Increasing Potato Yields through Improved Potato Storage Pits

Prepared by Jessica Schweiger (IPO), Michael Potts (CRS), Dylan Keith (IPO), Maria-Paz Santibanez (IPO), Michelle Neukirchen (CRS), Farid Yari (CRS), and Mark Bell (IPO)

UC DAVIS COLLEGE OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES
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Potatoes in Afghanistan

Potatoes are produced in all regions of the country. Of the 34 provinces in Afghanistan, 24 report potatoes as a major commodity. Potato storage is especially important in the cooler highland provinces where potatoes are harvested in September and October for household consumption during the winter and the lean food period (late winter to early spring). Potatoes grown in lowland provinces are typically harvested and sold when prices are near the peak (May/June). Currently, potatoes are stacked loosely in pits and covered in dirt (Figure 1). Losses from traditional potato storage pits average 40%. The **best way to decrease losses** is through **better harvest techniques** and **storage pits with ventilation**.

Figure 1. Traditional potato storage pit.

Reducing postharvest losses depends on 1) the construction of a good storage pit, 2) proper harvest and handling, and 3) removal of damaged tubers before storage.

Cultivation and Harvest Practices

A thorough harvesting and post-harvest training program helps guarantee the success of pit storage.

Factor	Practice	Reason
Irrigation	Harvest potatoes when dry. Make the last irrigation about 20 days before harvest (Figure 2).	Harvesting potatoes when they are wet will cause more disease. Soil will stick to potatoes and carry diseases into storage. Also, when potatoes are wet their pores are open, which allows diseases to easily infect the potato.
Cutting stems	Cut off stem at ground level 12 - 15 days before harvest and remove this from the field (Figure 3)	This practice toughens the skins, making the potato more resistant to damage and diseases and better for long term storage. Removing the stem and leaves from the field reduces the number of pests and diseases in the potato field next year.
Careful Handling	Place only healthy undamaged potatoes into storage.	Even with improved storage pits, storage losses will remain high if damaged or diseased potatoes are stored.
	Do not drop potatoes more than 30 cm.	When dropped, potatoes can bruise leading to rotting.
	Try not to damage the potato skins during and after harvest	Diseases can enter where the potato skin is broken. Fusarium spp (Figure 4) is the most common disease.
Protect against pests	Remove any potatoes damaged by pests before storage.	While pests that damage potatoes are not a big problem in Afghanistan, diseases can enter potatoes where any damage has occurred.
Pit cleanliness	Use a new pit, or clean old pits thoroughly before use.	While using the same pit each year can reduce labor and costs, it can lead to a build-up of pests.

Figure 2. Make the last irrigation 20 days before harvest. *(Source: CRS, 2013).*

Figure 3. Cut and remove stems from the field to reduce disease and toughen skin.

Figure 4. Fusarium rot. (Source: CRS,2013)

Improved Potato Storage Pits

Improved Potato Storage - What is it?

Improved underground storage pits use two simple modifications to improve upon the traditional Afghan techniques for storing potatoes - over winter - in pits dug in the ground. By adding ventilation ducts and a means to monitor temperature and humidity, farmers can reduce postharvest losses, maintain crop quality, and increase storage time.

Improved Underground Storage Quick Facts

Cost	$
Time	< 1 day
Season	Summer / Fall
Gender	♂
Region	Highland areas only
Level	Easy

How does it work?

Improved storage pits work by allowing air circulation through the stored potatoes. The air movement reduces temperature and humidity in the pit and allows gases that favor the development of pests and diseases in the pile to escape (Figure 5). The vertical and horizontal ventilation ducts allow cool outside air to enter, cool the stack and circulate through the pile. The warm, moist air and any gases generated by the potatoes exit through the exhaust vent above the potatoes. The storage pits can work for a variety of crops (see section below "Suitable crops").

