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EFFECT OF CIPC TREATMENT ON KEEPING AND PROCESSING ATTRIBUTES DURING SHORT TERM STORAGE

ASHIV MEHTA[1], BRAJESH SINGH[2] AND R. EZEKIEL[2]

[1]Central Potato Research Station, Post Bag No. 1, Model Town P.O., Jalandhar 144 003, Punjab.
[2]Central Potato Research Institute, Shimla 171 001, Himachal Pradesh

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SUMMARY

Indigenous non-refrigerated storage methods are used in India for short-term storage of potatoes (*Solanum tuberosum* L.) to avoid distress sale. Use of isopropyl N-(3-chlorophenyl) carbamate (CIPC) was evaluated in potato heaps on nine potato cultivars. Single spray application of a commercial formulation of CIPC 50% a.i. (Oorja, UPL, Mumbai) @ 20 mg a.i. kg^{-1} tubers significantly reduced sprouting (by 95.6%), sprouting index (by 80.2%), sprout weight (by 98.8%) and total losses in potatoes (by 29.8%) up to 90 days of storage. Stored potatoes fetched market rates comparable to cold stored potatoes which were 54.3% higher than the rates at harvest. Contents of reducing sugars in treated potatoes decreased and chip colour improved after storage. Cultivars, Kufri Chipsona-1, Kufri Jyoti, Kufri Lauvkar, Kufri Surya and Kufri Chandramukhi were suitable for table and processing purposes whereas Kufri Pushkar, Kufri Bahar, Kufri Pukhraj and Kufri Badshah were found suitable only for table purpose. Stored potatoes were safe for human consumption as the CIPC residue levels in peels (0.81-3.85 mg kg^{-1} fresh tuber weight) were far below the permissible limit.

***Key words*: CIPC, heap, potato, processing quality, sprout inhibition, storage losses**

INTRODUCTION

In the major potato (*Solanum tuberosum* L.) growing areas of India, the crop is harvested at the beginning of the summer in February-March. Seasonal production patterns, limited alternative market outlets (e.g., processing) and inadequate cold storage capacity often result in market gluts and heavy price reduction during the main harvesting months. Prices start increasing from April-May and are almost double in July-August (Pandey *et al.* 2007). Farmers use indigenous storage practices like heaps, pits and trenches to hold some of their produce for short terms to get higher prices, but the tubers must be desprouted before marketing (Dahiya *et al.* 1997).

Storage of potatoes in heaps is commonly practiced in many states of India to avoid distress sale at harvest. Sprouting of potatoes is the main problem under heap storage and losses due to shrinkage, sprouting and attack by microorganisms are generally enormous (15-25%) (Mehta *et al*. 2001). Extensive studies have been conducted to improve the storage efficiency of heaps (Mehta 2005, Mehta *et al.* 2007). An improved heap storage technology involving essential pre and postharvest measures *viz*. potato tuber maturity, sufficient interval from haulm cutting to harvest, curing and selection of healthy potatoes prior to storage, providing proper ventilation during storage and sprout inhibition with the use of CIPC (isopropyl N-(3-chlorophenyl) carbamate) has been developed for short-term storage of table and

*Corresponding author, E-mail: ashiv_mehta@yahoo.com

processing potatoes (Mehta *et al.* 2007). For successful adoption of a technology, its suitability over a wide range of varieties is essential. This investigation was therefore, designed to evaluate nine commercial potato varieties varying widely in storability and processing quality for their suitability after storage for processing into chips. The CIPC residues during storage were also analyzed in different potato parts as a matter of health concern.

