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EFFECTIVENESS OF A DEVELOPED POTATO STORAGE SYSTEM IN SHELF LIFE AND NUTRITIONAL QUALITY COMPARED TO TRADITIONAL PRACTICE IN BANGLADESH

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ABSTRACT

This research was carried out to achieve the objective of finding out the performance of a developed potato storage system in storage life and nutritional quality and comparing the system to the traditional practice in Bangladesh. A laboratory version of improved design of potato store and its construction was made at Bangladesh Agricultural University which consisted an evaporative cooling chamber, made of reinforced concrete cement; partially filled-in with water. Two varieties of potato (Diamant and Lal Pakri) were used in this research. Both large and small types for each kind of potato varieties were taken. Experimental design was set up for both improved storage bin and farmer's traditional practice. Spoilage, sprouting, shrinkage, moisture content, vitamin C, and total sugar content of potato were determined for both methods of storage at a regular interval and results were compared. Economic benefit of the developed storage system over traditional practice was also determined. From the result of the study, it appeared that the improved potato storage bin was better in shelf life and nutritional quality for storing potato than the farmer's traditional practice.

Keywords: Evaporative cooling; potato; sprouting; shrinkage; storage

INTRODUCTION

Potato is one of the most important staple crops in the human diet around the world. Potatoes have been grown in Bangladesh since the 19th century. By the 1920s, the first commercial production of the crop was established in the country **(Islam, 1983)**. Nowadays, potato has emerged as a major food crop in Bangladesh and is being cultivated throughout the country. The total production of potato is 6648 thousand tons from the area of 400 thousand hectares **(BBS, 2008)**. About 81% of the total potatoes produced in the country are harvested from January to April and are available for market, but only 28% of those potatoes are demanded as ware potatoes during the period. This creates a surplus of 53% of ware potatoes, which have to be used or stored over the next 6 months from May to November **(Hossain et al., 2009)**. With respect to the role of post-harvest technology in the development of Asian economies, **Tsubota (1999)** noted that post-harvest technologies become more complex along with economic development. Potato is one of the major food items in Bangladesh which are preserved in cold storage for commercial storage purpose. During 2007 – 2008 potato coverage of 402 thousand hectare, production of 6650 thousand MT and average productivity of 16.6 t.ha^{-1} have been reported. **(Rabbani et al., 2010)**. During 2009 – 2010 production of potato was even higher than the previous years. Due to lack of storage space in nearby cold storage and limitation of household storage facilities it has been quite difficult for farmers to store it in nearby cold storages. At present, only 25 – 30% of the total potatoes produced in the country can be preserved in cold storages. Therefore, there is a need for both short and long term storage of potato. During post harvest operations, some losses occur which is called post-harvest losses **(Ritenour, 2003)**. There are about 300 cold storages in Bangladesh with a capacity of 2.2 million tons. In the year 2008, about 27.5% of total production of potato was stored in the cold storage including seeds **(Rashid, 2008)**. Rest of the potatoes was stored by using traditional storage system.

The chemical composition of the potato tuber is dependent on the cultivar, growing season, location, soil temperature, soil water quality, fertilization, as well as the duration and condition of storage **(Burton et al., 1992; Kumley et al., 2002)**. Variations in chemical composition have a major impact on processing stability and quality **(Iritani, 1981; Burton et al., 1992; Shock et al., 1993; Kumlay et al., 2002)**. Good storage should prevent excessive loss of moisture, development of rots, and excessive sprout growth. It should also prevent accumulation of high concentration sugars in potatoes,

which results in dark-colored processed products **(Hossain et al., 2009)**. To help prevent the Maillard reaction accompanied by undesirable sensory symptoms, low reducing sugar content is appropriate **(Mareček et al., 2016)**. Temperature, humidity, carbon dioxide and air movement are the most important factors during storage **(Harbenburg et al., 1986; Maldegem, 1999)**. When potatoes lose excessive moisture they shrink and may become unmarketable. Sprouting will significantly increase water loss in stored and transported potatoes. Sprouting will also diminish the nutritive quality of the potato. Therefore, sprout inhibitors are required after potatoes pass their dormant phase **(Shetty et al., 1998)**.

In India, Central Potato Research Institute **(Ilangantileke et al., 1996)** has developed a community level Evaporative Cooled Store (ECS) for potato that could store potato up to 120 days beyond the growing season. Moreover, to overcome the problem of inadequate cold storage capacity and heavy price reduction short term non-refrigerated storage of potatoes has been recommended in northern plains of India in a potato store (ECS) cooled by passive evaporative cooling **(Kaul et al., 1984)**. Evidence from on-farm trials showed that, with good management, use of evaporative cool stores (ECS) could reduce storage losses by half compared with farmers' traditional storage methods. With evaporative cooling system, on-farm potato storage can be extended to up to four months, compared with one to three months using traditional methods. Therefore, the present experiment was carried out to design and construct a laboratory version of an improved potato storage bin based on the principles of forced evaporative cooling system, to conduct experiment with the developed potato storage bin and farmers traditional practice as well as to compare the performance between the developed and existing methods of potato stores.