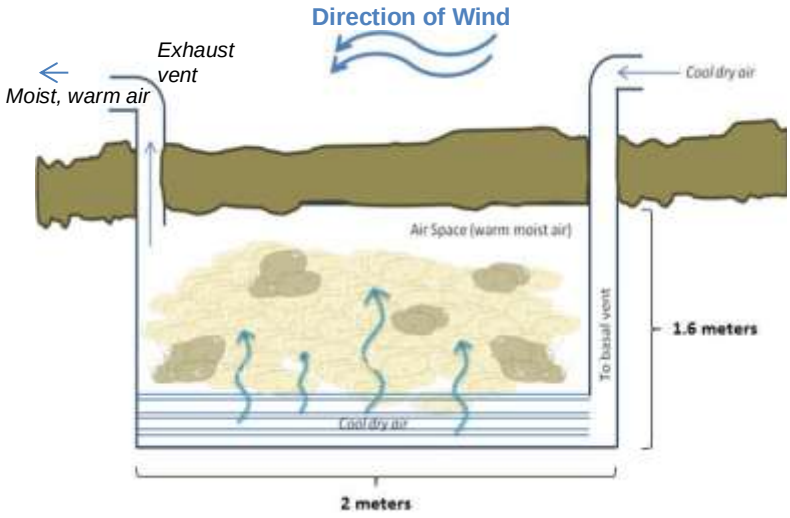

Figure 5. Example of underground storage with ventilation. Source: CRS

Advantages

Simple, inexpensive, and familiar to farmers. Improved pit storage units are easy to construct as they build upon the traditional Afghan storage technique for potatoes. The concept of ventilation is also easily understood by farmers.

Reduced storage losses. Because Potatoes are alive after they are harvested, they respire and give off heat and moisture. With traditional pit storage, heat and moisture increase within the pit. The warm, moist air encourages the growth of diseases that cause potatoes to decay. Cooling the potatoes with cool outside air preserves the crop. Having some warm air at the top of the improved storage pit can also reduce losses due to freezing during winter. Such losses are common in traditional pits.

Higher prices. Because farmers can store their potatoes longer, they have more flexibility in their potato marketing. For example, prices for crops are often higher later in the year compared with harvest time as seen in Bamyan province, where spring potato prices are often exceed 88% higher than at harvest-time.

Key Considerations

Feasibility and need. Determine storage issues, postharvest losses, and market prices from talking to village leaders, elders, farmers, and market traders. Assess the value of the storage losses and potential benefits from storage. Questions to consider:

- How many farmers in the village currently store their potatoes after harvest?
- How much crop do they store in an "average" year?

- What percent of the crop do they lose?
- What quantity of potatoes would they store for sale later (winter/ spring) if they had a reliable storage practice.
- What is the difference in prices between in-season and off-season crops?

Site selection. The storage units can be used in highland provinces, such as Ghor, Bamyan, Daikundi and Baghlan. Choose a site that is dry and well-drained, preferably slightly elevated with a slope to provide natural drainage. **Avoid areas that flood or have a high water table.** If possible, rotate storage sites every year to prevent any build-up of pests. Using the same pit every year will decrease construction costs significantly; however, the pit must be cleaned after emptying every year.

Storage capacity. Underground storage (Figure 5) is suitable for households or small farms. In practice one should make the pit to suit the amount to be stored. A full pit (plus airspace) is required to make the system work. Most Afghan farmers store around 2 MT of potatoes. 1 m^3 of potatoes weighs approximately 700 kg. A pit of around 4.5 cubic meters is required to store around 1.5-1.7 MT of potatoes. The capacity of the 2 m x 1.4 m x 1.6 m pit described here is approximately 2.1 - 2.5 m^3 of potatoes, or **1,470 kg/ 1.47 MT - 1,680 kg/ 1.68 MT**. While the overall capacity of the storage pit is ~4.48 m^3, this includes a mandatory air space above the potatoes of 40 cm/ 1.12 m^3 and space for the vents, leaving 2.1 – 2.4 m^3 for the potatoes alone.

