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Increased Production of Horticultural Crops Through the Introduction of Postharvest Handling Technology

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Abstract: Low-temperature storage structures are the major weapon that the postharvest operator uses to maintain quality and extend life of harvested horticultural products. A low temperature not only reduces respiration rate, but also water loss through transpiration, nutritional loss, postharvest decay and ethylene production. Laboratory studies were conducted on the water holding capacity of the selected walling materials after socking them in water overnight. Scoria, charcoal and filla (single strap and double strap) were used for the study at different times. A water holding capacity of up to 122.72% was recorded in 24 hours of soaking in the case of the filla walling material. Similar studies were conducted on other walling materials like scoria and charcoal. Tests were conducted under no load and loaded conditions. Longer shelf life is manifested in the scoria and charcoal storage structures, attributed to higher humidity, lower temperature, less color change indicates lower rate of spoilage. Three creates of cleaned potato were stored in the potato store and in the laboratory as a control. Data on weight loss, spoilage and sprouting were taken for 50 days for the ware potato. Then the test was extended for another two months to assess the quality of the structure as a seed potato store. The degree of spoilage was lower compared to the control, but the difference was not significant in the ware potato. As a seed store, the number of sprouts, especially higher number of potatoes with greater than 5 sprouts was recorded in the control, which was also significant. From this preliminary result the structure could be a better choice as a potato seed store.

Keywords: Charcoal, Filla, Scoria, Spoilage, Temperature

1. Introduction

Field studies over the past 40 years have revealed that 40-50% of horticultural crops produced in developing countries are lost before they can be consumed, mainly because of high rate of bruising, water loss and subsequent decay commencing at harvesting and through the chain of post-harvest handling processes [1-3]. The lack of sufficient cool storage space at farm level and refrigerated storage at market level further enhances loss of fruits and vegetables [8, 9]. In Ethiopia about 20% loss is estimated, though not properly documented (personal communication with growers and unions in Meki Zwaye area). In Meki Zwaye area, tomato is harvested up to three times. The first two harvests are usually picked by contract buyers directly from the field, but the third harvest is usually left in the field, because the farmers' do not have the means to store the product and is prone to spoilage. Harvesting cost cannot be recovered from the sale of the produce and the producers have underlined the need for a scheme to extend the shelf life of their produce. Due to their highly perishable nature, about 20-30% of total fruit production and 30- 35% of total vegetable production go waste during various steps of the post-harvest chain [14].

Evaporative coolers, often called "swamp coolers", are cooling systems that use only water and a blower to circulate air. When warm, dry (unsaturated) air is pulled through a water soaked pad, water is evaporated and is absorbed as water vapor into the air. The air is cooled in the process and the humidity is increased [10].

The study [11] reported that Evaporative coolers could be classified into: 1) Direct evaporative coolers, in which the working fluids (water and air) are in direct contact; 2) Indirect evaporative coolers, where a surface/plate separates between the working fluids; 3) Combined system of direct and indirect evaporative coolers and/or with other cooling cycles.

A study [12] reported that Evaporative cooling is based on two important phenomena: i) at standard temperature and pressure, roughly 60 times more heat is required to evaporate a certain amount of water than to raise its temperature by 10°C; ii) air that is unsaturated with moisture can absorb a certain additional amount of water vapor, in which case the heat contained in the air is absorbed by the vaporization of the water. This liquid-to-vapor phase change causes the simultaneous cooling of the air and of the water remaining in liquid state.

Evaporative cooling is of specific interest to engineers concerned with the efficiency and energy demands of post-harvest storage. While providing a humid environment required for storage, humidifiers also offer the potential to provide some cooling [13].

Sanni [15] did a research on the development of evaporative cooling system on the storage of vegetable crops. The major development was implemented by adding a regulated fan speed, water flow rate and wetted thickness. This was possible as a result of varying temperature and relative humidity within the facility. Dvizama [16] researched on the performance evaluation of an active cooling system using the principles of evaporative cooling for the storage of fruits and vegetables. He developed mathematical models for the evaporative process at the pad-end and the storage chamber and a stem variety of sponge was considered to be the best pad material from the local materials tested as pad material.