MATERIAL AND METHODOLOGY

Experimental site and period

A potato storage bin was installed inside a newly built Post-harvest Preservation and Processing Laboratory in the Department of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh, Bangladesh. The experiment was started on 1st April 2013 and continued up to 30th November 2013. Laboratory experiments for the determination of nutritional parameters were conducted in laboratory of Food Technology and Rural Industries, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Design of improved potato storage bin

The improved potato storage bin works on the principle of evaporative cooling. The height and diameter of the experimental storage structure were 3.0 m and 2.0 m

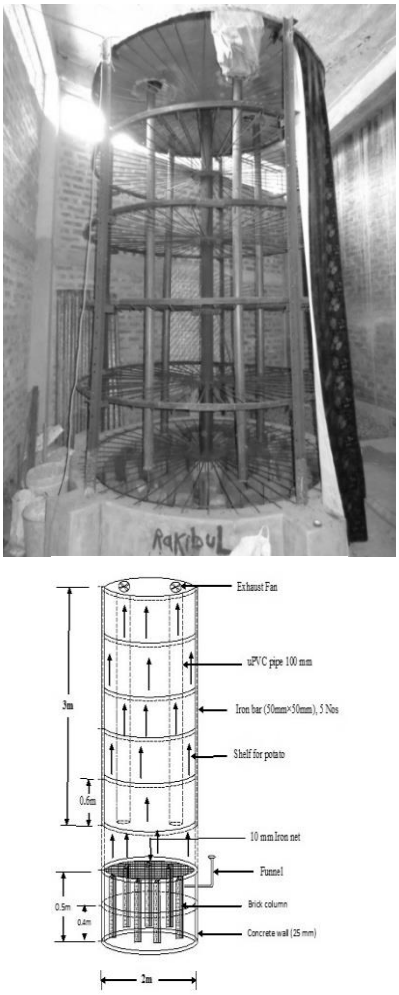

Figure 1 Improved potato storage bin (a) Complete drawing with dimensions (b) Photographic view.

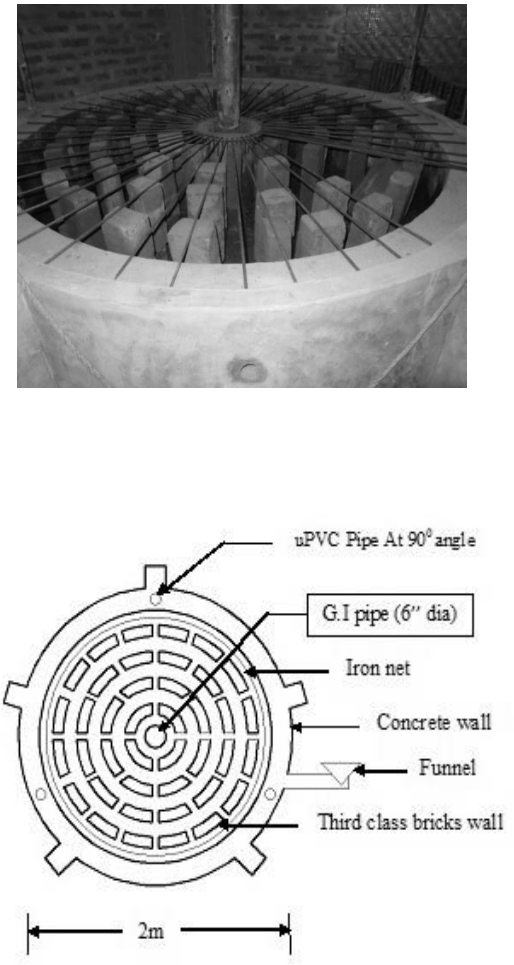

Figure 2 Evaporative cooling chamber (a) Photographic (b) Top view.