Potato Weight (kg)	Total Pit Volume Needed (m^3)	Pit Air Space (m^3)	Required Pit Space (m^3)	Pit Depth (m)	Pit Width (m)	Pit Length (m)	Number of Vents
1,680	2.4	1.1	4.5	1.6	1.4	2	1
3,528	5.0	2.0	8.0	1.6	2.5	2	1
7,056	10.1	4.0	16.0	1.6	2.5	4	2

Suitable crops. Many crops, such as carrots, cabbage, onions and apples, store well in pits. Seed potatoes and potatoes for consumption can be stored in the same pit but should be kept separated. Net bags (similar to those used for onions) are a good way to keep seed potatoes separated in storage. **Do not use grain sacks** to store seed potatoes, they do not allow for sufficient ventilation.

Have separate pits for fruits and vegetables. In general, storing fruits like apples with vegetables like potatoes causes faster deterioration of the vegetables. If apples or other fruits or vegetables need to be stored in the same pit, the fruit (which typically produces a gas called ethylene) must be stored on top of the potatoes so the ethylene escapes up before affecting the potatoes.

Begin with a high quality product. Crops being stored should be mature, dry, undamaged and disease-free. Damaged produce always has a shorter post-harvest life than undamaged produce. Crops such as potatoes should also be cured before storage to reduce the chance of disease, water loss and sprouting (see step 2 below on how to use the pit for detailed curing instructions).

Control temperature and humidity. Optimal long-term storage temperature and humidity varies by crop; for potatoes 4°C/ 38°F is ideal. Monitor humidity using a small mirror (see Mirror Technique below).

Ensure air flow. Air must be able to move through and exit the pile to release heat and moisture generated by the vegetables. See Instructions section for specifications on ventilation ducts.

Improved Potato Storage Pits

Materials

- ☑ **Wood strips**, such as small poplar or willow branches (or any thin material)
  - ***2 m strips for the triangular ventilation frames***
    Each triangular ventilation frame is a 40 cm equilateral triangle (*Figure 6)*. The number of vents needed depends on the length of the pit.
    Example: For a 2 m long pit, you will need only one vent and therefore:
    1 vent x 3 sides per frame x 2 m/ side= 6 m minimum of framing material
  - ***40 cm strips for the side slats of the ventilation frames***
    The number needed will depend on size and spacing of slats on the vent and length of the pit. Gaps between slats should be not more than 3 cm. Vents should run the full length of the pit.
    Example: A pit 2 m long with slats 2 cm wide spaced 2 cm apart on the vent requires:
    50 slats per vent side x 2 sides x 1 vent for the length of the pit = 100 slats 40 cm long

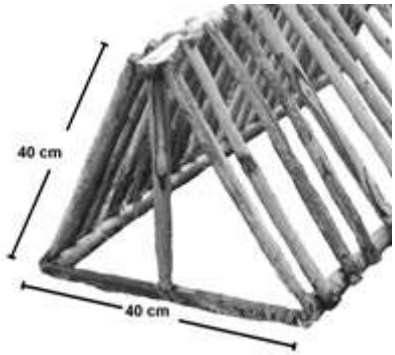

Figure 6. Wooden floor ventilation duct. *(Source: CRS, 2013).*

- ☑ **Input Pipe (to connect to basal vent)**, 10 – 15 cm dia. x 3 m long.
- ☑ **Exit (exhaust) Pipe**, 10 – 15 cm dia. x 1.5 m long. Pipes can be any material; plastic, old metal *bukari* flues work well, or bricks stacked like a chimney.
- ☑ **Elbow joint** (s) and **glue** for the vertical ducts, if available
- ☑ **Poles** or other timber the width of the pit plus 1.5 m, to cover the pit. Seven per meter of pit length. *Example:* A pit 2 m long x 1.4 m wide requires:
  7 x 2 m = 14 poles
  1.4 + 1.5 m ≈ 2.9 m in length each
- ☑ **Boards** for covering the pit**,** enough to cover a 2 m x 1.4 m area.
- ☑ **Boards** for covering the pit opening, enough to cover a 45 x 60 cm area
- ☑ **Brushwood**
- ☑ **Shovel**
- ☑ **Hammer & nails**