MATERIALS AND METHODS

The experiments were conducted at Central Potato Research Station, Jalandhar during March to June, 2007 and 2008. Nine varieties varying widely in dormancy period and processing quality, were selected for this study (Table 1). Kufri Lauvkar has the shortest dormancy period of five weeks after harvest followed by Kufri Bahar, Kufri Pukhraj and Kufri Badshah (6-7 weeks), Kufri Chandramukhi, Kufri Chipsona-1 and Kufri Jyoti (8 weeks) and Kufri Pushkar and Kufri Surya (9-10 weeks) (Mehta and Kaul 1997, Mehta *et al.* 2006). Kufri Chipsona-1 with low tuber reducing sugar content was developed exclusively for processing whereas, the varieties *viz.* Kufri Jyoti, Kufri Lauvkar and Kufri Surya are still being extensively used in the organized and unorganized sector of potato processing industry in India. The other five varieties are popular table varieties grown in different agro-climatic regions of India. Among the varieties, first six (Table 1) are good keepers while last three are average keepers.

Seed tubers weighing 45-60 g were planted in the field on 8 and 9 October, 2006 and 2007, respectively. Fertilizers were applied at the recommended dose of 150 kg N, 80 kg P_2O_5 and 100 kg K_2O/ha. Half the nitrogen was applied at planting and the remaining half at earthing up stage. All the other recommended cultural practices were followed for raising the crop. Crop was dehaulmed at maturity and harvested after 25-30 days of skin curing. The harvested tubers were kept in covered heaps for 15-20 days for wound healing and curing. Undamaged and apparently healthy large sized potatoes (>70 g) were selected.

For treatment, potatoes (8 quintals of each variety) were spread in thin layers on the ground under a thatched roof made of straw (S*arkanda*) and bamboos supported on a wooden beam at a height of 10ft. Perforated plastic pipes of 4-6 inches diameter were placed in the centre at the base to facilitate the removal of accumulated carbon dioxide. CIPC (trade name Oorja, United Phosphorus Limited, Mumbai, 50 % a.i.) was uniformly sprayed in commercial grade methanol @ 40 ml tonne^{-1} to get concentration of 20 mg kg^{-1} a.i. on tubers during first week of March, 2007 and 2008. Spraying process was repeated with each layer of tubers and after the treatment, the potatoes were collected in the shape of a conical heap and then covered with 1.5 to 2 feet thick layer of rice straw (*pural)*. Heaps of untreated control potatoes raised with all recommended pre- and post harvest measures were laid nearby under the same shed. 10 kg of potatoes with three replications in each treatment packed in nylon bags were also placed in all heaps. Methanol spray alone did not show any effect on sprouting behaviour and biochemical constituents of tubers in a preliminary study (Mehta 2005)**,** therefore data on control potatoes with methanol spray has not been included in this study.

The maximum and minimum temperatures and relative humidity were recorded daily during the storage period in heaps. Final observations on number of sprouted tubers, sprout weight (g kg^{-1} tuber weight), loss in weight due to tuber rotting and total weight loss (physiological + pathological + sprout loss) were recorded in potatoes stored in bulk as well as in the nylon bags after 90 days of storage (DOS). Percent sprouting was calculated on number basis and each tuber having at least one sprout measuring 0.2 cm or more in length was recorded as sprouted. Tubers with slight evidence of decay were weighed to represent loss due to tuber rotting. Sprouting Index (SI) was recorded on 50 tubers per treatment after storage (Mehta 2005). Both at 0 and 90 days of storage, tubers were assessed for reducing sugars, sucrose, total phenols and free amino acids as per the standard methods (Mehta and Singh 2004).

Potatoes were hand peeled and cut into slices of 1.4 mm thickness with a semi-automatic slicing machine. The slices were washed thoroughly in cold water, air dried and immediately fried in groundnut oil at 180^{o}C till the bubbling on the chip surface stopped. Chip colour was scored on 1-10 scale of increasing colour using the chip colour cards (Ezekiel *et al.* 2003a). Chip colour score up to and including 5 was considered acceptable.

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All the estimations were done in three replicates and the data was statistically analyzed using completely randomized design through MSTAT C software (Gomez and Gomez 1984). CIPC residues were analyzed (Ezekiel *et al.* 2003c) in potato peel and cortex separately with the help of HPLC equipment (LaChrom, Dermstadt, Germany).