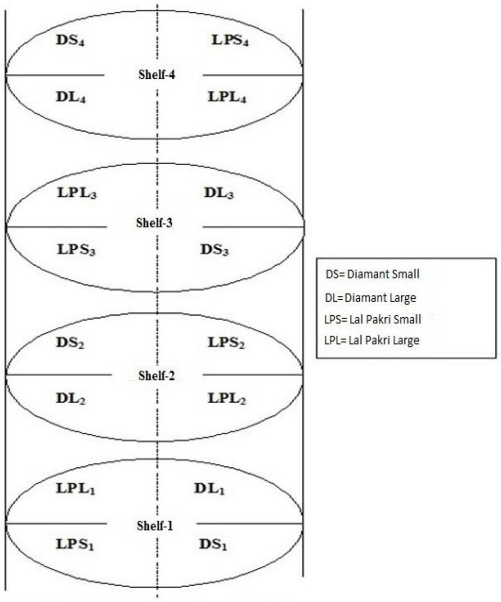

Figure 3 Loading pattern of potato in the improved storage bin.

respectively and the height of each shelf was 0.6 m. To facilitate evaporation and successive cooling action, two exhaust fans that powered by solar panel were used. Four perforated PVC pipe at 90° angles were used so that cool and moist air flowed from evaporative cooling chamber passed uniformly thorough the improved storage bin. A schematic diagram and an experimental prototype of the bin and its cooling chamber are shown in Figure 1 and Figure 2

Description of principle of forced evaporative cooling of stored potato

Evaporative Cooling System (ECS) store is a small store house where potato could be stored in bulk on a raised platform inside an insulated closed structure. Improved ECS was constructed using locally available material such as cement, sand, and M.S. rod. Reinforced cement concrete and bricks were used to build the evaporative chamber having 2.0 m diameter and 0.5 m height at the bottom of the store. At least half of the chamber holds water all the time so that rest of the brick block (having water socking properties) at upper portion can get wet by capillary action. Water was poured in to the evaporative chamber time to time to maintain a constant level of water. An outside transparent plastic tube indicated the required level of water. A forced air ventilation by a rotary exhaust fan, powered by solar panel, located at the top of the storage bin helped accelerate evaporate water from the evaporative chamber kept below the storage bin. Cool and moist air flow helped maintain the inside storage temperature below the air temperature inside the bin. Two exhaust fans (each 300 mm dia), placed on the top of the storage bin and powered by three solar panels forced the inside air out so that the potato enjoyed fresh air/oxygen from outside the bin. These exhaust fans generated an airflow rate of 0.6 $m^3/m^2/sec$ and was operational only during 12 hours day time.

Selected varieties of potato for the experiment

Two potato varieties (Lal pakri and Diamant) in two different sizes (small and large), were stored inside the bin on 25 March 2013. Before loading into the bin the potatoes were sorted and allowed several days for curing. Potatoes were stored in four different shelves. Each shelf contained four categories of potatoes (Lal Pakri-small, Lal Pakri-large, Diamant-small, and Diamant-large). All potatoes were stored in nylon netted sack of 10 kg each. In addition, ten small nylon netted sack of one kg potato from each category was placed in each shelf for determination of moisture content, vitamin C, and total sugar content. Equivalent Farmers' Traditional Storage (here after called Farmer's Practice) was also maintained inside the laboratory with the same categories of the potato.

Design of experiment

The principle of Completely Randomized Block Design (CRBD) with 3 factors, 4 replications was considered for experimentation. There were eight treatment combinations (2×2×2=8) as follows:

- Factor A (Storage condition: 2 levels): (a) Improved storage (b) Normal storage,
- Factor B (varieties of potato: 2 levels): (a) Diamant (b) Lal Pakri,
- Factor C (Size of tubers: 2 levels): (a) Large (b) small.

Sixty kg (in 6 bags) potatoes of each of (a) Diamant Large (about 100 gm/tuber), (b) Diamant Small (about 51 $gm.tuber^{-1}$), (c) Lal pakri Large (about 23 gm/tuber) and (a) Lal Pakri Small (about 11 $gm.tuber^{-1}$) were loaded on all the 4 shelves of the Improved Storage Bin as per loading pattern shown in Figure 3. In total, 960 kg potatoes were loaded into the Improved Storage Bin for experimentation.

For the Equivalent Farmer's Traditional Storage (Farmer's Practice) 115 kg of Diamant Large, 110 kg of Diamant Small, 85 kg of Lal Pakri Large and 120 kg of Lal Pakri Small potatoes were kept on C.C. floor (over a bamboo mat with a thin layer of dry sand) inside the same room in which the Improved Storage Bin was located.

Figure 4 Photographic view of equivalent farmer's traditional practice.

Figure 5 Photographic view of data measuring instruments: (a) Data logger (b) Digital thermometer, hygrometer, anemometer, and blower.

