Technical Bulletin No. 82

Modified Heap And Pit Storage For Table And Processing Potatoes

Central Potato Research Institute
(Indian Council of Agricultural Research)
Shimla - 171 001, H.P. (India)

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Printed: March 2007, 500 copies

Production : **Avnish Atrey**

Published by : **Dr. SK Pandey, Director**
Central Potato Research Institute
Shimla 171 001, HP, India
Email: dircpri@sancharnet.in

Designed & Printed at : Nirmal Vijay Printers
B-62/8, Naraina Industrial Area
Phase-II, New Delhi - 110 028
Phone : 51418526, 25891449, 9811053617

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Preface

Over the past two decades, there has been a steady increase in potato production in the country accompanied by 'unsteady markets' frequently resulting in peak harvest gluts and consequent economic losses to the farmers. One of the main reasons for this unfortunate situation is the inadequate and unevenly distributed infrastructure for refrigerated storage in the country and that too beyond the reach of small and marginal potato growers. One of the ways to solve this problem is to hold the produce on-farm for short periods by cheap storage methods to bypass the immediate post harvest period when the prices are the lowest. Traditional methods of potato storage are practiced by farmers in different parts of the country for on-farm storage for 3-4 months. The method followed varies from place to place and each traditional method has its own advantages and disadvantages. Heap is the most common traditional method of potato storage being practiced in several parts of the country. In the Malwa region of Madhya Pradesh both heap and pit methods are quite popular and farmers store large quantities of potatoes in heaps and pits for 3-4 months. Though these methods are popular, farmers suffer considerable losses (10-40%) during storage and if rainwater enters heaps and pits, the losses can be as high as 80%. Central Potato Research Institute started extensive studies in 1998 at its regional stations, Jalandhar (Punjab), Modipuram (UP) and Patna (Bihar), in areas of the hot semi-arid eco-regions of India, where the postharvest period is marked by low humidity and high temperature. Investigations were conducted to improve the efficiency of commonly used traditional methods, *viz.,* heaps and pits through better post-harvest handling of potatoes, through modifications in the storage methods and reduction in storage losses by sprout suppression with the use of CIPC.

Useful information collected on following aspects: losses in stored potatoes, keeping quality of commercial potato varieties, marketability of stored potatoes, taste and processing quality of stored potatoes, control of sprouting with the use of CIPC, residue analysis of CIPC in potatoes and economics of storage in heaps and pits has been presented in this bulletin for the benefit of farmers and potato

processing industries. It is hoped that they will find this bulletin informative and useful.

We thank former Directors, late Dr. G.S. Shekhawat and Dr. S.M. Paul Khurana for their constant support and cooperation in conducting the work and Dr. B.P. Singh, Jt. Director, CPRIC, Modipuram, Dr. G.S. Kang, Head, CPRS, Jalandhar and Dr. R.P. Rai, Head, CPRS, Patna for providing the necessary facilities. Thanks are also due to Dr. N.P. Sukumaran, former Head, Division of Crop Physiology and Biochemistry, CPRI, Shimla for useful suggestions and critical evaluation of this manuscript. The cooperation received from Sh. V.K. Singh, Area Manager (north zone), United Phosphorus Ltd., New Delhi for CIPC fogging in heaps is acknowledged with thanks.

Shimla
March, 2007

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Introduction

Potato production in India has shown a gradual and steady increase in the last 50 years. Increase in production often resulting in gluts at harvest, has led to several post-harvest problems including that of storage. A total of 90 per cent of potato crop of the country is harvested during January-February from the Indo-Gangetic plains, comprising the states of Punjab, Haryana, U.P., Bihar and West Bengal, where the harvest is followed by rising temperatures of hot and dry summer and further by warm and humid rainy season. Under these conditions potato, a semi-perishable commodity, can not be stored without refrigeration for more than 4-6 weeks after harvest because of enormous losses resulting due to shrinkage, sprouting and attack by microorganisms. Therefore, they have to be either consumed or stored immediately after harvest. Dormancy, a varietal characteristic enables the tubers to remain in a relatively firm condition for only few weeks after harvest. But once the dormancy period is over, sprouting begins and losses due to evaporation and respiration increase many folds. The present day high yielding potato varieties have a dormancy duration ranging from 4-8 weeks and they need proper facilities for short or long term storage.

Recurring gluts are common in areas of large production due to inadequate refrigerated storage and transport infrastructure, lack of modern marketing avenues, low domestic utilization and insignificant processing and export. Wholesale and retail prices of potato vary from time to time during the year and from year to year depending upon the supply and demand. Potato prices generally crash drastically at harvest and increase rapidly a few months later. Wholesale potato prices in the major markets have shown a variation of 3% (Mumbai) to 35% (Kolkata) over the last ten years **(Fig. 1)**.

