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RESEARCH PAPER

Design and development of an improved on-farm potato storage system suitable for climatic conditions of southern Karnataka

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SUMMARY : An improved on-farm potato storage system was designed and developed. The new system was basically an improvement over traditional heap storage in which a tubular natural convection aeration system was incorporated. The aeration system consisted of a perforated PVC pipe with vertical raisers at one meter intervals laid along the length of the heap. Potato storage study was conducted for 90 days with one tonne of fresh, suberized tubers using improved potato storage system at ambient conditions of ARS, Madenur, Hassan during *Kharif* season. For comparison, identical traditional heap storage was also laid out.

Key Words : Natural convection, Aeration, Heap, Suberized tubers

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Potato (*Solanum tuberosum* L.) is one of the world's most important food crops, only being surpassed by wheat, rice and maize in total production. Potato is the main source of carbohydrate in human diet. It also has substantial amount of proteins, vitamins, minerals and traces of other elements. Hence, potato is known as "poor man's crop". Potatoes are generally stored in different conditions in order to make their availability throughout the year for table purpose and processing (Salunkhe *et al.,* 1991). This helps to prevent seasonal glut and thus fetches better prices to the farmers. Most important thing for storage of potatoes is to maintain them in marketable condition by preventing moisture loss, spoilage by pathogens, etc. (Jadhav and Kadam, 1998).

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After harvest, the potato tubers are usually stored in a traditional on-farm storage system (in pit or over ground) covered with straw and other plant residues for about 2-3 weeks in Hassan district during *Kharif* season and up to 3 months in Bangalore Rural district during *Rabi* season (Karnic, 1996). Though there are several constraints in these storage practices, the farmers still have little alternative to this age-old practices since, availability of cold storage facilities are limited.

In Karnataka, the potatoes are stored in pits and also indoors. In pit storage, the pits of varying dimension usually 50 cm to 60 cm deep are dug in shady place. The open pits are soaked with water and allowed to dry for 4-5 days, the sides of the pits are lined with neem leaves and tubers are heaped 2 to 5 ft above ground level. Sometimes, a ditch is dug around the pits and filled with water to bring down the temperature. The heap is covered with straw or bamboo mats. Whereas in case of indoor storage, the storage practices include spreading potatoes on floor and heaping, storing in gunny bags and storing in small or big baskets of bamboo. The storage period under above methods ranges from 15 to 60 days. As much as 10 to 30 per cent rottage occur during storage. Large farmers in Kolar and Bangalore districts use pit method to store for more than 60 days (Grewal, 1991).

EXPERIMENTAL METHODS

Design and construction of improved on-farm potato storage system:

Design principle:

The design of improved on-farm potato storage system was based on the following principle: the moisture laden warm air respired out by potato tubers in a heap will rise up through the heap and move out at the top, if unrestricted, by natural convection facilitating the entry of relatively cooler ambient air from bottom (sides) of the heap. However, in the on-farm potato storage system, both the tuber heap and the thick layer of straw on the surface of the heap form a resistance to the free convective air movement. Facilitating the free air movement or forcing the air through the heap will remove respiration heat as well as prevent concentration of humid air inside the heap and possibly condensation of moisture. Therefore, in the present study, a tubular aeration system was introduced in the traditional storage to help air circulation through the heaped potato tubers by natural convection.

Design and construction of tubular aeration system for improved storage system:

The tubular aeration system that was introduced in the case of improved on-farm potato storage system consisted of a horizontal perforated duct with vertical tubular risers as shown in the Fig. A. The main duct was made up of 100 mm diameter PVC pipe with 13 mm diameter perforations at a pitch distance of 50 mm along the axial direction. The hole-to-hole distance in the lateral direction (along the circumference) was also 50 mm. However, in the sector at the bottom of the duct, there was no perforation so as to make it as a drainage channel for the condensed moisture, if any, that may collect inside the aeration system. There were two air vents (risers) at a distance of 1 m between them. The vents were 60 mm in diameter and 1.2 m long PVC pipes whose bottom ends were connected to the main horizontal aeration duct and the top ends emerge out of the potato heaps to the atmosphere. The vents basically helped the warm air collected inside the main duct to go up to the atmosphere.

The main duct was placed horizontally along the length of potato heap at the centre, 0.30 m above the bottom surface and the ends of the duct protruded outside the heap by about 50 mm. A gentle slope of about 2° to the horizontal was kept for the duct so that moisture, if any, that may condense shall run down the slope of the duct and go out of the potato heap. The aeration system was designed in such a way that the main duct collected warm air in the vicinity inside the potato heap which go out through air vents (risers) due to natural convection.

Improved and traditional on-farm potato storage systems were exactly identical in all respects except for the aeration system in the former.