Loading pattern of potato into the improved storage bin

There were two varieties (Lal pakri and Diamant) of two different sizes (small and large) of potato. Before loading into the bin potatoes were sorted and kept laid on the floor for several days for curing. Sorting was done manually. Potatoes were stored in four different shelves. Each shelf contained four categories of potatoes: Lal Pakri-small (LPS), Lal Pakri-large (LPL), Diamant-small (DS) and Diamant-large (DL). Every 10 kg of potato was kept in nylon netted sack. In addition, ten small nylon netted sacks containing 1 kg potato from each category was placed in each shelf for determination of moisture, vitamin C, and sugar content. Potato loading pattern for experimentation is shown in Figure 3.

Equivalent farmer's traditional practice

Farmer's traditional equivalent practice was also maintained inside the laboratory for comparing with the improved potato storage bin for different categories of potatoes viz. Lal Pakri-small (120 kg), Lal Pakri-large (85 kg), Diamant-small (110 kg), and Diamant-large (115 kg) (Figure 4). Potatoes were observed to figure out spoilage, sprouting, shrinkage, moisture content, vitamin C, and sugar content.

Experimental data collection

Experimental data collection was started on April 2013 and continued up to November 2013. Air temperature above four shelves (inside the bin) and the temperature of potato at sixteen points were recorded by a data logger and Lab View software (Figure 5). Air flow through the bin, relative humidity of air inside the bin, and ambient air temperature were measured. Sample potato was taken from 16 different cells of the shelves to find out the spoilage, sprouting, shrinkage, moisture content, vitamin C, and total sugar content.

Determination of biological parameters

Determination of potato spoilage

Number of potato spoiled (i.e. unacceptable due to rotten) was recorded by observation method at 15 days interval for all categories and population of potato kept in the sacks. The amount (by weight) of spoiled potato was calculated multiplying the number of spoiled potato found by the mean weight per potato tuber. Similarly, same method was followed to determine the spoilage found in farmer's traditional practice. Thus, monthly spoilage of potato was obtained for both the storage methods.

Determination of sprouting

The method of eye observation and measured by length of sprouts was considered in estimating the percent of potato sprouted in each sack kept in four shelves of the experimental potato storage bin as well as potato of Farmer's Equivalent Traditional Storage. Sprouting of a potato was considered here for its growth 10 mm and above. It was observed when potato samples were taken for determination of other parameters mentioned above.

Determination of shrinkage

Shrinkage is another phenomenon of natural potato stores. It was estimated by the volume decreased in a

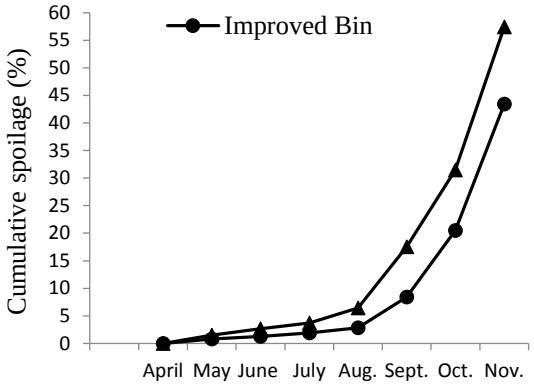

Figure 6 Spoilage of Diamant (small) variety.

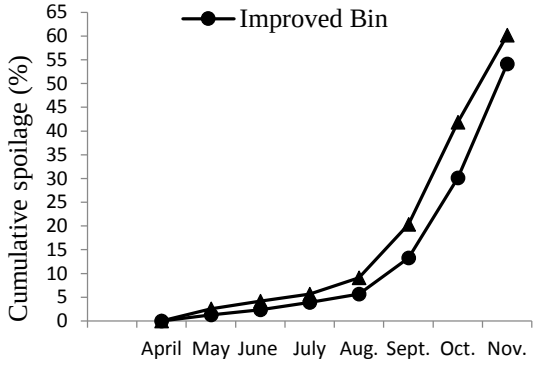

Figure 7 Spoilage of Diamant (large) variety.

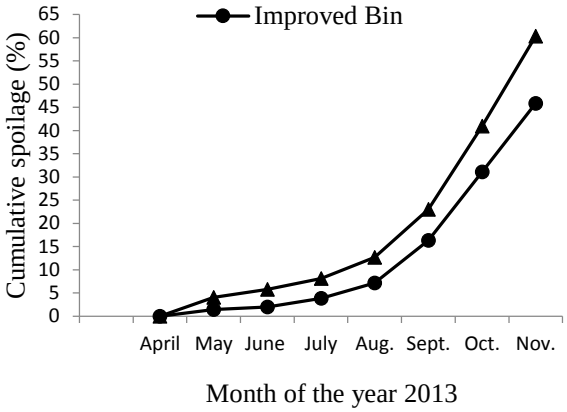

Figure 8 Spoilage of Lal Pakri (large) variety.

