Indian J. Plant Physiol., Vol. 10, No. 3, (N.S.) pp. 287-291 (July-Sept., 2005)

SHORT COMMUNICATION

EFFECT OF CROP MATURITY AND ON-FARM STORAGE ON SUGAR CONTENT AND CHIP COLOUR OF POTATO *(SOLANUM TUBEROSUM* L.*)* TUBERS

VIJAY PAUL[1]*, DINESH KUMAR[1] AND R. EZEKIEL[2]

[1]Central Potato Research Institute Campus, Modipuram-250 110, [2]Central Potato Research Institute, Shimla-171 001

Received on 25 March, 2004, Revised on 16 Sept., 2005

Dry matter content and sugar levels were determined in the tubers of three potato (*Solanum tuberosum* L.) cultivars at four harvest dates, i.e. 60, 75, 90 and 105 days after planting and also before and after the on-farm storage. The reducing sugar content was found to be unacceptable for chip colour in tubers of Kufri Bahar at all harvest dates. It was high in Kufri Jyoti but within the acceptable limits for Kufri Chandramukhi at full maturity. At the time of on-farm storage, reducing sugar level and chip colour score in tubers of Kufri Jyoti were 2.2 mg g^{-1} fw and 4.9 respectively. These values for reducing sugars level and chip colour score decreased to 1.32 mg g^{-1} fw and 2.6 in heap, 1.16 mg g^{-1} fw and 1.7 in katcha pit and 1.37 mg g^{-1} fw and 3.3 in pucca pit respectively after 90 days of storage. Thus indicating the benefit of on-farm storage, especially the katcha pit method, for improving the processing quality of potato tubers.

***Key words*: Chip colour, dry matter, on-farm storage, *Solanum tuberosum*, sugar content, tuber maturity**

Potato (*Solanum tuberosum* L.) production in the country is increasing steadily resulting in increased processing of potatoes in the organized as well as unorganized sectors. For processing, raw potatoes should have the required processing quality and the two important processing quality parameters are the dry matter content and reducing sugar level (Ezekiel *et al.* 1999). Besides cultivar and environmental factors, crop maturity is also known to affect the dry matter and sugar content of potatoes (Burton 1989). Changes in several biochemical parameters at different stages of crop growth have been determined (Marwaha 1998, Dinesh Kumar *et al*. 2003). Potatoes stored under non-refrigerated conditions are reported to be suitable for processing (Uppal and Ezekiel 2002, Paul *et al*. 2002). But no attempt has been made to link the potato chip quality to sugar content at crop maturity and before and after on-farm storage. The aim of this study was to determine the dry matter and sugar contents at different stages of crop maturity and before and after on-farm storage (in heap and pits) and to relate them to chip colour.

Three potato cultivars viz. Kufri Chandramukhi (short duration), Kufri Jyoti (medium duration) and Kufri Bahar (medium duration) were planted on 26-10-2000 at the Central Potato Research Institute Campus, Modipuram, U.P. Seed tubers weighing 50-100 g were planted at a spacing of 60x20 cm. The design followed was RBD with three replications. Fertilizer was applied at the recommended dose of 150 kg N, 80 kg P_2O_5 and 100 kg K_2O per hectare. Half the nitrogen was applied at planting and the remaining half at earthing up stage. Other cultural practices recommended for the region were followed. At 60, 75, 90 and 105 days after planting (DAP), dehaulming was done and the tubers were harvested after 10 days to allow sufficient curing for proper skin set. At each harvest; dry matter, reducing sugars, total sugars, sucrose and chip colour were determined. Dry matter was determined by oven drying 50 g of tuber pieces from the representative tubers at 80 ºC until constant weight was obtained. Reducing sugars were estimated by the arsenomolybdate method (Nelson 1944) and total sugars by the anthrone method

* Corresponding author's present address: Division of Plant Physiology, IARI, New Delhi-110 012

(Yemm and Willis 1954). Sucrose content was calculated from values of reducing sugars and total sugars. Chip colour was scored on a scale of 1-10 of increasing dark colour with 1 denoting the lightest colour and 10 denoting the darkest. The data were analyzed following the statistical procedure as described by Gomez and Gomez (1984) and the means were then separated by using Duncan's Multiple Range Test.