RESULTS AND DISCUSSION

Storage environment: Storage in heap reduced the diurnal variation in temperatures while maintaining a high relative humidity (RH). Mean minimum-maximum temperatures during March to June ranged between 18-30°C inside the heap compared to 14-43°C in the ambient (Fig. 1). RH inside the heap remained continuously high (60-92%) compared to lower levels of 38 to 78% in the ambient (Fig. 2).

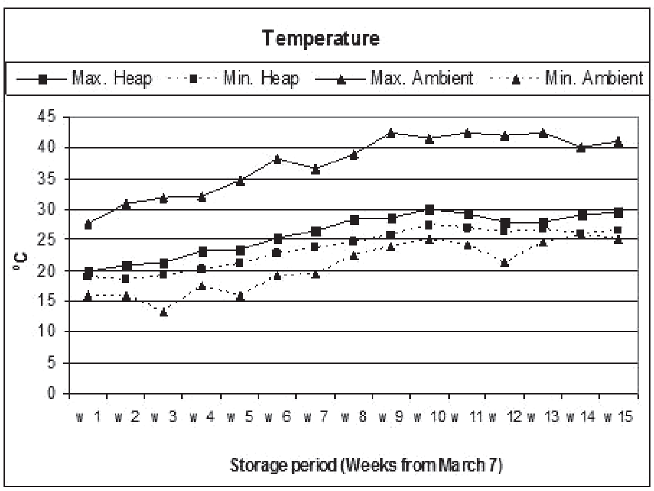

Fig. 1. Ambient and heap temperature (minimum and maximum) during the storage period

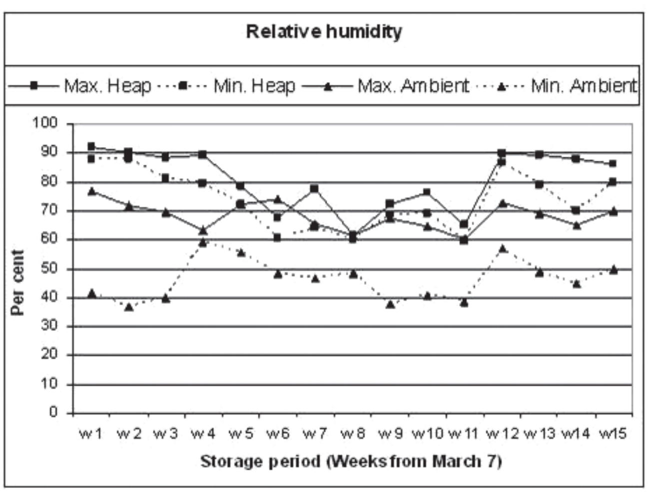

Fig. 2. Ambient and heap relative humidity (minimum and maximum) during the storage period

Sprouting, sprouting index and sprout weight: Untreated (control) tubers of all the cultivars had 100% sprouting in both the years. While with CIPC treatment, sprouting was reduced to 3.90% after 90 DOS in 2007 and 4.97% in 2008 (Fig. 3). Sprouting index in treated tubers was also reduced to 1.08 and 1.29 in 2007 and 2008, respectively as compared to control tubers (6.0). Mean sprout growth remained remarkably suppressed (by 96.4-99.5%) in different cultivars in CIPC treatment compared to control (Fig. 3). This is consistent with