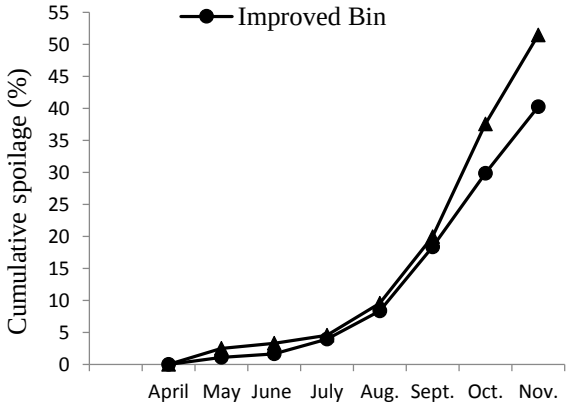

Figure 9 Spoilage of Lal Pakri (small) variety.

particular time of sample collection and was recorded by observation method and scaled using Likert scale (0 – 5) of quality assessment. Zero (0) and 5 indicates 0% and 50% shrinkage by volume, respectively.

Determination of nutritional parameters

Determination of moisture content

Moisture content was determined by following the AOAC official method 934.06 (2005).

Determination of vitamin c content

Vitamin C content was determined by using AOAC International Methods of Analysis volume 16 Method 967.21 (1995)

Determination of sugar content

Total sugar content of the sample was determined by following the method of Rangana (1991)

Economic benefit

Ignoring the fixed cost of the facilities, calculation of the gross economic benefit using improved storage bin may be calculated using the following model. The model determines the relative savings of potato from loss in the Improved Storage Bin over farmer's traditional storage.

$$B = p \times [(ps – plsp \times ldsp – plsk \times ldsk)] \quad (1)$$

Where:
B = Gross benefit in the improved storage bin over farmer's storage in any month, $Tk.kg^{-1}$,
p = Unit market price of potato, $Tk.kg^{-1}$,
ps = Percent of potato saved,
plsp = Price loss factor for sprouting, fraction,
ldsp = Percent loss difference due to sprouting,
plsk = Price loss factor for shrinkage, fraction,
ldsk = Percent loss difference due to shrinkage.

Optimum duration of storage

The optimum duration of potato stored in the improved storage bin may be determined by the time unit (month) when the economic benefit (B) becomes maximum. Mathematically, it could be obtained by taking first derivative of the benefit equation (1) and equating to zero value. That is:

$$d(B)/d(t) = p \times [(ps – plsp \times ldsp – plsk \times ldsk)] = 0$$

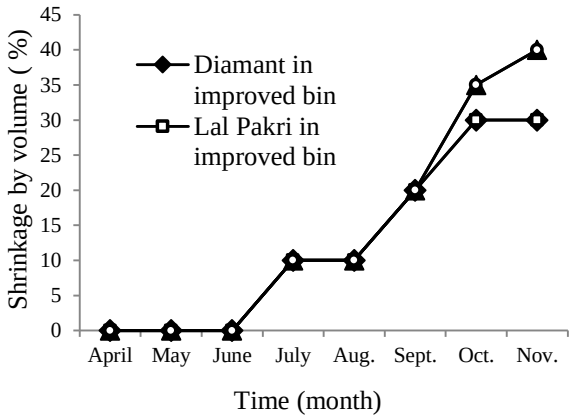

Figure 10 Shrinkage of different varieties of potato for improved bin and farmer's practice.

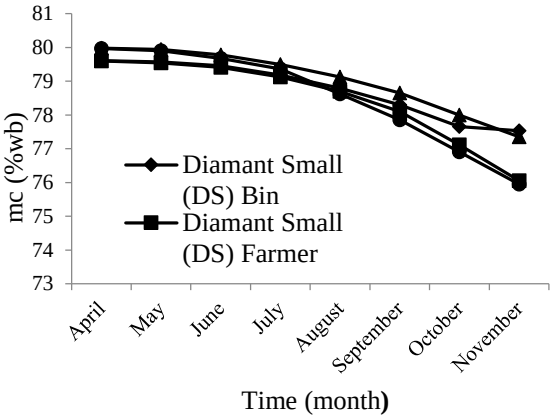

Figure 12 Moisture content of potato (Diamant variety) for improved bin and farmer's practice.