Out of these three cultivars, Kufri Jyoti is moderately resistant to late as well as early blight (Gaur *et al.* 1999), widely grown and commonly used for processing into chips by the potato processing industry in India. Therefore, Kufri Jyoti was chosen over the Kufri Chandramukhi for further storage study, although, the later showed superior chipping quality. Fully matured tubers of Kufri Jyoti, dehaulmed after 105 DAP and harvested at 115 days after allowing 10 days for skin set, were stored in a shed for 10 days to facilitate further curing and wound healing. They were then stored under three traditional methods of potato storage, viz. heap, katcha pit and pucca pit. Heaps and pits were made in the shade of trees. For heap storage, one tonne of potatoes were heaped and the heap was covered with a mat (chatai) followed by 25 cm thick layer of rice straw. For pit storage, a layer of sand (about 15 cm thick) was spread at the bottom of the pit and two tonnes of potatoes were stored, the potatoes being covered by a chatai followed by 25 cm thick layer of rice straw. There were two types of pits. The katcha pit was a simple circular pit dug under the shade of trees. The pucca pit was different from the katcha pit in that, it was lined with a brick wall. Both the pits measured 3 feet in diameter and 5 feet in depth. Under the heap, katcha pit and pucca pit the dry matter content, reducing sugars, sucrose, total sugars content and chip colour of the tuber were determined as described above at 60 and 90 days after storage (DAS).

Data presented in Table 1 showed that dry matter content generally increased with increase in crop maturity, though, there was only a small difference between 75 and 90 days. Amongst cultivars, Kufri Chandramukhi showed higher dry matter content. The reducing sugar content decreased significantly with crop maturity and was least at full maturity at 105 DAP. Kufri Chandramukhi had lower and Kufri Bahar had higher reducing sugar content. The sucrose content also decreased with crop maturity but the differences between 75 and 90, and 90 and 105 days were non-significant. Kufri Chandramukhi had lower sucrose content as compared to the other two cultivars. Total sugar content followed a trend similar to that of reducing sugar and sucrose content. Although there was no significant difference in the chip colour with DAP, but the data indicated gradual improvement.

Higher dry matter content is desirable in processing potatoes since higher dry matter content results in higher chip yield, lesser time for frying and lesser oil absorption during frying. Therefore, if the potatoes are to be used for processing, it is required to harvest the tubers after full maturity. Immature tubers have lower dry matter content and it increases with crop maturity (Pavlista and Ojala 1997, Dinesh Kumar *et al*. 2003). The reducing sugars content in processing potatoes is important because it reacts with free amino acids in the Maillard reaction leading to the development of brown colour in potato chips during frying. Reducing sugar content up to 1 mg and 1.60 mg g^{-1} tuber fw gives highly acceptable chip colour (Ezekiel *et al*. 2003). According to Pavlista and Ojala (1997) reducing sugar content of 1mg g^{-1} tuber fw is taken as optimum for processing into chips. The reducing sugar content was, therefore, unacceptable for chip colour in tubers of Kufri Bahar at all harvest dates. It was high in Kufri Jyoti but within the acceptable limits for Kufri Chandramukhi at full maturity. Higher reducing sugar content in Kufri Bahar makes it unsuitable for processing. Even in Kufri Jyoti, which is suitable for processing, the reducing sugar content was higher even at full maturity, probably due to more sensitive nature of this variety towards the lower temperatures during crop growth (Ezekiel *et al*. 1999). Kufri Chandramukhi showed acceptable reducing sugar level at 105 days and near acceptable level at 90 days of harvest. Only in Kufri Chandramukhi, the chip colour was just acceptable at full maturity. Kufri Chandramukhi being a short duration cultivar matures early and is also known to be suitable for processing (Ezekiel *et al.* 1999). The sucrose level at harvest is influenced by crop maturity (Es Van and Hartmans 1987, Burton 1989). When the sucrose level in tubers is lowest, the tubers are considered chemically

Table 1. Effect of tuber maturity on processing quality of three potato cultivars.

Cultivar (C)	Days after planting (DAP)				
	60	**75**	**90**	**105**	**Mean (C)**
			Dry matter (%)		
Kufri Chandramukhi	16.1	17.6	17.3	20.4	17.8[a]
Kufri Jyoti	14.9	15.6	17.1	18.6	16.6[b]
Kufri Bahar	15.9	16.5	15.9	19.6	17.0[b]
Mean (DAP)	15.6[c]	16.6[bc]	16.8[b]	19.5[a]	
LSD (P=0.05)			C= 0.78; DAP= 1.08; CxDAP= N.S.		
			Chip colour (scale 1-10)		
Kufri Chandramukhi	5.7	5.0	6.0	4.7	5.3
Kufri Jyoti	6.7	5.7	4.3	5.0	5.4
Kufri Bahar	6.3	6.0	6.7	5.3	6.1
Mean (DAP)	6.2	5.6	5.7	5.0	
LSD (P=0.05)			C= N.S.; DAP= N.S.; CxDAP= N.S.		
			Reducing sugars (mg g^{-1} fw)		
Kufri Chandramukhi	1.56	1.33	1.16	1.02	1.27[b]
Kufri Jyoti	2.09	1.81	1.69	1.45	1.76[a]
Kufri Bahar	2.31	2.16	1.70	1.55	1.93[a]
Mean (DAP)	1.99[a]	1.77[b]	1.52[c]	1.34[d]	
LSD (P=0.05)			C=0.23; DAP=0.16; CxDAP= N.S.		
			Sucrose (mg g^{-1} fw)		
Kufri Chandramukhi	2.51	2.02	1.66	1.58	1.94[b]
Kufri Jyoti	3.32	3.27	2.51	2.45	2.89[a]
Kufri Bahar	3.82	2.35	2.74	2.52	2.86[a]
Mean (DAP)	3.21[a]	2.54[b]	2.30[bc]	2.18[c]	
LSD (P=0.05)			C= 0.40; DAP= 0.26; CxDAP= NS		
			Total Sugars (mg g^{-1} fw)		
Kufri Chandramukhi	4.07	3.35	2.82	2.60	3.21[b]
Kufri Jyoti	5.41	5.08	4.20	3.90	4.65[a]
Kufri Bahar	6.13	4.51	4.44	4.07	4.79[a]
Mean (DAP)	5.20[a]	4.31[b]	3.82[bc]	3.53[c]	
LSD (P=0.05)			C= 0.98; DAP= 0.69; CxDAP= N.S.		