Storage of potato tubers in the improved system:

Like in traditional system, the potato tubers were heaped in a similar manner in the improved system. First, the tubers were spread on the sand to a height of 0.30 m and the base width of storage was 1.5 m. Then, the aeration system was placed at the middle along the length of the heap maintaining the design slope of 2° to the horizontal. Further, the tubers were poured to make a heap of height 0.61 m and the top width of the heap was 0.20 m. Care was taken that the air vents of the

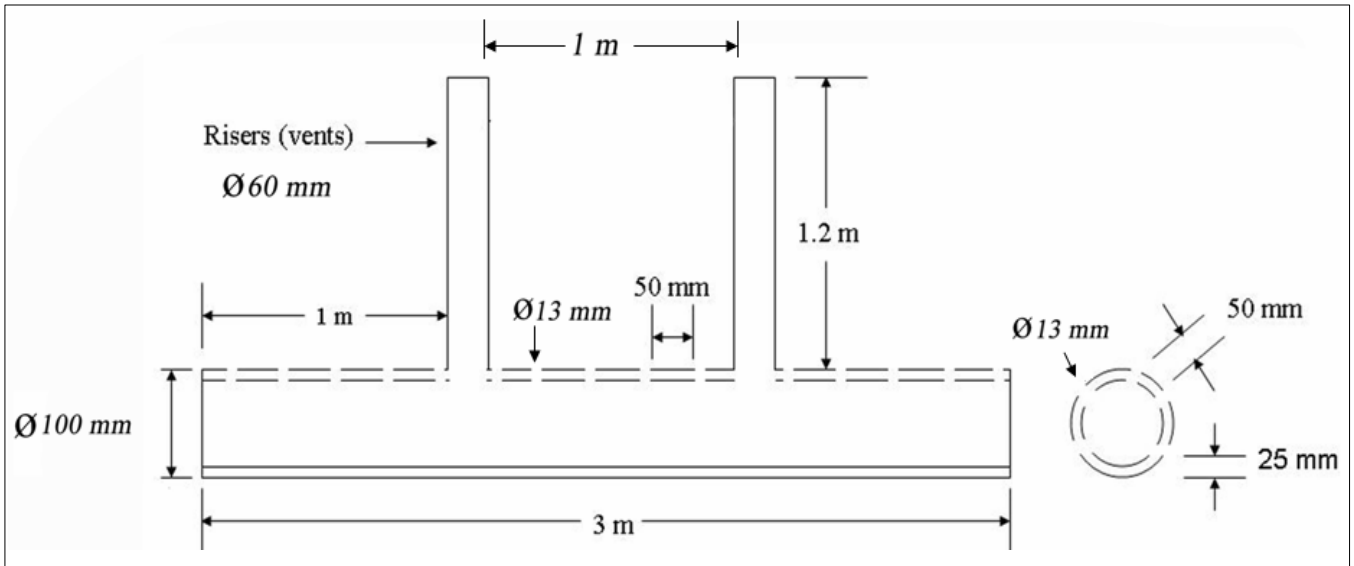


Fig. A : Schematic diagram of tubular aeration system used in improved on-farm potato storage system

aeration system were vertical. Finally, the heap was covered with paddy/ ragi straw to a thickness of 0.15 m.

Study of temperature and relative humidity distribution inside potato storage:

To measure and record temperature and relative humidity inside the potato heap, data loggers (make: HTA Instruments, Bangalore; model: EQ171,) were used. The data loggers used in the present study were compact piece of electronic gadgets (battery operated) that can be programmed to measure temperature and relative humidity at a desired interval of time. It was possible to download the recorded data to a personal computer at the end of the storage study for analysis. There were five data loggers used in the present study, two each in traditional and improved potato storage systems and one to measure ambient conditions near the vicinity of the storage.

Positioning of data loggers was such that one measured air conditions 0.15 m above the bottom surface and the other about 0.3 m below the top surface of the heap. Data loggers were set to measure and record temperature and relative humidity at an interval of 10 minutes throughout the storage period of 90 days.

EXPERIMENTAL FINDINGS AND ANALYSIS

The results of the present study as well as relevant discussions have been presented under following sub heads:

Storage study of potato tubers in traditional and improved on-farm potato storage systems:

Storage study was conducted with 2 tonnes of freshly harvested, sound potato tubers, 1 tonne in each in traditional and improved potato storage systems. To record various observations on the stored tubers, inside the storage heaps, 3 samples (R_1- Top, R_2- Middle, R_3- Bottom) of 5 kg each were placed in plastic wire nets (fruit nets) at different locations such that they could be removed during observation and placed back inside the heap with little disturbances. During storage study, observations on total storage loss, weight loss due to rottage, physiological loss in weight and sprouting percentage were made at 15 days interval.