Respiration is highly temperature dependent. The lower the temperature (down to 0±C) of harvested fruit and vegetables the lower is the respiration rate. Lowering respiration rate, results in reduction of carbohydrate loss, decreased rate of deterioration and increased storage and shelf life [4].

Low-temperature storage is the major weapon that the postharvest operator uses to maintain quality and extend life of harvested products. A low temperature not only reduces respiration rate, but also water loss through transpiration, nutritional loss, postharvest decay and ethylene production.

One weapon to meet the low temperature storage requirement is to deploy an Evaporative Cooling system that extracts the heat from the product. Evaporative-cooling techniques are very energy-efficient and economical [5]. A well-designed evaporative cooler produces air with a relative humidity greater than 90%. Its main limitation is that it cools air only to the wet-bulb temperature of the outside air.

Currently, growing horticultural crops is on the increase, but the introduction of post-harvest handling technology is lagging. The Central Rift Valley Zone of Ethiopia is a major tropical fruit and vegetable production area in the country, where tomato, papaya, snap beans, onion and green paper are widely grown. At times farmers sale these crops at throw away prices as they have no means of proper storage system in order to keep the quality of the product even for few days after harvest. Produce which is not sold immediately deteriorates and turns out to be totally unmarketable at the end. The minimum temperature in this zone ranges from 9.6-15.2, whereas the maximum temperature from 26-30 degrees. This temperature range is acceptable to store some commodities, like tomato (ripe 4-7 days at 13-15 degrees, green 1-3 weeks at 18-22 degrees), papaya (1-3 weeks at 7-13 degrees), orange (3-8 weeks at 3-9 degrees), mango (2-3 weeks at 13-15 degrees, avocados (2 weeks at 13 degrees) [4]. All these are kept at a relative humidity range of 85%-90%, which is possible through a proper design and construction of an evaporative cooling system. In small farms storage structures can be made from natural materials that can be moistened with water. Wetting the walls and roof first thing in the morning which creates conditions for evaporative cooling of the store. The store house could be made with walls of wire mesh that hold charcoal, loosely woven bag filled with river sand or perforated bricks [6]. By moistening the store house wall with water each morning, the structure will be evaporative cooled during the day. Cooling will be enhanced if the unit is kept shaded and used in a well ventilated area.

1.1. Overall Objective

The objective of the study was to minimize losses and increase the shelf life of some common vegetables, fruits tuber and root crops through the introduction of improved postharvest Technologies.

1.2. Specific Objectives

a. Develop storage technology for potato
b. Develop evaporative cooling storage structure for some fruits and vegetable crops

Figure 1. *Evaporative cooling structure.*

2. Methodology

The construction of prototype and laboratory experiments were conducted at Melkassa Agricultural Research Center(MARC), 17 km South of Adama, or it is located 117 km South East of Addis Ababa, Ethiopia. Melkassa has a highly variable rainfall that ranges between 500 and 800 mm annually. The agro- ecology is termed as Kolla (Warm, semi-arid lowlands). Any adjustment or maintenance of the proto type was conducted in AIRIC workshop, which is found in the center.

The methodology encompasses the material selected and methods followed to address the specific objectives.

Development of storage technology

a. Literature and past works by FAO, CIP EIAR horticulture department were reviewed.
b. Different evaporative cooling designs were studied from standard books and publications were studied.
c. One charcoal design was selected from existing designs and three other designs, scoria, *filla* and RHB designs were selected on availability of material and traditional practice.
d. A site with enough shade and with a long wind corridor area, with proximity to water source was selected
e. The stores with the (dimension of 1.5m×1.5m of 2 meter height) using the selected materials were constructed at the selected site staggered in such a way that air flow in any side is not obstructed during the study period.
f. Testing procedure was developed, where each structure was watered every 2. hours using 200 litres of water
g. Data without load were taken for few days under the stated condition.
h. Data on humidity, temperature outside and inside the structure were recorded twenty minutes after each watering.
i. Data with load using tomato, banana and carrot were recorded for a minimum of two weeks in each case.
j. At the end each week weight loss, spoilage and damage were recorded besides the climate data.
k. Analysis on colour change, climatic condition and weight loss (WL) were done after collecting the data

$$WL\ (\%) = \frac{Wi - Wf}{Wi} x100 \quad (1)$$

3. Results and Discussion

3.1. Evaporative Cooler Evaporative Cooler

Laboratory studies were conducted on the water holding capacity of the selected walling materials after socking them in water overnight. Scoria, charcoal and *filla* (single strap and double strap) were used for the study at different times. A water holding capacity of up to 122.72% was recorded in 24 hours of soaking in the case of the *filla* walling material (table 1). Similar studies were conducted on other walling materials (tables 2 and table 3). Tests were conducted under no load and loaded conditions (table 4).