mature (Pavlista and Ojala 1997). Sucrose level is high in immature tubers as the arrival of sucrose from the leaves is high in actively growing tubers. It reaches its minimum level when the tuber matures.

The improvement in dry matter content during storage in heap, katcha pit and pucca pit (Table 2) could be due to moisture loss during storage (Verma *et al.* 1974) The reducing sugar content decreased during

storage. The decrease in heap, katcha pit and pucca pit was 35, 44 and 34 % at 60 DAS and 40, 47 and 37 % at 90 DAS respectively. The decrease in reducing sugar content was accompanied by an increase in sucrose content. The increase in sucrose content in heap, katcha pit and pucca pit was 60, 72 and 80 % at 60 DAS and 103, 94 and 98 % at 90 DAS, respectively. Total sugar content showed little change at 60 DAS but increased at 90 DAS. Statistically, values for total sugars were non-significant. The chip colour improved greatly after storage from just acceptable to highly acceptable colour (Table 2).

Reducing sugar content decreased considerably and the chip colour improved greatly at 60 and 90 DAS and this could be attributed to higher storage temperatures in heap and pits. During the storage period, the temperature ranged from 19.3 to 29.4 ºC in heap, 19.3 to 28.4 ºC in katcha pit and 19.3 to 29.4 ºC in pucca pit. The higher temperatures prevailing in heap and pits during storage prevent accumulation of reducing sugars and result in lower level of reducing sugars and highly acceptable chip colour (Ezekiel *et al*. 2002). Reducing sugar content is positively correlated with chip colour score, i.e. lower the reducing sugar content, lighter the chip colour score (Ezekiel *et al*. 2003). Uppal and Ezekiel (2002) also observed decrease in reducing sugar content and improvement in chip colour after storage under non-refrigerated conditions. The improvement in chip colour could be attributed to decrease in reducing sugar content, as reducing sugars are the major component deciding the colour of fried potato products (Roe *et al.* 1990). Low activities of invertase or synthesis of invertase inhibitor have also been shown to be responsible for reduction in reducing sugars at higher temperature of storage (Pressey and Shaw 1966) besides the loss of sugars due to respiration as well as synthesis of sucrose. Although the sucrose level at harvest was 2.45 mg g^{-1} fw in Kufri Jyoti (Table 1), it decreased during curing and wound healing before storage, and was 1.35 mg g^{-1} fw at the time of storage. Sowokinos and Preston (1988) reported that if the sucrose level is low before storage, the accumulation of reducing sugars would also be less during storage. However, sucrose content increased during storage. Sucrose accumulation in tubers stored at high temperature has been reported earlier (Verma *et al*. 1974, Uppal 1999). Although, this has not affected the chip colour as the sucrose does not participate in Maillard reaction, which causes browning in potato chips.

It may be concluded that out of three cultivars tested for crop maturity with respect to their processing quality, Kufri Chandramukhi when harvested at 105 DAP produces chips of acceptable colour due to the low level of reducing sugars. Kufri Jyoti on the other hand, produced the acceptable chip colour at 90 and 105 DAH but reducing sugars remained higher. During on-farm storage (up to 60 and 90 days) the reducing sugars in the potato tubers of Kufri Jyoti decreased further resulting in highly acceptable chip colour in this popular cultivar of potato in India.

Table 2. Chiping quality for the tubers of Kufri Jyoti (having crop maturity of 105 days) during storage under heap (H), katch pit (KP) and pucca pit (PP) methods of on-farm storage.