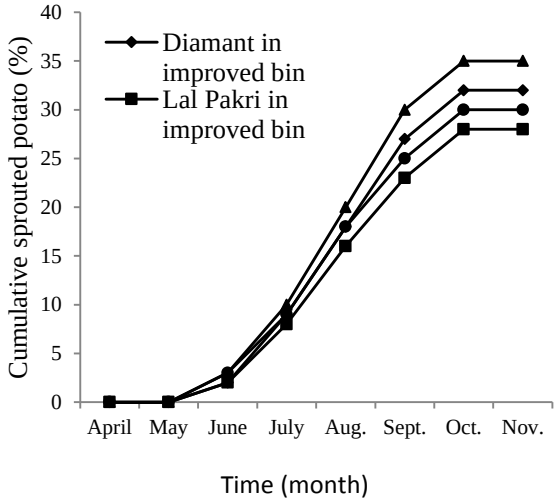

Figure 11 Sprouting of different varieties of potatoes for improved bin and farmer's practice

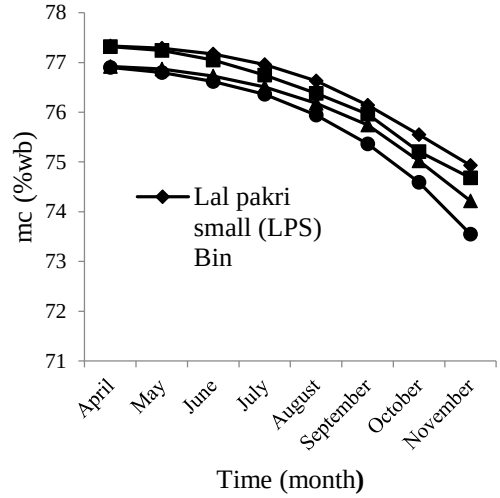

Figure 13 Moisture content of potato (Lal pakri variety) for improved bin and farmer's practice.

RESULTS AND DISCUSSION

Potato spoilage

Spoilage of potatoes is shown in Figure 6 to Figure 9, for four categories of potatoes. These figures indicate that the average spoilage of all four categories of potatoes in the Improved Storage Bin was 20.06% lower than that of Farmer's Traditional Practice. On the other hand, the figures also show that the spoilage rate was also higher in Farmer's Practice than that of Improved Storage Bin. The quality in terms of physical appearance of potatoes (before and after experimentation) found better in the Improved Storage Bin than that of Farmer's Practice. No difference of spoilage of potatoes was found between the shelves of the Improved Storage Bin. The Evaporative Cooling Chamber at the bottom of the Improved Storage Bin positively contributed in cooling the potato as well as maintaining the required humidity inside the bin. As a result the spoilage and the shrinkage of potato were found 20.06% and 25.00% less, respectively, in the Improved Storage Bin than that of farmer's practice.

Shrinkage

Shrinkage is another phenomenon of natural potato stores. Figure 10 shows the percent of shrinkage of potato over time. Shrinkage increased with the increase of time. It was observed after six months of storing (i.e. beyond September); it was 25% higher in case of farmer's practice than that of improved bin. It revealed that shrinkage of potato was lower in the Improved Storage Bin than that of farmer's practice.

Sprouting

Sprouting was the common phenomenon of stored potato in both the method of storage. Sprouting of potato started after four months of storing but growth stopped after six months in both the method. Figure 11 represents the growth of sprout. It indicates that the percent of sprouting was 8.57% lower for Diamant variety in the Improved Storage Bin than that of farmer's practice. Sprouting was found lowest (6.66%) in case of Lal Pakri stored in the Improved Storage bin. That means Improved Storage Bin performed better regarding control of sprouting. It may be mentioned here that no control measure for sprouting was undertaken in both the storage methods.

Moisture content of potato

Moisture content of stored potatoes decreased with the increase of time. The average moisture content of Diamant

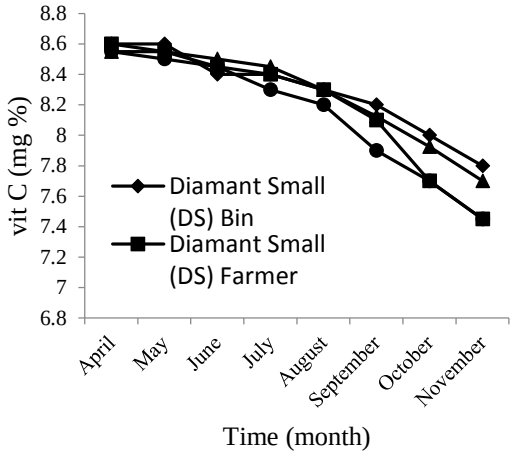

Figure 14 Vitamin C content of potato (Diamant variety) for improved bin and farmer's practice.