Instructions

Building the Pit

1. **Dig the pit.** Dig a rectangular pit 2 meters long, 1.4 m wide and 1.6 m deep (Figure 7). Depth and width can be adjusted, however:
   - Deeper pits impede air flow and can lead to rotten produce. They are also less practical to dig and unsafe (walls can collapse).
   - Pit width should not exceed 2.5 m wide (1 m either side of the vent), as this is the maximum floor area that one triangular floor vent can aerate.

Figure 7. Digging storage pit. *(Source: CRS, 2013).*

   The walls should be allowed to dry prior to filling as the walls absorb quite a lot of moisture and also help to regulate the humidity. Digging the pit one month before covering is best.

2. **Construct the horizontal ventilation ducts.** Using any thin material (for example, willow or poplar tree branches), construct an equilateral triangle of 40 cm sides in cross-section made up of units approximately 2 m long for easy handling (Figure 6). Slats 2 cm wide run vertically with 2-3 cm gaps between the slats.

3. **Install horizontal ventilation ducts.** Place on the bottom of the pit evenly centered between the two sides (Figure 8). Notice in Figure 8 that they are using a flat vent instead of the triangle design. The triangle vent is better, but the flat design will also work.

   One vent will adequately aerate a stack 2.0 m long, 2.5 m wide and 1.6 m deep (the width and depth of a typical Afghan pit). Thus one vent along the center of the floor of a 2 m length pit is sufficient.

Figure 8. Installing vent. *(Source: / CRS, 2013).*

4. **Install vertical ventilation ducts.** Vertical ventilation ducts can be made of many things. Some possibilities include old *bakari* flu pipes, plastic pipe, or pipes made from bricks. Pipes should be between 10 -15 cm in diameter, and long enough that they will extend approximately 30 cm above the surface of the soil when the pit is covered. Attach an elbow joint with glue at the top or bend the top horizontally to assist air movement through the stack. Connect one vertical duct to one end of the horizontal vent that is sitting in the bottom of the pit – this ensures proper movement of cool, dry air through the base of the potato stack (Figure 9). The shorter exhaust vent should stick out from the opposite end of the stack to vent warm air and gases. The top of the input pipe should face into the wind and the exhaust pipe should face the opposite direction (Figure 2), this helps push air through the storage pit.

Figure 9. Installing pipe. *(Source: CRS, 2013).*

5. **Cover the pile**. Cover the pit with rough timber poles (Figure 10) to provide strength. Then cover poles with flat boards (Figure 11), followed by a layer of brushwood to prevent soil falling through (Figure 12). Cover brushwood with 50 cm of soil to ensure good insulation (Figure 13). Less soil cover can increase the chances the crop will freeze. Leave an opening approximately 45-60 cm square (large enough for a basket to pass through) to allow access to the storage to empty the pit. Cover the opening with boards and the same amount of soil as for the rest of the pit. The creation of a roof to the pit is necessary so that there is a space between the

Figure 10. Support poles. *(Source: CRS, 2013).*

Figure 11. Cover with boards. *(Source: CRS, 2013).*

Figure 12. Cover with brush. *(Source: CRS, 2013).*

Figure 13. Cover with dirt. *(Source: CRS, 2013).*

potato stack and the roof. This traps the warm, moist air that is rapidly expelled when the exhaust vent is opened, causing air to be drawn in and pass through the stack.