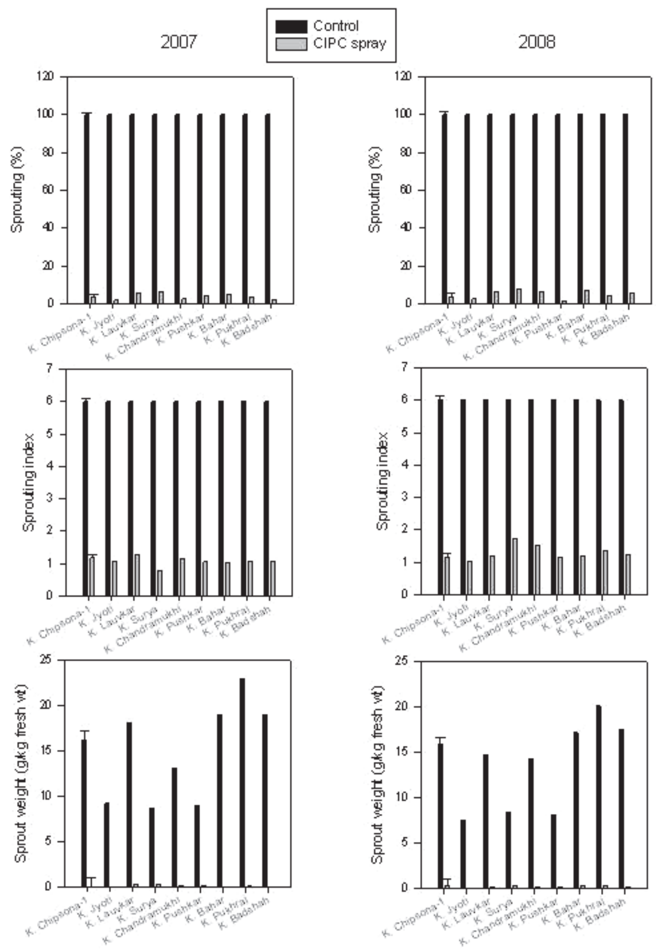

Fig. 3. Sprouting parameters as affected by CIPC treatment under heap storage (error bars represent SEm value of variety x treatment interaction at 36 degrees of freedom in particular set of data)

earlier findings using CIPC dust (1 % a.i.) (Mehta and Kaul 1991), CIPC fog (Mehta *et al*. 2008) and CIPC spray (Mehta *et al*. 2010) under non-refrigerated storage conditions. CIPC treatment was effective in all the cultivars including Kufri Lauvkar which has the shortest dormancy period and shows profuse sprout growth under high temperature storage (Mehta and Kaul 1997).

Loss due to rotting: The proportion of rotted tubers after storage in untreated heaps was 0.55 % (mean of nine cvs), mainly attributable to soft rot (*Erwinia carotovora*) and charcoal rot (*Macrophomina phaseolina*). CIPC treatment had no effect on rotting in tubers during both the years (Fig. 4).

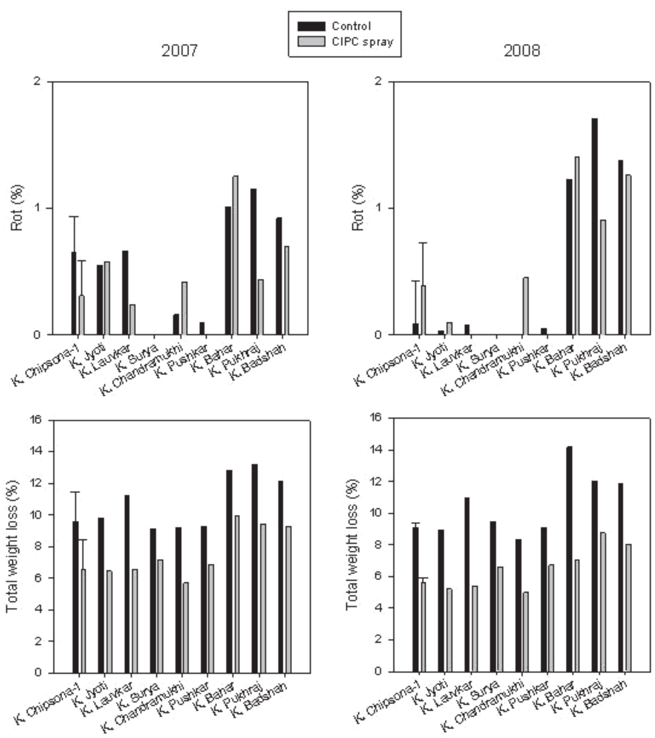

Fig. 4. Rot incidence and weight loss as affected by CIPC treatment under heap storage (error bars represent SEm value of variety x treatment interaction at 36 degrees of freedom in particular set of data)