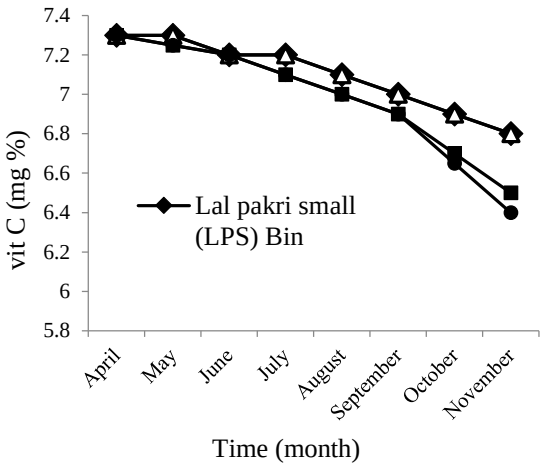

Figure 15 Vitamin C content of potato (Lal pakti variety) for improved bin and farmer's practice

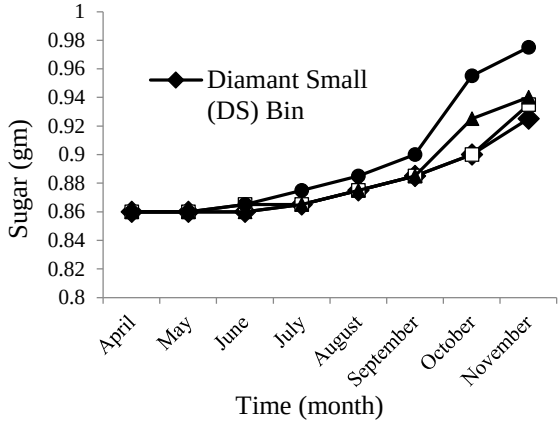

Figure 16 Sugar content of potato (Diamant variety) for improved bin and farmer's practice

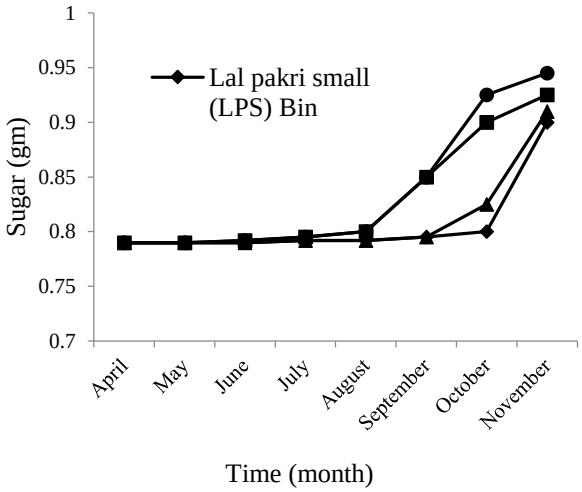

Figure 17 Sugar content of potato (Lal pakri variety) for improved bin and farmer's practice.

variety as measured in the beginning of storing was about 79 percent for both the method of storage. The rate of moisture loss for Diamant variety with respect to time is shown in Figure 12. It can be said that potatoes from improved bin had experienced a less amount of moisture loss during the eight month period while moisture loss of potatoes from farmer's practice was higher. Moisture loss of Diamant small variety in improved bin and farmer's practice was 2.61% and 4.4% respectively. In case of Diamant large variety it was 3.28% and 5.02% respectively. Similar types of results were observed in Lal Pakri variety as shown in Figure 13. Loss of moisture of Lal Pakri small variety in improved bin and farmer's practice was 3.10% and 3.41% respectively, where loss of moisture of Lal Pakri large variety in improved bin and farmers' practice was 3.51% and 4.32% respectively.

Vitamin-c content

Vitamin C content of stored potatoes decreased with the increase of time. Figure 14 shows that the loss of vitamin C content was found 4.07% and 2.92% higher in Diamant small and Diamant large varieties, respectively, in farmer's practice than that stored in the Improved Storage Bin. Same kind of trends can be seen in case of Lal Pakri small and Lal Pakri large varieties from Figure 15 where loss of vitamin C was found 4.1% and 5.47% higher respectively in farmer's practice than that of improved storage bin. However, the level of vitamin C loss was higher in the Diamant variety than that of Lal Pakri variety. It may be concluded that the Improved Storage Bin could help maintain higher level of vitamin C than that of farmer's practice.

Sugar content

When stored at relatively low temperature, tubers of conventional potato varieties accumulate sugars. Figure 16 and Figure 17 indicates that Diamant Large variety accumulated much sugar than Diamante Small variety and Lal Pakri Large variety accumulated much sugar than that of the Lal Pakri small variety. However, total sugar content of stored varieties in farmer's practice found slightly higher than that of improved storage bin.