! **In storage pits larger than 2.5 m wide, more than one ventilation duct should be used, with horizontal and vertical ducts evenly spaced every two meters.**

Using the Pit

1. **Fill the pit with potatoes.** Stack the potatoes up to 1.2 m deep. Leave approximately 40 cm from the top of the stack to the top of the pit wall (air space). The size of the pile is limited by:
   a. Adequate ventilation. If the stack is too small, it will not generate the heat required for convection to drive the ventilation system. If the pile is too large, vegetables in the middle will heat up and accelerate spoilage. Long piles will need an extra vertical ventilation duct in the middle of the stack.
   b. Amount needed. Once opened, the storage should be emptied because it is difficult to re-close securely. Make several small storage pits rather than one large one.

   Potatoes in storage should be stacked evenly to ensure even air flow throughout the pile (Figure 14). In an uneven potato stack, moving air at the bottom will take the shortest route to the surface of the stack and thus may not circulate through potatoes piled too high.

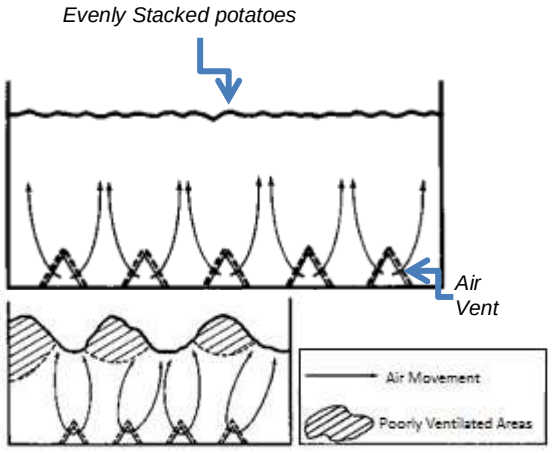

Figure 14. Distribution of potatoes in a storeroom affects ventilation. Triangles in the drawing are basal air ducts. The figure at the top shows evenly distributed potatoes receiving equal air circulation throughout the pile. The bottom 2 figures show uneven piles and area of the pile that will receive poor air flow. *(Source: CIP. 1981. Principles of Potato Storage. Lima, Peru: International Potato Center (CIP) 105 pp).*

2. **Curing**. After covering the pit, the above-ground ends of the inlet and exhaust pipes should be sealed with a rag (figure 15) for ten days in order to allow the stack to warm gently and become humid.. This encourages curing-- skin healing which prevents the entry of disease and loss of moisture – which is very important when selling potatoes by weight. After the curing period the vents should be opened to allow the expulsion of the warm moist air and the stack to return to the optimal long-term storage temperature.

Figure 15. For curing, cover both pipes to reduce air movement. *(Source: CRS, 2013).*

3. **Check pit temperature and humidity every 5-7 days.** Initially, leave the pit vent open until the ambient temperature drops to near freezing at night as this allows the maximum of warm humid air to escape. When ambient temperatures are near freezing plug the vent with rags and control the temperature and humidity using the "mirror" technique described below.

   The "mirror" technique. The temperature in the pit should be around 38^{o}F, which is around the temperature reached by mid-morning in winter. Warm moist air forms small drops (condenses) on a cold surface. A small shiny piece of metal, such as the back of a tobacco tin adjusted to the outside temperature, can be used to check temperature and humidity inside the pit. Open both the vents and hold the metal just in front of the exhaust opening (figure 16) and see if small water drops form on the metal surface

Figure 16. The mirror technique. *(Source: CRS, 2013).*

(condensation). If condensation occurs when the vent is opened then the pit is warmer than the outside air and too humid, ventilation is needed. Leave the vent open until no condensation occurs. This may take a few hours (and the outside temperature may rise, but not by much).

Additional Resources

- Small Scale Postharvest Practices: A Manual for Horticultural Crops: http://postharvest.ucdavis.edu/libraries/Small-Scale_Postharvest_Practices_A_Manual_for_Horticultural_Crops/
- UC Davis Postharvest Technology Center: http://postharvest.ucdavis.edu/
- Principles of Potato Storage, International Potato Center (CIP), http://cipotato.org/resources/publications/manual/principles-of-potato-storage
- e-Afghan Ag postharvest page: http://afghanag.ucdavis.edu/other-topic/postharvest