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A STUDY ON PRE-COOLING AND STORAGE FACILITIES FOR PROLONGING SHELF LIFE OF THE POMEGRANATE AND APRICOT PRODUCTS IN AFGHANISTAN

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1. Introduction

Without doubt, the ability to store harvested plant fruits for extended periods of time has played a critical role in the development of agriculture. Fruits and vegetables are perishable products and it is estimated that in Afghanistan 30 percent of the fresh fruit and 20 percent of the fresh vegetables are lost because of rapid quality deterioration after harvest, mainly due to poor product handling and improper storage; further, about 40 percent of fresh fruit and 40 percent of fresh vegetables reduce their value before they are bought by the final consumers (Ken Neils, RAMP, 2006). Thus, only 30 and 40 percent of the fresh fruits and vegetables, respectively, are sold without price reduction. The shelf life of fresh produce can be extended with cold storage and improved handling practices.

The annual production of fruits and vegetables in Afghanistan is one and four million metric tons, respectively. Accurate statistics are not readily available in Afghanistan. FAO surveys in 1996 and 2003 indicated Afghanistan had approximately 77,000 and 95,000 ha of perennial crops. According to the 1996 survey, about 13 percent of this area or 10,000 ha were devoted to apricots. Grapes (50 percent), almonds (20 percent), apple (8 percent) and pomegranate (7 percent) were other important crops. The 2003 survey estimated the area under apricots had dropped to less than 7,000 ha. According to the FAO statistical website4 the area under apricots in 2005 was some 5,200 ha (NUHDA, 2008).

The prospect for cold room development for fruits and vegetables in Afghanistan is very low. Cold rooms could store about 400,000 to 450,000 metric tons of produce year round. However, cold rooms in the country are almost non-existent. Currently, the operating cost of cold rooms is high in areas with unreliable municipal power. Recent research found that the majority of consumers are willing to pay a premium prices for fresh produce out of season.

Storage time depends on the intrinsic characteristics and perishability of the product. Shelf life ranges from short periods for products such as raspberries and other berries to long periods for products such as onions, potatoes, garlic and pumpkins. Storage conditions also depend on specific product characteristics. For example, leafy vegetables tolerate temperatures close to 0 ºC, while most tropical fruits cannot tolerate exposure to temperatures below 10 ºC. In order to optimize storage conditions, only one crop should be stored in a room unless it is for a short period of time. Using the same storage area for different products can result in product damage because of incompatibility of temperature and relative humidity conditions, chilling and ethylene sensitivity, odor contamination and other problems affecting shelf life and quality. Generally, storage facilities are linked or integrated to packinghouses or other areas where there is a concentration of produce. However, often produce can be stored on farm, either naturally or in specifically designed facilities. Location and design have an impact on system operations and efficiency even when mechanical refrigeration is used. Climate is an important factor for the location of the storage facility. For example, altitude reduces temperature by 10 ºC for every 1,000 m of elevation. It also increases the overall efficiency of refrigeration equipment by facilitating heat exchange with ambient temperature, thereby reducing energy costs. Shading, particularly of loading and unloading areas, reduces thermal differences between field and storage temperatures (Tables 6 and 7; FAO 2004).

Fresh fruits are living tissues subject to continuous change after harvest. Some changes are desirable from consumer point of view but most are not. Post-harvest changes in fresh fruit

cannot be stopped, but these can be slowed down within certain limits to enhance the shelf life of fruits.

Pre-cooling of the produce soon after their harvest is one of the important components of the cool chain, which ultimately affects the shelf life of the produce. The main purpose of precooling is to immediately remove the field heat from the produce. Presently there are various type of pre cooling systems in the world such as room cooling, forced air cooling, hydro cooling, vacuum cooling and package icing.

2. Scope of the study

This study is undertaken to find out technologies and ways that can help increase shelf life of the pomegranate and apricot by introducing new ways of pre-cooling and storage facilities that can help farmers and traders increase their profitability.

3. Literature Review of Cold Storage and Pre-cooling

The marketable life of most fresh fruits vegetables can be extended by prompt storage in an environment that maintains product quality. The desired environment can be obtained in facilities where temperature, air circulation, relative humidity, and sometimes atmosphere composition can be controlled. Storage rooms can be grouped accordingly as those requiring refrigeration and those that do not (El-Ramady, Domokos, Abdalla, Taha, & Fári, 2015).