Total weight loss: Total weight loss (physiological + pathological + sprout loss) in untreated tubers (mean of nine cvs.) was 10.70 and 10.43 %, respectively, in 2007 and 2008 (Fig. 4) mainly due to reduced temperature and high humidity inside the heap (Mehta and Ezekiel 2003). Higher total losses up to 26% are however reported under ambient temperature storages without sprout suppression (Mehta and Kaul 1997). Single spray application of CIPC was effective in all the cultivars in both the years and significantly reduced total weight loss (by 33.5%) with maximum reduction recorded in cv Kufri Lauvkar (46.2%). Though evaporative and respiratory losses were not separately quantified in this study, higher total losses in the control tubers were likely attributable to higher evaporative losses because of 100 times more permeability of sprouts as compared to tuber skin (Booth and Shaw 1981). A significant positive correlation (r=0.693*) between weight loss and sprout weight in tubers under ambient temperature storage is also reported (Mehta and Kaul 1997)

Total losses in CIPC treatment recorded at 90 DOS remained less than 10% in all the cultivars including Kufri Bahar, Kufri Pukhraj and Kufri Badshah, which are considered average keepers (Mehta *et al*. 2007) and the potatoes maintained tissue turgor. When weight loss approaches 10%, tubers become increasingly flaccid and unacceptable for marketing as it results in higher peeling losses (Booth and Shaw 1981). The CIPC treated potatoes of all the cultivars appeared firm whereas the control (untreated) potatoes with multiple sprouts had a shriveled appearance. There was no need to desprout the tubers before marketing and treated potatoes after storage fetched 54.3 % higher market price than the price at harvest (the price at harvest in 1st week of March was Rs. 350 quintal^{-1} and after storage it was Rs. 540 quintal^{-1} in June in Jalandhar (Punjab) vegetable market). The price of heap stored potatoes was comparable to the price of potatoes stored in refrigerated cold stores maintained at 2-4^{o}C (Rs. 538 quintal^{-1}). Normal cold storage rent varies from Rs. 100-120 quintal^{-1} of potatoes whereas, on-farm storage in heaps is much less expensive (Rs. 20-25 quintal^{-1}).

Processing quality of stored potatoes: Mean content of reducing sugars was higher at 0 day of storage in 2008 (243mg 100 g^{-1} fresh weight) compared to 2007 (192mg 100 g^{-1} fresh weight) (Table 1). This may be due to increased invertase activity under low temperature conditions during the crop growth, particularly in the months of December and January (Marwaha 1998). Reducing sugars decreased during storage and were

Table 1. Effect of CIPC spray on processing attributes of potatoes under heap storage