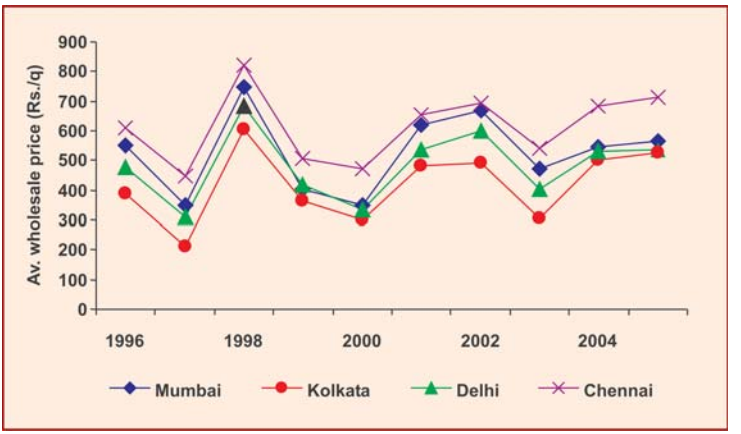

Fig. 1. Fluctuations in wholesale prices of potato in four metropolitan cities over the last ten years

Seasonal indices show that prices reach peak in September-November and are low in February-March in majority of markets **(Table 1)**. Indigenous potato storage methods can be used as a part of marketing strategy to increase remunerations from potato cultivation. Surplus produce can be held on-farm for short periods by cheap storage methods to bypass the immediate post-harvest period when prices are the lowest. Short term storage can thus help avoiding distress sale at peak period of production by regulating the arrivals in the market.

Table 1. Seasonal indices of wholesale prices of potato in the major markets of India over the last ten years (1996-2005)

Month	Mumbai	Kolkata	Delhi	Chennai
January	84	72	53	81
February	79	54	53	67
March	77	69	62	68
April	88	87	74	88
May	96	102	83	105
June	104	108	105	114
July	107	110	133	119
August	113	111	139	119
September	112	112	147	95
October	119	119	154	111
November	122	130	124	120
December	99	126	71	112

Need for non-refrigerated storage of potato

Fresh potatoes are available only for a short period of about three months in a year. Though there is need to store seed potatoes for 6-8 months, the potatoes for table and processing purposes have to be stored for up to 9 months to maintain the potato supply through out the year. Seed potatoes have to be stored at 2-4^{o}C to maintain them in the right physiological age till the next planting season but storage of table potatoes at low temperatures is not desirable due to accumulation of large amount of sugars which makes them unfit for processing due to resultant browning in chips after reaction with free amino acids. These potatoes are also not preferred for table consumption due to their apparent sweet taste. Marketing of these potatoes again is a problem due to their poor keeping quality once they are removed from the cold store.

There has been a surge in potato processing sector over the last decade due to increased demand of processed potato products by the consumers. Processing potatoes need to be stored under higher temperatures. In many

developed countries potatoes meant for processing are stored at 10-12°C, with the use of sprout inhibitor isopropyl N-(3-chlorophenyl) carbamate (CIPC). At this temperature the accumulation of reducing sugars is minimum and the chips produced are light in colour. But the commercial facilities for potato storage at 10-12°C are not yet fully developed in India. Under the present circumstances, the refinement of traditional on-farm storage methods like pit and heap are attractive propositions for short term storage of table and processing potatoes. Though refrigeration is essential for long term storage of potatoes, non-refrigerated storage methods can be well utilized to meet the short-term needs and for achieving proper returns to the farmers.

Traditional methods of potato storage

Farmers use indigenous storage practices like storing in pits, heaps, trenches and basements to hold some of their produce for short-term to fetch better prices. Several traditional methods of potato storage practiced in the states of Assam, Bihar, U.P., M.P., Gujarat, Maharashtra and Karnataka are region specific. These on-farm storage methods are continuing for many years because they are cheap, materials required are locally available and construction can be done by the farmers themselves. Besides, there is less cost involved in handling and storage than for cold storage and prices fetched by the potatoes are generally higher due to their good taste. Though these methods are economical and practical, they are not efficient because of higher losses due to rottage during storage. Extensive studies were therefore conducted at CPRI regional stations, Jalandhar (Punjab), Modipuram (UP) and Patna (Bihar) to improve the efficiency of commonly used traditional methods, *viz.,* heaps and pits, through better post-harvest handling of potatoes, modifications in the storage methods and reduction in storage losses by sprout suppression with the use of CIPC. The study areas are part of the hot semi-arid eco-regions of India where temperatures begin to increase from February onwards. May and June are the hottest months when temperatures often rise above 40°C. Thus, the post-harvest period is marked by low humidity and high temperature.