Table 1. *Water holding capacity of filla mat walling material.*

Walling material	Weight before soaking (gms)	Weight after soaking (gms)	Water holding capacity (%)
Single mat	550	1225	122.72
Double mat	709	1947	174.61

Table 2. *Moisture holding capacity for charcoal and scoria walling material.*

Starting Date		The last Date	Weight Before Water (kg)	Weight After water 24 h/r	Water holding (%)
Scoria					
Sample 1	27/03/09 9:30 AM	28/03/09 9:30 AM	1	1.133 kg	
Sample 2	27/03/09 9:30 AM	28/03/09 9:30 AM	1	1.138 kg	
Sample 3	27/03/09 9:30 AM	28/03/09 9:30 AM	1	1.113 kg	
Mean			1	1.128	12.81
Charcoal					
Sample 1	27/03/09 9:30 AM	28/03/09 9:30 AM	1	1.433 kg	
Sample 2	27/03/09 9:30 AM	28/03/09 9:30 AM	1	1.336 kg	
Sample 3	27/03/09 9:30 AM	28/03/09 9:30 AM	1	1.367 kg	
Mean			1	1.378	37.8

The following results were recorded under no load and loaded condition using different crops

Banana Dwarf Cavendish

The banana was thoroughly cleaned and samples of the same amount in weight and all matured but green were put in the different stores for weeks. Temperature and humidity were monitored. Data on spoilage and pictures were taken at the end of the storage period, where the refractive index was recorded using image analysis, the higher indicating ripening (lower shelf life) (table 4).

Table 3. *Test on Banana dwarf Cavendish Data Analysis input for dwarf Cavendish (Ranking 1_green 2_medium 3_yellow 4_ black).*

Walling Material	Inside the store		Outside		Mean colour score	Spoiled	Ranking
	Temp	Humidity	Temp	Humidity			
Rectangular hollow Block	25	67	25	63	32.66	4.66	4
Filla	23	65	25	63	29	2	3
Charcoal	22	69	25	63	21	2	1
Scoria	25	69	25	63	26.33	0	1

Longer shelf life is manifested in the scoria and charcoal storage structures, attributed to higher humidity, lower temperature, less color change indicates lower rate of spoilage.

Table 4. *Temperature and humidity variation exhibited among the four structures using tomato as a taste crop in October 2009 E.C.*

Date	Time	Structure	Temp inside	Temp outside	Relative Humidity inside	Relative Humidity outside
29/03/09	8:30	Charcoal	16	21	79	73
29/03/09		Scoria	15	21	80	73
29/03/09		Fila	17	21	75	73
29/03/09		Block	17	21	76	73
29/03/09	11:00	Charcoal	21	26	75	68
29/03/09		Scoria	23	26	74	68
29/03/09		Fila	20	26	69	68
29/03/09		Block	21	26	72	68
29/03/09	1:30	Charcoal	20	27	72	64
29/03/09	1:30	Scoria	20	27	72	64
29/03/09	1:30	Fila	23	27	66	64
29/03/09	1:30	Block	23	27	68	64
30/03/09	8:30	Charcoal	15	21	70	73
30/03/09	8:30	Scoria	14	21	80	73
30/03/09	8:30	Fila	17	21	76	73
30/03/09	8:30	Block	17	21	76	73
30/03/09	11:00	Charcoal	18	26	74	66
30/03/09	11:00	Scoria	17	26	76	66
30/03/09	11:00	Fila	21	26	69	66
30/03/09	11:00	Block	20	26	70	66
30/03/09	1:30	Charcoal	19	28	72	64
30/03/09	1:30	Scoria	21	28	73	64
30/03/09	1:30	Fila	23	28	65	64
30/03/09	1:30	Block	24	28	66	64
03/04/09	8:30	Charcoal	17	22	75	71
03/04/09	8:30	Scoria	17	22	76	71
03/04/09	8:30	Fila	19	22	72	71
03/04/09	8:30	Block	19	22	72	71