Variety		2007/ Treatment (T) 90 days				2008/ Treatment (T) 90 days		
	0 day	CIPC	Control	Mean	0 day	CIPC	Control	Mean
Reducing sugar (mg/100 g fresh weight)								
K Chipsona-1	45	36	58	47	89	55	50	65
K Jyoti	151	113	87	117	211	86	95	131
K Lauvkar	161	112	144	139	136	61	106	101
K Surya	90	134	154	126	108	133	150	130
K Chandramukhi	127	167	200	165	168	157	120	148
K Pushkar	385	255	242	294	400	267	230	299
K Bahar	360	137	165	221	225	104	94	141
K Pukhraj	239	156	121	172	448	395	387	410
K Badshah	166	144	163	158	401	297	263	320
Mean	192	139	148		243	173	166	
LSD (P=0.05)	V=11.9, T=6.8,VxT=20.4				V=18.7,T=10.7,VxT=32.2			
SEm VxT		7.2				11.4		
Sucrose (mg/100 g fresh weight)								
K Chipsona-1	232	413	386	344	168	268	284	240
K Jyoti	184	689	640	504	163	438	472	358
K Lauvkar	412	733	941	695	193	478	582	417
K Surya	235	445	580	420	212	448	514	391
K Chandramukhi	220	580	551	450	160	374	365	300
K Pushkar	143	363	346	284	92	487	344	308
K Bahar	207	599	610	472	92	467	448	336
K Pukhraj	213	561	563	446	88	338	314	247
K Badshah	235	481	489	402	161	366	379	302
Mean	231	540	567		147	407	411	
LSD (P=0.05)	V=33.9, T=19.5,VxT=58.8				V=28.3,T=16.4,VxT=48.9			
SEm VxT		20.8				17.3		
Free amino acids (mg/100 g fresh weight)								
K Chipsona-1	72	78	71	74	75	55	63	64
K Jyoti	102	96	124	107	113	96	109	106
K Lauvkar	105	112	120	112	101	90	84	92
K Surya	95	87	97	93	101	95	98	98
K Chandramukhi	83	104	99	95	93	83	77	84
K Pushkar	64	77	85	75	69	83	73	75
K Bahar	93	96	87	92	72	95	122	97
K Pukhraj	78	74	73	75	72	39	49	54
K Badshah	96	97	81	91	79	54	71	68
Mean	88	91	93		86	77	83	
LSD (P=0.05)	V=10.2, T=NS, VxT=17.5				V=5.9,T=3.4,VxT=10.5			
SEm VxT		6.2				3.7		

Variety		2007/ Treatment (T) 90 days				2008/ Treatment (T) 90 days		
	0 day	CIPC	Control	Mean	0 day	CIPC	Control	Mean
Total phenol (mg/100 g fresh weight)								
K Chipsona-1	35	54	50	46	39	46	58	48
K Jyoti	76	94	87	86	77	88	105	90
K Lauvkar	65	88	121	91	58	64	66	63
K Surya	71	90	95	85	67	89	91	82
K Chandramukhi	62	85	74	74	61	66	101	76
K Pushkar	58	76	85	73	46	64	69	60
K Bahar	56	111	101	89	30	76	80	62
K Pukhraj	40	36	46	40	38	78	80	66
K Badshah	46	53	43	47	56	46	66	56
Mean	56	76	78		52	69	80	
LSD (P=0.05)		V=5.9, T=3.4,VxT=10.2				V=7.4,T=4.2,VxT=12.4		
SEm VxT		3.6				4.41		
Chip colour score								
K Chipsona-1	2.8	1.7	2.2	2.2	2.8	1.8	2.2	2.3
K Jyoti	6.2	3.2	3.3	4.2	5.8	3.2	2.5	3.8
K Lauvkar	4.7	2.8	2.8	3.4	4.8	2.3	2.3	3.2
K Surya	5.5	3.7	3.8	4.3	4.3	3.3	3.2	3.6
K Chandramukhi	6.8	3.2	4.2	4.9	6.8	3.3	5.7	5.3
K Pushkar	8.8	6.7	7.5	7.7	7.8	6.3	5.8	6.7
K Bahar	7.3	5.7	5.3	6.1	7.5	5.8	6.8	6.7
K Pukhraj	7.7	7.2	7.3	7.4	8.2	7.3	7.3	7.6
K Badshah	6.8	7.2	7.2	7.1	7.2	6.7	6.2	6.7
Mean	6.3	4.6	4.9		6.1	4.5	4.7	
LSD (P=0.05)		V=0.3, T=0.3,VxT=0.6				V=0.3, T=0.3,VxT=0.6		
SEm VxT		0.2				0.2		

always low after 90 DOS in both the treated and untreated tubers during the two years. This could be due to the reconditioning effect of high temperature under heap storage compared to refrigerated storages (Dogras *et al*. 1991). A higher rate of starch resynthesis and respiration during storage is also known to be responsible for this kind of decrease (Hughes and Fuller 1984). Reducing sugar values were generally lower in Kufri Chipsona-1 as compared to other cultivars during both the years. The level of reducing sugars in potato tuber is an important factor affecting colour of processed products (Roe *et al*. 1990) due to Maillard reaction with free amino acids at higher frying temperatures (Habib and Brown 1957) and the contents of reducing sugars should be below 0.2% of tuber fresh weight for producing acceptable quality chips (Ezekiel *et al.* 2003b). By the end of storage in 2007 all cultivars except Kufri Pushkar had acceptable reducing sugar concentrations in treated and untreated potatoes, whereas in 2008, the concentration was unacceptable in Kufri Pushkar, Kufri Pukhraj and Kufri Badshah.