Improved heap and pit storage of potatoes

The heap method of storage is a very simple way of storing potatoes generally under the shade of trees or a thatched roof made of straw (*Sarkanda*) and bamboos. Heaps ranging from 1-2 m height are covered with 30-60 cm thick layer of locally available material such as rice straw (*pural)*. The *pural* cover can be further covered with loose soil or soil clumps irregularly positioned as weight to prevent the *pural* from being blown away

by strong winds. The size of the heap can vary depending upon the quantity of potatoes stored but the height of the heap should not be more than 1.5 m. Lowering of perforated PVC pipes in the centre of potato heap helps in the removal of carbon dioxide accumulated due to respiration during storage **(Fig. 2).**

Fig. 2. An uncovered and a covered potato heap fitted with temperature-humidity recorder

To enhance ventilation to bigger heaps, basal ventilators should be placed under the potato piles. Basal ventilators can be triangular or square ducts made of wooden strips or a well perforated tube **(Fig. 3)**. Pits, *katcha* and *pucca (*with an inside lining of bricks) can be dug under the shade of trees. *Katcha* pit dug at a cost of Rs 200/tonne of potatoes has a life of 10 years and needs minor repairs every year. Construction cost of *pucca* pit is about Rs 2500/ tonne with a life span of 50 years. Proper aeration of heaps and particularly pits is essentially required. Providing a platform made of bamboo sticks tied at 5 cm spacing at about 60 cm above the base **(Fig. 4)** and placing perforated PVC pipes in bulk stored potatoes in pits increases

Fig. 3. A potato heap with a triangular and a tubular basal ventilator

Fig. 4. Base structure of pit

ventilation and significantly reduces the losses resulting due to rottage in tubers. A thatched roof over the heaps and pits helps to further reduce the temperature and protects the stored potatoes from rain water. When rain or drizzle is expected, heaps and pits without the thatched roof may be

covered with polyethylene sheets or tarpaulin to prevent percolation of water into the potatoes.

Storage environment

The two storage systems (heaps and pits) reduce the daily range of variation in temperatures while maintaining a high relative humidity (RH). While the day time variation in ambient temperature and relative humidity is considerable, the atmosphere is quite stable inside the heaps and pits. Minimum-maximum temperatures inside heap and pit during storage (March to June) range between 13-31°C and 13-27°C as compared to 8-44°C of the ambient and RH remains consistently high (60-95%) compared to wide variation and lower levels (27-87%) of the ambient. A generalized picture of mean monthly temperatures and RH during storage in heaps and pits in comparison to the ambient is given in **Table 2**.

Table 2. Generalized picture of decrease in maximum temperature and increase in relative humidity under heap and pit storage as compared to the ambient*

Parameter/Month	Ambient		Inside heap		Inside pit	
	Maxi.	Mini.	Maxi.	Mini.	Maxi.	Mini.
Temperature (°C)						
March	26.8	13.6	20.3 (-6.5)**	17.5	19.2 (-7.6)	17.3
April	32.2	16.0	22.8 (-9.4)	20.5	21.7 (-10.5)	20.1
May	34.4	23.1	29.3 (-5.1)	25.4	24.3 (-10.1)	23.2
June	36.8	25.2	30.9 (-5.9)	27.2	26.4 (-10.4)	25.3
Relative humidity (%)						
March	75.9	53.6	84.5 (+8.6)**	84.5 (+30.9)	87.6 (+11.7)	86.3 (+32.7)
April	68.3	43.8	70.5 (+2.2)	67.6 (+23.8)	80.1 (+11.8)	76.4 (+32.6)
May	65.0	49.5	71.5 (+6.5)	62.9 (+13.4)	82.0 (+17.2)	78.7 (+29.2)
June	67.8	53.3	68.2 (+3.2)	61.2 (+11.7)	79.8 (+14.8)	75.7 (+26.2)

* Values are mean of 3 years (2004-06) at CPRS, Jalandhar (Punjab).

** The values in parenthesis show the decrease in temperature and increase in relative humidity

Maximum ambient temperatures in May-June are generally 40-43°C while the maximum temperatures observed in heap and pit are 30-31°C and 26-27°C, respectively. Inside the pit, maximum temperature is lowered down by more than 10°C and RH during mid noon is increased by >26% as compared to the ambient during hot months of April-June.

Losses in stored potatoes

Weight loss and rottage are significantly reduced in potatoes stored in heaps and pits as compared to those stored at room temperatures **(Table 3)**. Weight loss up to 10% is considered acceptable because no visible shriveling takes place up to this level. When the weight loss exceeds 10%, shriveling takes place which reduces the market value of potatoes for table and processing purposes. Further, peeling losses increase with increased weight loss affecting the processing quality of potatoes. Weight loss in potatoes is minimum under pit storage throughout the storage period, but losses due to rottage can be heavy in pits in the absence of proper curing and sorting out of tubers and lack of proper ventilation.