Storage method	Days after storage (DAS)							
	0	60			90			LSD
	-	H	KP	PP	H	KP	PP	(P=0.05)
Dry matter (%)	17.7^{c}	18.4^{bc}	18.7^{bc}	19.1^{ab}	19.9^{a}	18.2^{bc}	19.4^{a}	1.15
Chip colour (scale 1-10)	4.9^{a}	4.4^{ab}	1.1^{d}	1.6^{d}	2.6^{cd}	1.7^{d}	3.3^{bc}	1.50
Reducing sugars (mg g^{-1} fw)	2.20^{a}	1.43^{b}	1.22^{cd}	1.44^{b}	1.32^{bcd}	1.16^{d}	1.37^{bc}	0.20
Sucrose (mg g^{-1} fw)	1.35^{e}	2.16^{d}	2.33^{cd}	2.44^{bcd}	2.75^{a}	2.64^{abc}	2.67^{ab}	0.29
Total Sugars (mg g^{-1} fw)	3.55	3.59	3.55	3.88	4.07	3.78	4.04	N.S.

ACKNOWLEDGEMENTS

The authors thank Director, CPRI, Shimla and Joint Director, CPRIC, Modipuram for providing the required facilities.

REFERENCES

Burton, W.G. (1989). The Potato (2nd Edn.). Longman, Singapore.

Dinseh Kumar, Singh, S.V. and Pandey, S.K. (2003). Chemical maturity of potato processing cultivars grown in western Uttar Pradesh. *J. Indian Potato Assoc.* **30**: 225-232.

Es van A. and Hartmans, K.J. (1987). Starch and sugars during tuberization, storage and sprouting. In: A. Rastovski and A.van Es. (eds.), Storage of Potatoes, pp. 79-113. Pudoc, Wageningen.

Ezekiel, R., Dahiya, P.S. and Sekhawat, G.S. (2002). Traditional methods of potato storage in the Malwa region of Madhya Pradesh. Tech. Bull. No. 57, pp. 38. Central Potato Research Institute, Shimla.

Ezekiel, R., Singh Brajesh and Dinesh Kumar (2003). A reference chart for potato chip colour for use in India. *J. Indian Potato Assoc.* **30**: 259-265.

Ezekiel, R., Verma, S.C., Sukumaran, N.P. and Shekhawat, G.S. (1999). A Guide to Potato Processors in India. Tech. Bull. No. 48. pp. 39. Central Potato Research Institute, Shimla, India.

Gaur, P.C., Naik, P.S., Kaushik, S.K. and Chakrabarti, S. K. (1999) Indian Potato Varieties. Technical Bull. No. 51, pp. 15. Central Potato Research Institute, Shimla, India.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research (2nd Edn.). International Rice Research Institute, Manila. John Willey and Sons, New York.

Marwaha, R.S. (1998). Factors determining processing quality and optimum processing maturity of potato cultivars grown under short days. *J. Indian Potato Assoc.* **25**: 95-102.

Nelson, N. (1944). A photometric adaptation of the Somogyi method for the determination of glucose. *J. Bio. Chem.* **153**: 375-380.

Paul, V., Ezekiel, R. and Shekhawat, G.S. (2002). Traditional methods of potato storage in changing scenario. *Indian Farming*. **52**: 11-14.

Pavlista, A.P. and Ojala, J.C. (1997). Potatoes: Chips and french fry processing. In: O. Smith (ed.), Processing Vegetables-Science and Technology, pp. 287-284. Technomoc Publishing Co. Lancaster.

Pressey, R. and Shaw, R. (1966). Effect of temperature on invertase: invertase inhibitor and sugar in potato tubers. *Plant Physiol.* **41**: 1657-1661.

Roe, M.A., Faulks, R.M. and Belstein, J.L. (1990). Role of reducing sugars and amino acids in fry colour of chips from potatoes under different nitrogen regions. *J. Sci. Food Agric*. **52**: 207-214.

Sowokinos, J.R. and Preston, D.A. (1988). Maintenance of potato processing quality by chemical maturity monitoring (CMM). Station Bull. 586, University of Minnesota, St. Paul.

Uppal, D.S. (1999). Effect of storage environments on chip colour and sugar levels in tubers of potato cultivars. *J. Food Sci. Tech.* **36**: 545-547.

Uppal, D.S. and Ezekiel, R. (2002). Effect of traditional storage methods on sugar concentrations and chip quality of potatoes. In: S. M. Paul Khurana *et al.* (eds.), Potato, Global Research and Development, Vol. II, pp. 1091-1095. Indian Potato Association, Shimla, India.

Verma, S.C., Sharma, T. R. and Verma, S.M. (1974). Sucrose accumulation during high temperature storage of potato tubers. *Potato Res.* **17**: 224-226.

Yemm, E.W. and Wills, A.J. (1954). The estimation of carbohydrates in plant extracts by anthrone. *Biochem. J.* **57**: 508-514.