236.

Uri, C., Z. Juhasz, Z. Polgar and Z. Banfalvi. 2014. A GC–MS-based metabolomics study on the tubers of commercial potato cultivars upon storage. Food Chem. 159:287–292.