Table 3. Storage losses in improved heaps and pits at three locations

Method	Method/ location	Weight loss (%)	Loss due to sprouting (%)	Rottage (%)	Total losses (%)
Heap	Jalandhar (90 days)	7.90	0.38	0.30	8.58
	Modipuram (90 days)	7.50	0.65	0.30	8.45
	Patna (75 days)	4.45	1.95	0.10	6.50
Pit	Jalandhar (105 days)	6.66	0.52	1.12	8.30
	Modipuram (90 days)	6.70	0.80	3.20	10.70
	Patna (75 days)	3.13	0.77	0.10	4.00
Room temperature	Jalandhar (90 days)	16.35	0.23	5.20	21.78
	Modipuram (90 days)	11.20	0.80	4.75	16.75
	Patna (75 days)	23.4	1.72	30.6	55.7
Cold store (2-4°C)	Modipuram (90 days)	2.15	0	0	2.15

It has been demonstrated that it is feasible to store potatoes on-farm by improved traditional methods, *viz.*, heaps and pits for 3-4 months with acceptable storage losses. Though mean total losses after desprouting are higher (4-11%) in potatoes stored in heaps and pits **(Table 3)**, as compared to refrigerated cold storage (2-3%), the stored potatoes remain firm **(Fig. 5).** The desprouted potatoes fetch prices comparable to the cold stored potatoes, which are 40-50% higher than that at the time of harvest.

Fig. 5. Potatoes stored in heap and pit for 90 days

Keeping quality of commercial potato varieties under heap and pit storage

Commercial potato varieties developed by Central Potato Research Institute have been investigated for their suitability for non-refrigerated storage and genotypes with good storability have been identified. When properly cured and sorted out tubers are stored, generally tuber rotting is not observed until 90 days of storage in potato varieties except in Kufri Sutlej and Kufri Chipsona-2. When potatoes stored in bulk remain undisturbed under humid and cool environment throughout the storage period, total losses remain below 10% and tubers appear firm up to 90 days (May end) in the commercial varieties stored in the pit, Kufri Sutlej and Kufri Chipsona-2 being exceptions **(Table 4)**. In heap, total losses remain low (8.5-10.5%) in Kufri Chandramukhi, Kufri Jyoti, Kufri Chipsona-1, Kufri Lauvkar and Kufri Sindhuri up to 90 days of storage. Among varieties,

Table 4. Total losses (weight %) in commercial potato varieties after different periods of storage in heaps and pits

Variety	Heap		Pit	
	90 days	105 days	90 days	105 days
Kufri Chandramukhi	9.2	14.0	6.3	10.5
Kufri Chipsona-1	9.8	14.9	6.9	10.8
Kufri Jyoti	8.9	14.2	6.5	9.9
Kufri Lauvkar	10.5	15.5	8.2	11.0
Kufri Sindhuri	8.5	15.3	6.6	12.0
Kufri Lalima	11.2	15.4	8.3	11.9
Kufri Badshah	11.5	16.9	9.1	12.6
Kufri Bahar	11.0	17.5	9.8	15.4
Kufri Jawahar	12.3	15.0	8.5	12.1
Kufri Ashoka	11.2	16.8	8.7	13.5
Kufri Pukhraj	12.8	17.0	9.5	12.8
Kufri Sutlej	20.7	26.1	14.1	26.5
Kufri Chipsona-2	15.5	25.8	13.0	29.5

Kufri Sutlej and Kufri Chipsona-2 suffer maximum losses whereas, Kufri Chandramukhi, Kufri Chipsona-1 and Kufri Jyoti show minimum weight loss during storage under both the conditions.

Varieties Kufri Chandramukhi, Kufri Chipsona-1 and Kufri Jyoti can be stored for the maximum period of up to 90 days (May end) and 105 days (Mid June) in heaps and pits, respectively with minimum losses and gradually released in the market to avoid distress sale at harvest. These varieties with good keeping quality have promising export potential also as under the prevailing Indian conditions, export consignments are frequently exposed to higher temperatures before reaching their destination, due to poor infrastructure such as non- availability of refrigerated containers on the dry port and non-availability of warehousing facilities. Other varieties, *viz.,* Kufri Lauvkar, Kufri Sindhuri, Kufri Lalima, Kufri Badshah, Kufri Bahar, Kufri Pukhraj, Kufri Ashoka and Kufri Jawahar can be safely stored in pits for a period of 90 days i.e. by the end of May and in heaps up to 75 days without much deterioration in quality and appearance.

Marketability of stored potatoes

Rates fetched by the varieties with good keeping quality, *viz.,* Kufri Chandramukhi, Kufri Chipsona-1 and Kufri Jyoti stored in heaps and pits are comparable to cold stored potatoes up to 90 and 105 days of storage, respectively. However, heaped potatoes fetch significantly lower auction rates than the cold-stored material after 105 days of storage. The rates are, however, 40% higher than the rates at the time of harvest. Other varieties with medium keeping quality stored in heaps and pits can get remunerative prices up to 75 -90 days only.

Taste and processing quality of stored potatoes

Quality parameters of potatoes vary according to the market demand; dry matter, sugar content and fry colour are critical for processing, whereas skin finish, appearance and taste is more important for high quality table potatoes. For processing potatoes, the reducing sugar content should be as low as possible with upper limit of acceptability being 150 mg/100 g fresh tuber weight and tuber dry matter should be above 20%. The high reducing sugar content results in brown coloured and bitter tasting chips, while low tuber dry matter causes more oil uptake and higher energy consumption and reduces yield of the product. More than 1250 mg/100 g fresh weight of total sugars (reducing sugars and sucrose) impart a sweet taste to table potatoes and makes them less preferred by the consumers.