Physiological loss in weight (PLW):

The cumulative physiological loss of weight of potato tubers tested at different intervals of storage durations in two on-farm storage systems are presented in the Table 1. The cumulative PLW of tubers was 3.50 per cent after 15 days of storage which increased to 13.50 per cent after 90 days of storage in the improved storage system. Similarly, in traditional storage system, the PLW was 3.34 per cent after 15 days of storage that increased to 14.94 per cent at the end of 90 days of storage. Though there was no significant difference between the storage systems with respect to PLW at the beginning of storage period, after 30 days of storage and onwards the PLW values were significantly lower for tubers stored in the improved aerated storage system when compared to traditional system.

Weight loss due to rotting:

Stored potato tubers were periodically examined upto 90 days for damage due to potato tuber rot in both traditional and improved aerated storage system. In the present study, tuber rot was not observed in the stored potato even upto 60 days of storage. However, at the end of 90 days of storage duration, 4.05% and 6.85% of rotting were observed in improved and traditional storage systems, respectively.

Sprouting percentage:

The impact of on-farm potato storage systems on the sprouting behavior of potato tubers especially in *Kharif* season was studied over a period of 90 days and presented in Table 2. Though the sprouting was minimum and non-significant at the beginning of storage (15 days), it rapidly increased with progressive storage period. Nearly one-third of the tubers had some kind of sprouted appearance after 45 days of storage though the tubers were still of acceptable quality. Further, there was no significant difference between the sprouting percentage values of two storage systems studied. However, after 60 days of potato storage, more than 70per cent of the tubers had sprouts and in the improved system, it was significantly less than that of traditional system. At the end of 90 days of storage period, the tubers were with relatively longer sprouts and of second grade in quality in both traditional and improved

Table 1 : Physiological loss of weight of potato tubers during storage in traditional and improved storage systems

Storage system	Physiological loss of weight (%)					
	Days of storage					
	15	30	45	60	75	90
Improved storage	3.50	4.05	5.51	7.67	11.24	13.50
Traditional storage	3.34	4.63	6.16	9.56	12.35	14.94
SEM	0.07	0.09	0.22	0.77	0.28	0.53
F Test @ 5%	NS	*	*	*	*	*
C.D.(P=0.05)	--	0.183	0.4121	1.4369	0.5261	0.9866

* indicates significance of value at P=0.05 NS= Non-significant

Table 2 : Sprouting percentage of potato tubers in traditional and improved potato storage systems

Storage system	Sprouting percentage					
	Days of storage					
	15	30	45	60	75	90
Improved storage	3.21	16.39	34.92	70.44	84.11	89.07
Traditional storage	3.38	17.19	36.75	77.53	86.68	92.03
SEM	1.32	1.48	3.32	1.64	0.39	0.99
F Test @ 5%	NS	NS	NS	*	*	*
C.D.(P=0.05)	-	-	-	3.0263	0.7291	1.8372

* indicates significance of value at P=0.05 NS= Non-significant

systems of storage.

Biochemical quality changes in potato tubers during storage in different storage systems:

The effect of storage system on biochemical quality of potato tubers in terms of dry matter, starch, reducing sugars, total sugars and phenol contents was analyzed before and after 90 days of storage and is presented in the Table 3.

Table 3 : Biochemical quality changes in potato tubers during storage in different storage systems (on fresh weight basis)

Parameters	Before Storage	After 90 days of storage	
		Traditional storage system	Improved storage system
Tuber dry matter (%)	17.56	15.43	16.05
Total starch content (%)	19.50	15.96	15.51
Reducing sugar (mg/100g)	204.73	298.80	279.12
Total sugars content (mg/100g)	295.89	423.98	402.67
Phenol content (mg/100g)	19.90	24.33	23.91

Tuber dry matter:

The dry matter content of the potatoes stored both in improved and traditional on-farm storage systems decreased during storage. Initially, the dry matter content of the potatoes was observed to be 17.56 per cent. After storage for 90 days, it was found to be 16.05 per cent and 15.43 per cent in case of improved and traditional on-farm potato storage systems, respectively.

Total starch content (%):

The starch content of the potatoes recorded at the beginning of storage was 19.50 per cent. It reduced to 15.51 per cent and 15.96 per cent, respectively in improved and traditional on-farm storage systems.

Reducing sugars:

Reducing sugars content of potato tubers before storage was found to be 204.7 mg/100g on fresh weight of tubers. At the end of 90 days of storage the reducing sugars of tubers increased to 279.1 and 298.8 mg/100g (fresh weight basis) in improved and traditional on-farm storage systems, respectively.

Total sugars:

Total sugars content of potato tubers before storage was found to be 295.9 mg/100g on fresh weight of tubers. At the end of 90 days of storage the total sugars content of potato tubers increased to 402.7 and 424.0 mg/100g (fresh weight basis) in improved and traditional on-farm storage systems, respectively.