3.2. Potato Storage

The potato storage structure is 1.5 meter square floor size and is 1.80 meter on one side to 2.2 meter on the other side. The storage floor is place d at 120 cm above ground. It has a slatted floor and the walls below the floor have a slate opening which is kept open at night for letting air flow into the store for ventilating the product. It has a thatched roof and about 10 cm straw filled ceiling below the roof. The sides of the store are made with wooden board leaving 20-40 cm opening with wire mesh below the roof. The side of the store is insulated with 10 cm straw held in place with loosely netted sack kind of material. The product is filled in the chamber, with enough room above for air exchange (figure 2). The lower flaps are kept closed during the day time and are open at night to keep advantage of the night cool air ventilation. Maximum and minimum temperatures were monitored both inside and outside the store (table 7.). The store was used as a ware store and later as a seed store, where different data sets were considered (tables 5 and 6).

Three creates of cleaned potato were stored in the store and in the laboratory as a control. Data on weight loss, spoilage and sprouting were taken for 50 days for the ware potato. Then the test was extended for another two months to assess the quality of the structure as a seed potato store.

The degree of spoilage was lower compared to the control, but the difference was not significant in the ware potato. As a seed store, the number of sprouts, especially higher number of potatoes with greater than 5 sprouts was recorded in the control, which was also significant. From this preliminary result the structure could be a better choice as a potato seed store.

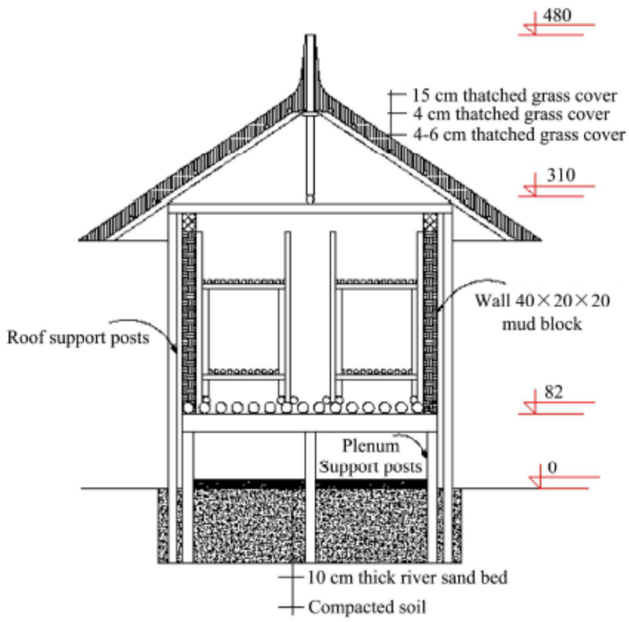

Figure 2. *Naturally ventilated potato store.*

Table 5. *Degree of spoilage inside the potato storage structure and the control room.*

Storage Structure					Room					date
Wt before	sprout	Spoiled (wt)	Wt. at the time		Wt before	sprout	spoiled	weight		
			total	clean				total	Clean	
30	-	-	28	28	30	-	-	29	29	06-11-2009
30	-	-	28	28	30	-	-	29	29	
30	-	-	29	29	30		-	29	29	
28	-	3 kg	28	25	29	2 (2 sprouts)	2	28	26	19-11-2009
28	-	2 kg	28	26	29	3 (2 sprouts)	5	28	23	
29	2 (one dominant)	2.5 kg	27	24.5	29	-	2	28	26	
Mean		2.5					3			
25	6 (2 places)	3.03	25	21.97	28	5	2.07	26	23.93	8-12-09
26	5 (one)	2.00	26	24	28	9	3	22	19	
24.5	5 (2 places)	2.00	26	24	28	3	3.97	25	21.03	
Mean		2.54		23.32			3		21.32	
Total		5.04					6			

Table 6. *Potato test data on degree of spoilage and sprouting on storage period of 18/10/2009-22/1/2010.*