The method used to preserve most of the produce generated by our ancestors is referred to as a common storage. This involves storing harvested produce in a darkened, cold area. There are various ways where this can be done including leaving the produce in the ground, burying it in the ground in pits, storing in cellars or basements and storing in wooden crates or barrels located in cool areas like a garage or porch (William, T. Kemper).

3.1. Underground cold Storage

Natural underground cold storage rooms provide a suitable environment to keep products from impairment losses for a long time. Because of their constant temperature and balanced humidity levels year round, natural underground cold storage rooms provide maintenance of products without spoiling their natural structure. By means of technological investments carried out for temperature and humidity control, it is possible to keep products for a long time, which makes it possible to avoid wastage.

One of the favored features of natural underground cold storage rooms is that they need no insulation. Their natural temperature, being between the temperatures of +10C and +12C, provides a cool environment in the summer months and warm in the winter. Against the temperature changes in the summer and winter months, natural underground cold storage rooms are ideal to keep temperatures under control by means of technology.

3.2. Refrigerated Storage

Refrigeration is the most widely used method for extending the product life and temperature control is one of the main tools for extending product life. Low temperatures slow product metabolism and the activity of microorganisms responsible for quality deterioration. As a result, reserves are maintained with a lower respiration rate, ripening is retarded and vapor pressure between products and ambient is minimized reducing water loss. These factors contribute towards maintaining freshness by reducing the rate at which quality deteriorates and the

nutritional value of the product is preserved. A refrigerated room is a relatively airtight and thermally insulated environment. The refrigeration equipment should have an external escape outlet to release the heat generated by the product. Refrigeration capacity of the equipment should be adequate to extract the heat generated by crops with a high respiration rate. It is also important to control precisely the temperature and relative humidity conditions inside the refrigerated storage environment (El-Ramady, et al. 2015).

Special refrigerated containers, commonly called reefers, can control temperatures, allowing everything from meat, fruit, vegetables and dairy products, to chemicals and pharmaceuticals to travel across the world. Special super-freeze reefers can keep goods frozen at temperatures as low as -60 degrees C. But other reefers can preserve goods at warmer temperatures if that is necessary. De-humidification systems are able to ensure optimal humidity inside reefer containers. Some reefers also allow the atmosphere in the container to be controlled. Reefer containers generally come in 20 foot and 40 foot lengths, with the same general dimensions as that of dry cargo containers of the same size. However, there is slightly less cargo space available inside the reefer container due to the space taken up by the refrigeration unit and ventilation equipment.

3.3. Pre-cooling

The temperature at which a fruit or vegetable is harvested is known as the field heat. It is important to remove or reduce the field heat as quickly as possible after harvesting. This helps to prevent them losing water and keeps them fresh for longer. If the field temperature can be reduced by 10°C, the shelf life of the produce will double.

There are a few simple steps that can be taken to cool the produce after harvest;

- Pick the fruits from the tree early in the morning.
- Keep the produce in the shade.
- Spread the fruit out to allow heat to escape (piling the fruit in large heaps does not allow the heat to escape).
- If possible (depending upon the type of fruit), immerse it in cold or iced water (using clean water to avoid contamination).
- Spray water on the collected fruits immediately after harvest.

3.3.1. Sorting

Fruit and vegetables should be sorted to remove objects such as leaves, stones and sticks. Any immature fruit should be removed and set aside to ripen – some fruit species will ripen after harvest, while others will not. Diseased, damaged and over-ripe fruits must be sorted out and removed as these can infect the other fruit.

3.3.2. Washing

Fruit and vegetables should be washed in clean water that is suitable for drinking. Dirty or contaminated water should not be used as this contains bacteria that can cause serious food poisoning if they are consumed (See the section on the preparation of clean chlorinated water, in Book Two).

3.3.3. Packaging

Fruit or vegetables should be carefully packed into baskets, trays or crates for transporting to the processing site. The more fragile fruits need to be packed in single layers to prevent crushing those at the bottom. It is advisable to sort fruits and vegetable by size, and package those of similar size together, for optimal use of space and to protect smaller produce from being damaged by larger and heavier produce.

Avoid packaging too many fruits or vegetables in one container, to prevent crushing and bruising of the produce. But avoid packaging too few fruits and vegetables into containers, to prevent the produce from moving around and becoming damaged during transport. Also, packaging too few produce together leads to loss of space and thus increased transport costs.