Potatoes stored in pits and heaps are highly suitable for processing **(Fig. 6)** due to high dry matter and low reducing sugar content whereas

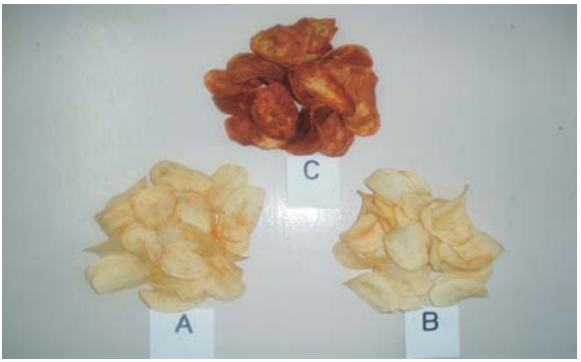

Fig. 6. Chip colour of potatoes stored in (A) heap, (B) pit and (C) cold storage for 90 days

content of reducing sugars in cold stored tubers is generally very high and chips made from all the Indian varieties are of dark colour, bitter in taste and highly unacceptable **(Table 5)**. Most of the varieties **(Table 6)** grown in north-western plains generally produce unacceptable chips (5.5-9.0 chip colour score) before storage due to high reducing sugar content as a result of prevailing low (<10°C) temperatures at harvest. However, reducing sugars in potatoes decrease during storage in heaps and pits, chip colour improves and potatoes become suitable for processing after 90 days of storage.

Processing quality of varieties differ significantly, with Kufri Chipsona-1 producing highly acceptable chips up to 105 days of storage in heaps and pits. Chips made of potatoes stored in pit are far superior in colour, taste and texture up to 105 days of storage **(Table 6)** except in Kufri Badshah and Kufri Sutlej, while acceptable chips can be made from potatoes stored in heaps up to 75-90 days only. A major problem of potato chip industry is the non-availability and continuous supply of potatoes with low reducing sugars and acceptable chip colour. Storage of potatoes in heaps and pits is a suitable alternative for providing potatoes with acceptable processing quality for 3-4 months after harvest, which will help not only in stabilizing potato prices, but also in accruing higher returns to the farmers.

Table 5. Processing quality of potatoes under non-refrigerated storage in comparison to cold storage (mean of 7 varieties)

Parameter	Before storage	After storage (90 days)		
		Pit	Heap	Cold storage
Reducing sugar (mg /100 g fr. wt.) range	127-400	66-217	67-189	1293-2397
Reducing sugar (mg/100 g fr. wt.) mean	310	130	118	2018
Chip colour score (1-10 scale of increasing colour)	5.5	3.0	3.5	10.0

Table 6. Processing quality of potato varieties stored in heaps and pits

Variety	Before storage			After storage					
				Heap (90 days)			Pit (105 days)		
	Dry matter (%)	*Chip colour	**Reducing sugars	Dry matter (%)	Chip colour	Reducing sugars	Dry matter (%)	Chip colour	Reducing sugars
Kufri Chipsona-1	21.7	2.0	44	22.9	3.0	62	22.6	3.0	68
Kufri Jyoti	16.8	6.5	301	18.6	4.5	113	17.2	4.5	142
Kufri Lauvkar	19.2	5.5	127	20.6	4.5	67	20.0	4.0	66
Kufri Chandramukhi	18.4	6.5	234	21.4	5.0	189	20.7	5.0	108
Kufri Jawahar	18.7	6.5	250	20.7	5.0	109	20.2	5.0	142
Kufri Ashoka	16.4	8.0	352	21.8	6.0	140	16.5	4.0	113
Kufri Badshah	17.3	8.0	397	19.2	6.0	143	17.4	6.0	213
Kufri Sutlej	17.9	9.0	432	19.9	5.0	73	19.7	6.0	165
Kufri Pukhraj	15.1	8.0	372	18.3	5.5	109	15.8	4.5	90
Kufri Chipsona-2	22.3	2.0	65	24.8	3.0	71	23.5	2.5	75
Kufri Bahar	18.6	6.5	250	20.8	3.9	151	20.1	3.8	142
Mean	18.4	6.3	258	20.8	4.7	111	19.4	4.4	132

*Scored on 1-10 scale of increasing colour, score up to 5 is acceptable
** mg/100 g tuber fresh weight

Due to low total sugar contents, the potatoes stored in heaps and pits are not sweet in taste and are more preferred as table potatoes. Therefore, the prices fetched by these potatoes in markets as table potatoes are also more than the cold stored potatoes.