Phenol content:

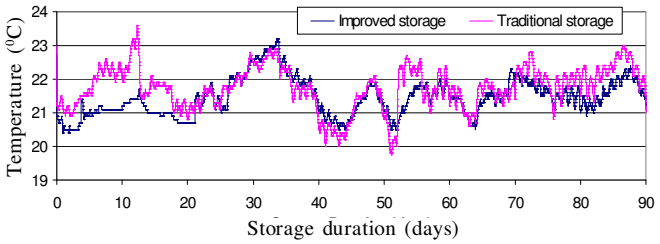
Phenol content of potato tubers was recorded as 19.90 mg/100g fresh weight before storage. Whereas, at the end of 90 days of storage, it was 23.91 and 24.33 mg/100g fresh weight in tubers stored in improved and traditional on-farm storage systems, respectively.

Comparative study of temperature and relative humidity distributions inside on-farm potato storage system:

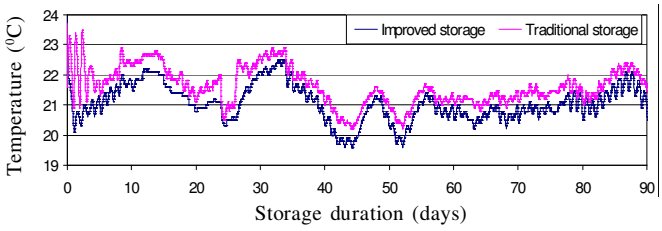
The temperature and relative humidity distributions inside the potato heaps of traditional and improved on-farm potato storage systems were constantly monitored using sophisticated data loggers to identify development of "hot spots", if any, during storage. The results are presented in Fig. 1 and 2.

Temperature distribution:

The temperature distribution inside the potato heaps of traditional and improved on-farm storage systems both at the centre and bottom of the heaps are shown in Fig. 1 (a and b). It could be observed that the temperature during 90 days of storage period varied from 19.8 to 23.9 ^{o}C in traditional system while in the improved potato storage system, it varied from 19.6 to 23^{o}C. With over 13,000 data points recorded over a period of 90 days in each storage system, it was clear that the temperature at any given time was at least 2-3^{0}C less inside the

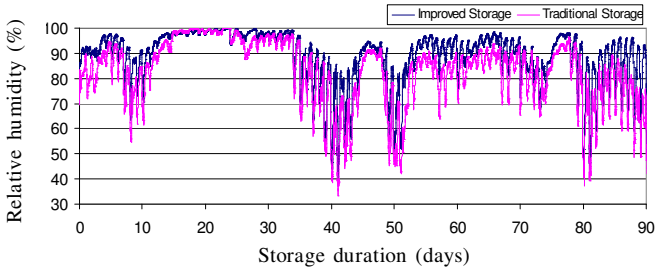


(a) At centre of potato heap

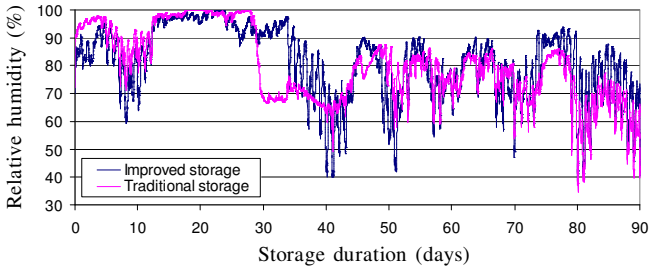


(b) At bottom of potato heap

Fig. 1 : Temperature distribution inside potato heaps during storage in traditional and improved storage systems



(a) At centre of potato heap



(b) At bottom of potato heap

Fig. 2 : Relative humidity distribution inside potato heaps during storage in traditional and improved storage systems

potato heap of improved system when compared to traditional storage system. Further, the temperature at a given point of time both at the centre and bottom of the heap were more or less uniform in the improved system where the tubular aeration was provided. It clearly established the effectiveness of tubular aeration system incorporated in the improved design to dissipate respiration heat of potato tubers. A relatively lower tuber temperature might have reduced respiration and transpiration of potatoes that ultimately might have reduced storage losses.

Relative humidity distribution:

The relative humidity distribution inside the potato heaps of traditional and improved on-farm storage systems both at the centre of heap and at the bottom of the heaps are given in the Fig. 2. It could be observed that the average relative humidity during 90 days of storage period varied from 34.1 to 100 per cent in traditional system while in the improved potato storage system, it varied from 40 to 100 per cent. With over 13,000 data points recorded over a period of 90 days in each system; it was observed that the relative humidity at any given time was uniform throughout the potato heap of improved system when compared to traditional storage system. It indicated the effectiveness of tubular aeration system incorporated in the improved design not only to reduce the temperature but also in maintaining uniform relative humidity throughout the heap.

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