Storage Structure							
Wt before	Wt at the end of	Sprout			Spoiled (wt)	Clean	
		single	3-5	>5		quantity	weight
30	22	64	98	26		39	3.5
30	21	41	100	27		18	1.5
30	21	57	99	30		40	4
	21.3	54	99	27.6			

Room							
Wt before	Wt at the end of	Sprout (wt)			Spoiled (wt)	Clean	
		single	3-5	>5		quantity	weight
30	18	12	61	89		0	0
30	20	36	77	130		6	0.5
30	20	38	92	62		22	1.5
30	19.3	28.6	76.3	93.6			

Table 7. *Minimum temperature attained inside the potato store. Potato storage data sheet.*

No	Date	Time	Temperature inside room (°C)		Temperature outside room (°C)	
			min	max	min	max
1	02-03/02/2009	2:45 morning	16	32	14	34
2	03/02/2009	11:45 afternoon	-	-	-	-
3	03-04/02/2009	2:45 morning	14	30	12	29
4	04/02/2009	11:45 afternoon	21	31	21	32
5	04-05/02/2009	2:45 morning	14	31	12	30
6	05/02/2009	11:45 afternoon	21	31	20	30
7	05-06/02/2009	2:45 morning	15	30	14	29
8	06/02/2009	11:45 afternoon	22	30.5	22	31
9	06-07/02/2009	2:45 morning	16	30	14	29
10	07/02/2009	11:45 afternoon	23	30	22	29
11	07-08/02/2009	2:45 morning	12	30	11	29
12	08/02/2009	11:45 afternoon	20	31	20	31
13	08-09/02/2009	2:45 morning	13	29	11	28
14	09/02/2009	11:45 afternoon	22	30	21	31
15	09-10/02/2009	2:45 morning	13	30	11	29
16	10/02/2009	11:45 afternoon	21	31	20	31
17	10-11/02/2009	2:45 morning	17	31	15	30
18	11/02/2009	11:45 afternoon	22	31	21	30
19	11-12/02/2009	2:45 morning	19	31	17	30
20	12/02/2009	11:45 afternoon	25	31	24	31

The evaporative cooling structure showed a remarkable reduction of temperature and Relative humidity, which has the potential to increase the shelf life of fruits like banana and vegetables like tomato. This was observed at the end of the storage period. No satisfactory result was recorded in the case of carrots, which may be difficult to attain the required environmental condition under this set up. This technology is promising and needs to be further tested with tropical fruits which have a better keeping quality up to a temperature of 10 degree centigrade.

The potato store has shown a good achievement of capturing the night time ambient temperature, but failed in inhibiting sprouting at the time of storage. As the material is bought from market, it was hard to know, whether it is from the prior history of the crop or the failure of the structure. Further test is expected in the rest of the time to clear up things.

In the extended period of study conducted for about two months some losses were recorded between the crop stored both in the room and the storage structure, but no significant difference was recorded between the control and the potato stored in the storage structure, which could be attributed due to the storage period, which was conducted in the months of August, September and October.

After studying the keeping quality the storage period was further extended to observe the performance on the quality of sprouting, sprout number, dominance and optimum size and number of sprout (3-5 sprouts) between the storage structures. More than 5 sprouts, significantly different were observed in the potato stored in the room. In this case a significant difference was recorded among the storage structures with the desired sprout number and quality observed from the storage structure.

4. Conclusion and Recommendation

Evaporative cooling is a well-known system to cool the environment. This is adiabatic process, in which ambient air is cooled as a result of transferring its sensible heat to the evaporated water carried with the air. In the evaporative cooled structure, the maximum advantage of the natural environment is taken for lowering down the temperature of outside ambient air to a considerable low level. Evaporative cooling storage system is easy to operate, efficient and affordable most especially for peasant farmers in developing countries who may find other methods of preservation quite expensive and unaffordable. In this review different evaporative cooling systems like developed, their construction materials were Scoria, Charcoal and Hallow block have been used. The fruit stored at the top of the shelf shrivels more than the middle and the bottom one because there is greater amount of air circulation. The pad thickness and density was not uniform which greatly affect the saturation efficiency of the storage structure and also the way of application of water was also somewhat difficult. By avoiding those problems which are mentioned above the required modification or rebuilding have to be done specially the material used to construct the wall have to be waterproof and also it is better if the cooling chamber is easy for the application of water.

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