Control of sprouting in stored potatoes

Though the storage losses are much reduced in modified heap and pit storage methods, the problem of sprouting in potatoes still remains which involves additional expenditure on labour for desprouting of tubers before sending them to the market. Studies conducted to overcome this problem has proved the effectiveness of CIPC under non-refrigerated storage also. Treatment with CIPC could extend the storage life of potatoes up to 14-16 weeks under heap and pit storage by reducing physiological weight loss, sprouting and sprout growth in tubers. Table potatoes can be treated with CIPC dust @ 25 mg a.i./tonne of tubers at the time of storage. For treating small quantity of potatoes, powder form of CIPC can be used but for large scale treatment, liquid formulation may be applied in the form of fog using a fogging machine without disturbing the stored potatoes. CIPC (chlorpropham) is being marketed in India by United Phosphorus Ltd., Mumbai with the trade name of 'Oorja'. This commercial product containing 50% a.i. is applied @ 50 ml /tonne of potatoes at a cost of Rs. 100/tonne of potatoes. However, the dose can vary depending upon the loss of fog during treatment due to leakage. CIPC fog is applied in heaps through a perforated plastic pipe placed at the base **(Fig. 7)** using a fogging machine **(Fig. 8).** The heaps are kept airtight with a plastic sheet during fogging and up to 48 hours after the treatment to avoid leakage of fog.

Even single application of CIPC fog in heaps, 20-30 days after storage i.e. on the onset of sprouting can significantly reduce sprout growth and total losses in potatoes up to 90 days of storage **(Table 7, Fig. 9).** Kufri Chandramukhi and Kufri Chipsona-1 showed the best results with minimum total losses and rottage in tubers.

Fig. 7. Placement of pipe for CIPC fog application in heap

Fig. 8. A fogging machine (Dyna fog, USA) used for CIPC application

Table 7. Reduction in storage losses in potatoes with CIPC fog after 90 days of storage in heaps

Variety	Treatment	Weight loss (%)	Loss due to sprouting (%)	Rottage (%)	Total loss (%)
Kufri Chandramukhi	CIPC	7.50	0.18	0.24	7.92
	Control	8.94	0.88	0.38	10.20
Kufri Jyoti	CIPC	8.34	0.08	0.54	8.96
	Control	11.30	0.55	0.35	12.20
Kufri Lauvkar	CIPC	8.84	0.32	0.67	9.83
	Control	11.47	1.65	0.08	13.20
Kufri Chipsona-1	CIPC	7.78	0.26	0.03	8.07
	Control	10.20	1.03	0.27	11.50

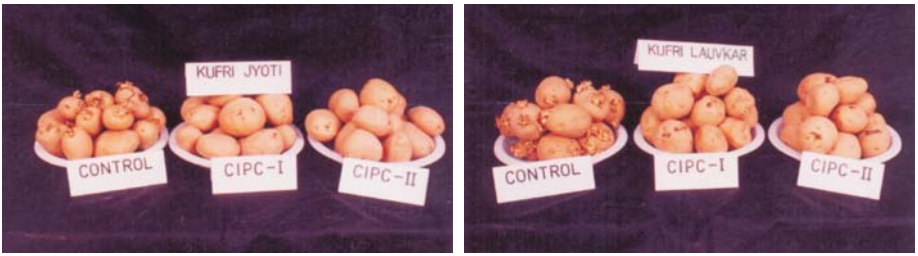

Fig. 9. Sprout suppression in two potato cultivars with single (CIPC-1) and double (CIPC-II) application of CIPC fog in comparison to control (untreated) after 90 days of storage in heaps

The sprout suppressant can be applied even as spray and single spray application of CIPC is more effective than the fog application under heap storage. 'Oorja' can be conveniently applied as spray @ 40-50 ml/tonne of potatoes at the time of laying of heaps using a good quality spray pump or rotary disc sprayer and there is no need to keep the heaps airtight following the spray treatment. Spray application of CIPC in heaps is effective in several potato varieties including Kufri Jawahar **(Fig. 10)**, a variety predominantly stored in heaps in Hoshiarpur district of Punjab where the farmers face the problem of excessive sprouting in potatoes. With this treatment they can save on additional labour cost for desprouting before sending the potatoes to the market.

Fig. 10. Sprout suppression in potatoes with CIPC spray (left) after 90 days of storage in heap as compared to control (right) (cv. Kufri Jawahar)

The efficiency of CIPC spray treatment is more pronounced under pit storage where complete sprout inhibition can be achieved up to 90 days of storage **(Table 8)**. Total losses in treated potatoes are significantly reduced under pit storage (2.9-5.3%) as compared to heaps (6.1-10.6%). There is no need to desprout the tubers before sending them to the market in case of spray application and the labour used for fog application is also reduced. The treated potatoes appear very firm **(Fig. 10, 11)** and fetch market rates better than the control (untreated) potatoes stored under respective conditions.