3.4. Pomegranate storage system:

Pomegranates have recently become one of the world's most sought after fruits for their antioxidant and nutritional qualities. They are being heavily promoted in western markets. Pomegranates are native to Afghanistan and Northern Iran, are strongly drought resistant, and can grow on many different types of soil. They have a tough outer rind, and are easily transported over bad roads. Some are grown in Iran, Turkey, California, Arizona, Spain, and the former Soviet Union. Limited quantities are grown in India and Pakistan.

Pomegranate keeps well for a long time and is similar to the apple in having a long storage life. In Afghanistan the controlled atmospheric and other modern stores are not available. Afghan producers use ordinary rooms as storage for pomegranate. To maximize pomegranate quality fruit should be picked when fully ripe because they do not ripen off the tree. Pomegranate should be carefully maintained in cold storage after harvest because fruit are susceptible to chilling injury (CI).

The minimum safe storage temperature is 5°C (41°F) for up to 8 weeks, if decay is not a problem. For longer storage, the temperature should be at 7oC (450F) to avoid chilling injury, but decay (Botrytis cinerea) and weight loss may become a limitation.

The products stored in the storerooms need humidity and natural underground cold storage rooms maintain 80% or 90% moisture. Generally Potatoes, Apples, lemons and pomegranates are mostly kept in natural underground cold storage rooms.

Temperature
Optimum temperature need for pomegranate is 5°C (41°F) for up to 2 months; longer storage should be at 7.2°C (45°F) to avoid chilling injury.

Optimum Relative Humidity
90-95%; pomegranates are very susceptible to water loss resulting in shriveling of the skins. Storing fruit in plastic liners and waxing can reduce water loss, especially under conditions of lower relative humidity.

Rates of Ethylene Production

Less than 0.1 µl/kg·hr at 10°C (50°F) or lower, Less than 0.2 µl/kg·hr at 20°C (68°F)

Responses to Ethylene

Exposure to ethylene at 1 ppm or higher stimulates respiration and ethylene production rates, but it does not affect their quality attributes. Pomegranates do not ripen after harvest and must be picked fully ripe to ensure the best eating quality.

Responses to Controlled Atmospheres (CA)

Very few studies of the responses of pomegranates to CA have been conducted. Storage in 2% O_2 reduces chilling injury if pomegranates are kept below 5°C (41°F). In one study, pomegranates were stored successfully at 6°C (43°F) in 3% O_2 + 6% CO_2 atmosphere for 6 months. In another study a combination of 5% O_2 + 15% CO_2 was found to be effective in decay control and scald prevention for up to 5 months at 7°C (45°F).

Chilling Injury
External symptoms include brown discoloration of the skin and increased susceptibility to decay. Internal symptoms include a pale color of the arils (pulp around the seeds) and brown discoloration of the white segments separating the arils. Chilling injury occurs if pomegranates are exposed for longer than one month at temperatures between their freezing point -3°C (26.6°F) and 5°C (41°F) or longer than two months at 5°C (41°F).

It has been reported that during the post-harvest storage of pomegranates from Israel at temperatures below 6°C, chilling injury is observed, with symptoms including the appearance of depressions and browning in the fruit husk. This cold damage can be inhibited by storage in atmospheres with 2-4% O2 and temperatures between 2 and 6°C (Ben-Arie and Or, 1986).

3.5. Apricot Storage System:

Apricots should be cooled in the field or immediately thereafter, usually by room cooling. If picked at the firm mature ripening stage and stored at 32°F with 90 to 95% RH, fruit can be stored for one to two weeks or more, depending on the variety. Some varieties are susceptible to chilling injury, but injury symptoms such as gel breakdown, flesh browning and loss of flavor occurs more rapidly at 41°F than at 32°F (Watkins, & Nock,. 2012).

Apricots are grown on trees that reach heights of 3 to 13 m. The fruit is 3.5 to 6.5 cm wide and require 3 to 6 months to develop and ripen. After harvest, the apricots have extremely short shelf life and need to be eaten fresh within a few days; otherwise, the fruit should be dried or processed for juice, jam, or canning (Glozer and Ferguson. 2007).

Controlled atmospheres of 2 to 3% oxygen and carbon dioxide can have moderate commercial benefits. Apricots are climacteric and exposure of fruit to ethylene can hasten softening, color change from green to yellow, and decay.

Normally, as for apricot recommended temperature is range between (-0.5 to 0°C), therefore we need to keep the produce in reefer container

Optimum Storage Conditions

Apricots are seldom stored in large quantities, though they keep for 1 to 2 weeks (or even 3 to 4 weeks, depending on the cultivar) at -0.5 to 0 ºC with Relative Humidity (RH) of 90 to 95%. Susceptibility to freezing injury depends on SSC, which varies from 10 to 14%. The highest freezing point is -1.0 ºC.