Sucrose concentration increased tremendously during storage in treated and untreated tubers in both the years, particularly in 2007 where the initial sucrose content was also higher (Table 1). This is probably due to the inhibition of invertase activity or synthesis of invertase inhibitor at higher temperature (Uppal and Verma 1990). Though sucrose is not directly involved in Maillard reaction, it can serve as a substrate for reducing sugar production via the storage activated invertase enzyme (Pressey 1969). The CIPC treatment

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did not show any consistent effect over cultivars and years on the sucrose concentration of stored potato tubers.

Mean free amino acid (FAA) content of tubers decreased in CIPC treated potatoes during storage in 2008 (Table 1). Increased proteolytic enzyme activity and *de novo* synthesis of a proteinase enzyme on dormancy release are thought to be controlling the FAA pool size (Suh *et al.* 1990). Though amino acids are important substrates in the Maillard reaction, their concentration could rarely be a limiting factor. In both the years total phenol contents in tubers increased during storage (Table 1) due to a probable decrease in polyphenol oxidase activity (Weaver *et al.* 1978). Phenolic compounds are involved in enzymatic discoloration of tubers on peeling and exposure to air due to oxidation by polyphenol oxidase enzyme (Sweeny and Simandale 1968).

Chip colour of treated potatoes improved during storage in heaps in both the years except in Kufri Badshah during 2007 (Table 1). Cultivars differed significantly in chip colour which was highly acceptable in treated tubers of Kufri Chipsona-1, Kufri Jyoti, Kufri Lauvkar, Kufri Surya and Kufri Chandramukhi after storage whereas rest of four cultivars could not produce acceptable chips and these were suitable only for table purpose. The lighter chip colour after storage in heaps vs. before storage in the two years, attributable to the corresponding decrease in reducing sugars is in agreement with earlier research (Mehta *et al.* 2008, Mehta *et al.* 2010)

The residues of CIPC in the peel (0.81-3.85 mg kg^{-1} fresh tuber weight) were approximately 10-20 times higher than the residues in the cortex of tubers (data not included). The levels were far below the permissible limits of 10 and 30 mg kg^{-1} of whole tubers, as recommended by the European Union and the US Environmental Protection Agency, respectively (EPA 1996, Kleinkopf *et al*. 2003) and the potatoes were safe for human consumption.

In conclusion, a single spray application of CIPC at a dose of 20 mg kg^{-1} (i.e. 40 ml of CIPC solution $tonne^{-1}$ of potatoes) can extend the storage life of potatoes up to 90 days under heap storage by inhibiting sprout growth, maintaining tissue turgor and reducing total storage losses. The treatment was effective in potato cultivars varying widely in dormancy periods. Farmers can store their produce on-farm for short-term and get remunerative prices by selling potatoes of Kufri Chipsona-1, Kufri Jyoti, Kufri Lauvkar, Kufri Surya and Kufri Chandramukhi to the processing industries and the rest of four cultivars namely Kufri Pushkar, Kufri Bahar, Kufri Pukhraj and Kufri Badshah as table potatoes.

As commercial facilities for potato storage under intermediate temperatures (10-12^{o}C) are still uncommon in India, potatoes for table purposes are generally stored along with seed potatoes in refrigerated stores maintained at 2-4^{o}C, which results in low temperature sweetening. Short term on-farm storage can maintain good flavour of table potatoes, improving the farmers' sale price while incurring lower storage cost.

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