Application of CIPC does not affect the processing quality of tubers and chips made from treated tubers stored in heaps and pits are of acceptable light yellow colour and superior in taste as compared to freshly harvested tubers **(Table 9, 10).** Processing quality of CIPC treated potatoes is acceptable up to 90 days of storage in heaps in several potato varieties including Kufri Bahar, a variety grown in more than 50% of area in western

Fig. 11. Sprout suppression in 4 potato cultivars with CIPC spray after 105 days of storage in pit

Table 8. Reduction in storage losses in potatoes with CIPC (Oorja) spray application after 90 days of storage in heaps and pits

Cultivar	Treatment Storage method	Weight loss (%)		Loss due to sprouting (%)		Rottage (%)		Total loss (%)	
		Heap	Pit	Heap	Pit	Heap	Pit	Heap	Pit
Kufri Chandramukhi	CIPC	5.73	2.92	0.17	0	0.21	0	6.11	2.92
	Control	8.00	4.87	1.04	2.07	0.18	0	9.22	6.94
Kufri Jyoti	CIPC	5.87	4.55	0.01	0	4.70	0	10.58	4.55
	Control	11.54	4.88	0.59	2.12	0.71	0	12.84	7.00
Kufri Lauvkar	CIPC	9.75	5.33	0.02	0	0.79	0	10.56	5.33
	Control	12.35	6.11	0.52	2.85	0.88	0	13.75	8.96
Kufri Chipsona-1	CIPC	8.09	3.89	0	0	0	0	8.09	3.89
	Control	9.78	4.94	0.79	1.95	0.87	0	11.44	6.89

Table 9. Effect of CIPC fog on processing quality of potatoes after 90 days of storage in heaps

Variety	Treatment	Reducing sugar (mg/100g fr. wt.)	Sucrose (mg/100g fr. wt.)	Chip colour score (1-10 scale of increasing colour)
Kufri	*BS	126	220	6.0
Chandramukhi	CIPC	50	576	5.0
	Control	198	531	5.0
Kufri Jyoti	*BS	152	176	5.5
	CIPC	86	671	5.0
	Control	82	665	4.5
Kufri Lauvkar	*BS	159	408	5.0
	CIPC	72	326	5.0
	Control	143	1311	4.0
Kufri Chipsona-1	*BS	44	231	3.0
	CIPC	26	540	2.0
	Control	62	381	2.0

* Before storage

Table 10. Effect of CIPC spray on processing quality of potatoes after 90 days of storage in heaps and pits

Cultivar	Treatment	Reducing sugar (mg/100g fr. wt.)		Sucrose (mg/100g fr. wt.)		Chip colour score (1-10 scale of increasing colour)	
Storage method		Heap	Pit	Heap	Pit	Heap	Pit
Kufri	*BS	126	126	220	220	6.0	6.0
Chandramukhi	CIPC	135	180	582	393	4.0	4.0
	Control	198	173	531	425	3.5	4.5
Kufri Jyoti	BS	152	152	176	176	5.0	5.5
	CIPC	178	119	904	605	4.0	5.0
	Control	82	111	665	584	4.0	4.0
Kufri Lauvkar	BS	159	159	408	408	5.0	5.0
	CIPC	95	127	841	610	4.0	4.0
	Control	143	36	1311	291	5.0	4.5
Kufri Chipsona-1	BS	44	44	231	231	3.0	3.0
	CIPC	42	35	399	321	2.0	2.5
	Control	62	69	382	372	2.0	2.0

* Before storage

Uttar Pradesh. This variety is considered unsuitable for processing as it produces dark coloured chips at 10-12°C, the temperature at which the potatoes for processing are commercially stored with the use of CIPC **(Fig. 12)**

CIPC residues in stored potatoes

Residue level of chemicals in treated foods has been a matter of health concern. Therefore, it is important that the residue level of CIPC in tubers

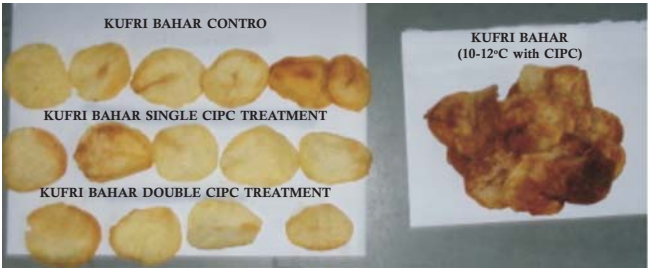

Fig. 12. Chip colour of potatoes after CIPC fog treatment in heap as compared to 10-12°C (cv. Kufri Bahar)

remains within the permissible limit. The maximum residue level of CIPC in potato tubers permissible for human consumption is 30 mg/kg of tubers. CIPC residues in treated potatoes stored in heaps and pits were analysed periodically during storage. Residues in peels and flesh of treated tubers ranging between 1.19-3.38 and 0.17-0.31 mg/kg of tuber weight respectively, after storage were far below the permissible levels. Besides, the higher amount of residues observed in peels are normally removed during peeling prior to cooking/processing and thus the CIPC treated tubers are safe for human consumption.