-0.5 to 0°C (31-32°F) is recommended. Susceptibility of cultivars to freezing injury depends on SSC, which may vary from 10-14%. Highest freezing point = –1.0°C (30.5°F).

Chilling Sensitivity

Chilling-sensitive cultivars develop and express chilling injury symptoms (gel breakdown, flesh browning, and loss of flavor) more rapidly at 5 ºC than at 0 ºC. Storage at 0 ºC is necessary to minimize incidence and severity of chilling injury on susceptible cultivars.

Rates of Ethylene Production and Sensitivity

Ethylene production rate increases with ripening and storage temperature from under 0.1 µL kg-1 h-1 at 0 ºC (32 °F) to 4 to 6 µL kg-1 h-1 at 20 ºC (68 °F) for firm-ripe apricots and higher for soft-ripe apricots. Exposure to ethylene hastens ripening (as indicated by softening and color changes from green to yellow). Also, ethylene may encourage growth of decay-causing fungi.

Recommended temperature, relative humidity and approximate storage life under these conditions for Pomegranate and Apricot adopted from (FAO):

Crop	Temperature (°C)	Relative humidity (%)	Storage life (days)
Pomegranate	5	90–95	60–90
Apricot	−0.5 to 0	90–95	7–21

4. Research Methodology

The primary data was obtained through pre-designed questions asked from the selected stakeholders. The data was collected through individual meetings with stakeholders that were visited during the course of this survey. The organizations visited are somehow involved working on the storage system in Afghanistan. The stakeholders which were selected for meeting include CARD-F, RoP, EAVS and Geres employees. The questions that stakeholders were asked about storage facilities are as follow:

1. Where the storages are located?
2. How the storages are structured (i.e. underground or above ground)?
3. What kind of material has been used for construction of storages?
4. For what purpose these storages are constructed? Which crops are stored in these storages?
5. Ownership of the storages: are the storages constructed for individual farmer, farmer's group or cooperatives?
6. How much is the farmers/ producers' contribution in the construction of storages?
7. What was the storage temperature and humidity rate?
8. How long the produce are kept in the storages?
9. How the organization sees the result of these storages? I.e. satisfactory or unsatisfactory?
10. What was the impact of the cold storage and explain the difference it caused after building of storages?
11. What was the suggestion and recommendation of the organization for building pomegranate/ apricot storages?
12. How many units are constructed by your organization?

Below is the meeting records and suggestions of the organizations consulted as part of the literature review. This information was obtained through interview from each of the stakeholder:

4.1. Root of Peace (RoP)

According to RoP, underground storage will not work properly in Kandahar because of its hot weather. RoP recommended that underground storages should be built in areas where the temperature is good and suitable for storing Pomegranate for a long period of time. Instead of underground storage in Kandahar, it is better to work and establish a pack house for sorting, grading and packaging of pomegranate. Also building of controlled atmosphere storage system is critical for producers and traders to sell and export their products to international market. It is vital to state that pack house and storages facilities can help to produce good quality pomegranate to international market. In case of producing fruits and vegetables for domestic market, underground storage is good but if we want to expand our market internationally, underground storage will not work due to its poor quality. In pre-cooling, the product must be pre-cooled prior to its storage as it helps prolong the products shelf life. Furthermore underground storages should be built for individual farmers while shared ownership proved difficult to work.

Suggestion for storage:

- Work with traders, rather than producers, on establishment of storages and pack house given that traders can make these facilities commercially sustainable and profit making enterprises.
- Establish pre-cooler which costs about 500-700 $
- Underground storage needs 7°C temperature, build storages in areas where the grade of temperature is suitable.
- In Kandahar cold storage is already available, but the capacity is 5000 tons that is very large for only pomegranate. If modified and divided into various partitions/ compartments, it could be used for pomegranate as it brings down the cost of electricity on one hand and allows for storages of other products in the various compartments, on the other hand.