Economic benefit

The economic benefit depends mainly on market price of potato. If the price of potato increases significantly with time of storage then the Improved Storage Bin will be more beneficial and attractive to the potato farmers and traders. In 2013, the increase of market price of potato beyond harvest season was not significant with compare to

last couple of years. The price trend of potato is graphically presented in Figure 18. This price trend was used to calculate the gross benefit of use of Improved Storage Bin over farmer's traditional practice. Gross benefit decreases with increased rate of sprouting and shrinkage. The price loss due to sprouting and shrinkage considered here were 10% and 80%, respectively. Ignoring

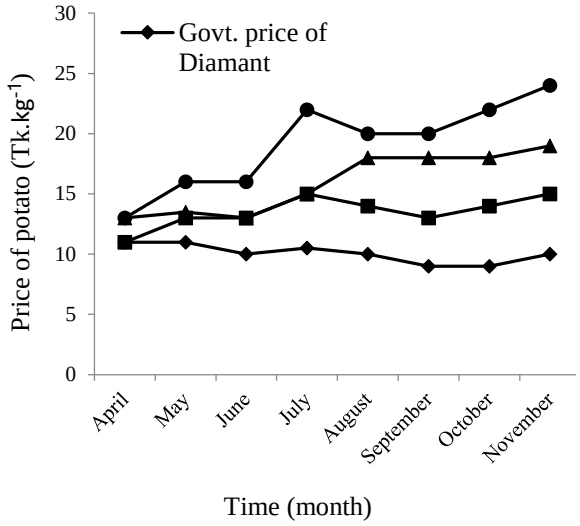

Figure 18 Government and market price of potato in the year 2013.

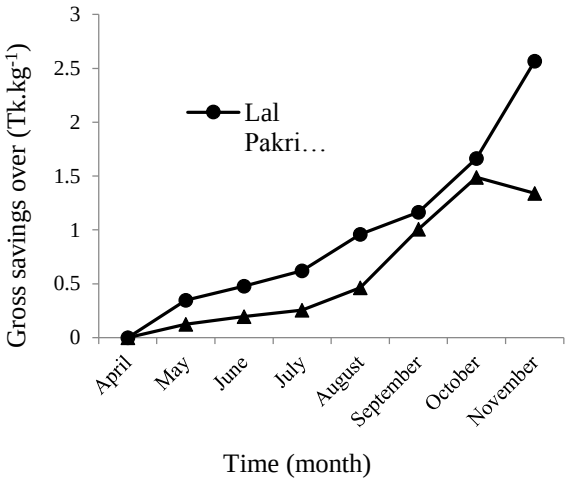

Figure 19 Gross savings in improved potato storage bin over farmer's practice.

fixed cost of the storage methods, the gross benefit of using improved storage bin over farmer's practice was calculated using equation no. 1 mentioned above and is presented in Figure 19. Fixed cost has been ignored here because the laboratory version of the storage structure cannot be compared with Farmer's Practice until a farmer version is available. Therefore, only the variable costs were considered. It reveals that the maximum gross benefit of storing Diamant variety using improved storage bin found in the month of October. Beyond October the gross benefit started decreasing due to price loss for higher level of shrinkage and/or sprouting. In other words, Diamant variety could be stored up to seven months after harvest. On the other hand, Lal Pakri could be stored in the improved storage bin for longer period with higher profit. This was mainly due to higher market price of Lal Pakri than that of Diamant variety. Figure 19 indicates that Lal Pakri would bring gross profit by Tk. 2.57 per kg (calculated using market price of November 2013) over Farmer's Practice, if stored up to November. On the other hand, Diamant variety would bring gross profit by Tk. 1.34 per kg over Farmer's Practice, if stored up to November.

CONCLUSION

Experimental results revealed that there was always a significant temperature difference between potato and air inside the bin. Potato spoilage gradually increased proportionally with the months. This trend was found in farmer's traditional practice also. But percentage of cumulative spoilage was lesser in the improved bin. No significant difference of spoilage was found among different layers of potato laid inside of the improved bin. Spoilage of potato progressively increased from April to November. Sprouting was found from the mid of June. It was higher in farmer's practice than that of storage bin. Sprouting of potato gradually increased from June to October, but stopped in November. Shrinkage of potato was almost same in both of the practices but found higher in farmer's practice than that of storage bin from October to November. In case of nutritional parameters the improved storage showed a good level of performances. Moisture content of potato kept decreasing at a gradual rate. But potatoes in the improved bin experienced a less amount of moisture loss than that of farmer's traditional practice. Same type of trend also found in case of vitamin C content. Besides, the sugar accumulation in the improved bin was a bit less than the farmer's practice. Moreover, the improved storage bin may bring benefit for both Diamant and Lal Pakri varieties but higher gross benefit and longer safe storage for Lal Pakri variety. In this study, we have also possibility of further research. The technology may be tested for multi-purpose use with similar crops so that it could be more profitable and attractive to farmers. Finally, it can be said that the improved potato storage bin was better for storing potato than the farmer's traditional practice.

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