Economics of storage in heaps and pits

Normal cold storage rent varies from Rs. 90-100/q of potatoes in addition to the expenditure incurred by farmers on transportation. Whereas, on farm storage is much cheaper. For 20 tonne of potatoes, heap storage costs not more than Rs. 5000 (Rs. 25/q) and for storage in *pucca* pit the cost is around Rs.55,000 (Rs 50,000 as cost of construction + Rs. 5000 as storage cost). The average life span of a *pucca* pit is about 50 years and the pits once dug can be used for many years thereby reducing the net storage costs to about Rs. 30/q.

Problems and remedial measures

- Potatoes stored in heaps and pits for more than 90 days sometimes become shriveled and do not fetch good price. Information on storability of varieties is essential for successful storage of potatoes under non-refrigerated conditions. Varieties with medium/average keeping quality should be sent for auction earlier than the good keepers to get remunerative prices.
- When there are untimely rains, potatoes stored in open heaps and pits suffer heavy losses due to rottage. All possible efforts should be made to protect heaps and pits from rain water either by erecting a thatched roof or by covering with tarpaulin sheets in case of rains.

- Sprouting of potatoes under non-refrigerated storage is the main problem faced by the farmers. Treatment with CIPC can significantly inhibit sprout growth in stored potatoes. It also helps in prolonging the storage life of potatoes by reducing total storage losses in tubers.
- Due to significantly lower maximum temperatures (27°C) inside the pits as compared to the ambient (>40°C) during May-June, the snakes often enter the pits. This becomes hazardous while unloading of pits. A net cover to the pits should be used after the loading of potatoes in the pits is complete, to avoid this kind of problem.

Recommendations for traditional storage systems

- Irrigation should be stopped two weeks before dehaulming and the crop should be harvested after 20-25 days to facilitate proper skin setting of the tuber.
- Only mature tubers should be stored because immature tubers have poor keeping quality due to lower dry matter content and a weak skin.
- As far as possible, the potatoes should be harvested in dry weather. If harvested under wet soil conditions, potatoes must be dried before storage because even little moisture on the surface of tubers could lead to infection and rotting during storage.
- Inspite of best efforts, cutting and bruising while harvesting cannot be completely eliminated and therefore, curing is essential to heal the wounds. Potatoes should be temporarily kept in heaps covered with rice straw for 10-15 days after harvest for creating the microclimate necessary for wound healing and skin curing.
- Since non-refrigerated storage conditions are congenial for growth of microorganisms, bruised, cut and diseased tubers should be carefully removed before loading the potatoes into heaps and pits.
- Storage in heaps and pits should be completed by the end of February so that the lower temperatures prevailing during this period can be taken advantage of. The farmers should plan their planting and harvesting schedules accordingly. Stored potatoes should be sent to the market before the temperatures inside the heaps and pits reaches 30°C.
- Heaps and pits should be protected from un-seasonal rains either by erecting a thatched roof or covering with a water proof sheet. If the rain water enters the heaps and pits, the entire quantity of potatoes may be lost due to rottage.
- Because the pit is a closed system with little air circulation, entry of water creates anaerobic conditions at the bottom and humidity level becomes very high. These conditions favour the spread of *Erwinia* bacteria causing soft rot. Lowering of perforated plastic pipes in the

bulk stored potatoes and raising the level of storage on a slatted floor 50-60 cm above the base helps in increasing ventilation and reducing losses due to rottage.

- Pits should not be filled to full capacity and about 20% of space above the potatoes should be left vacant. Storage in *katcha* pit is not safe due to seepage of rain water from the walls and damage caused due to frequently made rat tunnels.
- Potatoes stored in heaps and pits are highly suitable for processing. Potato processing units should make full use of these potatoes. This will be mutually beneficial since farmers will get better price for their produce and processors will locally get potatoes suitable for processing during summer months, thus saving on transportation costs.
- Selection of varieties with good keeping quality would ensure better performance with reduced storage losses.

Conclusions

- Indigenous storage practices have a vital role to play, particularly in the years when the farmers harvest a bumper crop of potatoes resulting in over abundance of ware potatoes and a consequent sharp fall in prices.
- These storage methods help in increasing returns to the potato growers by fetching a better price for their stored produce while incurring lower storage costs.
- Varieties with good keeping quality can be safely stored for 90-105 days by cheap and improved storage methods and gradually released in the market to avoid distress sale at harvest. The improvement in chipping quality of tubers stored in heaps and pits gives an additional option to the farmers to sell their produce to the processors and get better returns.
- Treatment of potatoes stored in heaps and pits by CIPC spray application may further benefit the farmers as they may even prolong the storage period without any increase in storage losses. They may be able to save on labour cost for desprouting, and the appearance of tubers will also be good, besides having acceptable processing quality in suitable potato varieties. This treatment is expected to provide better remuneration to the producers.
- Potato growers also face various problems in cold storing potatoes and sometimes suffer economic losses due to various types of malpractices, such as being overcharged for tariff rates, non-payment of compensation for damage caused due to improper functioning of cold storage and the substitution of their high quality potatoes with those of inferior quality. These problems can be mitigated to some extent by short-term on-farm storage of potatoes.