4.2. Comprehensive Agriculture and Rural Development Facility(CARD-F)

CARD-F is one of those organizations which work on bio-climatic (e.g. underground) storages in Badakhshan Province of Afghanistan. CARD-F built 76 units of underground storages for Potatoes and onions in the Keshm and Khash districts of Badakhshan. The structure of the storage is underground and the materials used for the construction are stones and concrete. CARD-F built underground storages for individual producers and the contribution of the producer is about 20% of the total cost. The total cost of a single underground storage is about 5,000 USD. Duration of the produce kept in these underground storages is nearly 5 months and losses of the produce during store period are reported to be only 2 to 5 percent. As CARD-F has built storages in the two districts of Badakhshan, the temperature in these areas are utterly different. In Khash district the storage temperature ranges between 2 to 7°C which is very good condition to store the produce for long period. Whereas in the district of kesham the storage temperature is about 25°C which is not a favorable condition compared to Khash district. Moreover late harvest helps to prolong the shelf life of the produce. Size of the underground storage is about 45 m3 that can have the capacity of 14000 kg.

Suggestions for storage:

- At first stage before establishing of underground storage, it is necessary to keep a close eye on the temperature and humidity situation of the area where the storage is planned for construction;
- The underground storage must be built and owned by individuals rather than group members as shared ownership does not work.

4.3. Enhanced Agricultural Value Chains for Sustainable Livelihoods (EAVS)

EAVS works on storage systems in Kabul, Parwan, and Bamyan cities of Afghanistan. EAVS constructed 965 units of underground storages in Bamyan province for potatoes and 698 units of above ground storages in the provinces of Kabul and Parwan for onions. The storage temperature is 4°C to 8°C and humidity rate is about 95%. Thermometer is used to control the inside temperature and humidity rate of the storage. For construction of the storage the material used included stones for walls and woods for roof of the building. Further, EVAS constructed cold storages for both individuals and groups but they are more preferring to construct storages for individuals rather than groups. Moreover, the contribution of farmers in the construction of storage is 50% and the total cost is near 4000$. The storages have the lengths, height, and width of 10, 3 and 3 respectively. The produce is kept in the storage for long period with no wastage.

4.4. Group Energies Renouvelables, Environment ET Solidarities (GERES)

GERES also work with farmers and groups of the farmers in the facilitation of cold storages. GERES constructed 200 units of underground storages in Kapisa Province for Potatoes, onions and Pomegranates. Storages constructed in two different sizes, for individual the size of the storage is 51 m3 which have the capacity of 10 tones and for the groups, size of the storage is 102 m3 which have the capacity of 20 tons. The materials used in storages were stones for walls and woods for the cover (roof) of the buildings. Furthermore, in Kapisa around 80% of the underground storages are used for storing pomegranates. According to GERES, for individual the result was good as compared to group due to some difficulties in ownership issues. Additionally, the contribution of farmers was 20% and the temperature of storage is almost 3°C to 5°C. The products kept or store for more than five month in the storages, it shows three months more than traditional format. Moreover for individual construction cost is about 4000 euro and for group cost of construction is about 7000 euro. Wastage of products in this storage is about 1 to 3 percent which obviously indicates low rate.

Suggestion for storage

- Conduct a needs assessment first; weather there is (in that particular area) a need for the construction of underground storage or not.
- Examine the temperature and rate of humidity, where underground storages will be constructed.

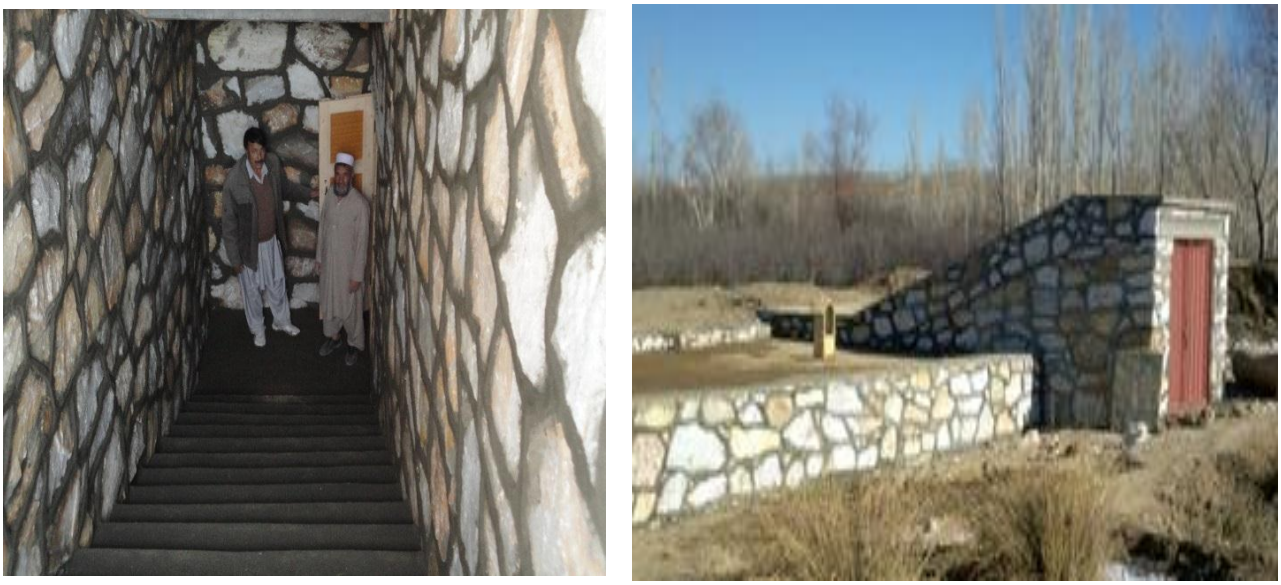
5. Conclusion & Recommendation

After primary and secondary data collection, the result of the study recommended and revealed that for prolonging shelf life of the produce, construction of underground storages and providing reefer containers could be the best options and the following points should be considered:

5.1. Underground Storage structure

This study suggest that for pomegranates if we provide underground storage, it will significantly help to store fresh pomegranate for long period. A storage structure can be made from the locally available materials. According to this study the structure should have the following characteristics:

- It should be built in a cool, shaded area, possibly under trees to make use of the natural shade.
- It should be rectangular in shape and its length, width, and height is 8, 3, and 3 respectively.
- It should be built in those areas where the grade of temperature is suitable.
- It should be built to individual rather than groups as shared ownership previously create difficulties.
- It should have ventilation chambers.
- It should have a thermometer for checking storage temperature.
- Ensure there is a ventilation system that allows cool, fresh air from the outside to be brought into the storage and stale air to be exhausted out.
- The walls should be built form stones and cover should be made from the concrete.



Underground storage structure constructed in Ghazni province for Apple in 2014.

5.2. Refrigerated container

This study propose that for apricot, if we provide reefer container to national traders, it will help to store fresh apricots for long period of time. When the supply of apricot is high in market, trader will buy it on cheap price and then store for a period in the storage container. Then, in the off season when the demand for the produce is at high point, the trader can send the produce to national and international market and gain significantly high margin of profit. Normally, storing the produce in reefer container from one hand will increase profit and on the other hand national producers and traders are familiar with international market.

This study also recommended the following points:

- According to RoP, in Kandahar there is a Controlled atmosphere storage which was already built and presently nobody use and store products. The reason is that the capacity of the storage for storing products are high and near to 5000 tons. Generally, in Kanadahar none of the traders and producers have the capacity of 5000 tons products to store at one time. Furthermore, if they kept and store low capacity of produce in that storage so the cost of electricity brings up which is not beneficial for both traders and producers. Thus, if this CA storage is partitioned and modified to various parts it will be a good for both producers and traders. They will kept their products in one part of the storage which will be low cost in terms of electricity and rent of the storage place.
- Primary and secondary data suggest that, establishing Pre-cooler system help producer to extend the shelf life of the product before storage. Pre-cooling is an easy method used for produce after harvesting and it allows heat of the produce to escape. It will double the product life. Therefore, for this purpose if we provide farmers the system of pre-cooling, they will get more benefit of the products. The method use to pre-cool the produce is simple, only tent, cooler and Solar are used. Tent use as a room to provide shade for the product. Cooler use to cool the produce inside the tent and solar use to provide energy/ electricity to run the cooler. This will help to remove field heat of the product and making it easy to sort, grade and even package the product in the orchard. The estimated cost of one unit of pre-cooler is around 500 USD. Furthermore, it is also worth mentionable that the ANHDO is pioneering of such type of pre-cooler system.
- According to this study, for pomegranates underground storage work properly, as it need 5°C temperature and it will store products for five months. However for Apricots underground storage is not working, thus for Apricot we need Refrigerated containers.
- Refrigerated or reefer container is significantly have high demand in Afghanistan for storing fresh fruits particularly, those products that have low shelf life. Thus for fresh apricot there is a huge need for such facilities. It is recommended that if we provide traders the reefer containers for storing fresh apricots will have the chance to avoid produce damages for specific period of time. Moreover, based on such facility the traders can have the chance to export high quality of apricots to regional and international market.
- The result also suggest that training to farmers regarding pre-cooling and cold storages can help them to increase the products shelf life.

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