International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(4): 2802-2806

Received: 01-05-2019
Accepted: 03-06-2019

MK Ghosal
Professor, Department of Farm Machinery and Power, College of Agricultural Engineering and Technology, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Jyoti Ranjan Rath
Research Scholar, Agricultural Economics, Department of Farm Machinery and Power, College of Agricultural Engineering and Technology, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Correspondence
MK Ghosal
Professor, Department of Farm Machinery and Power, College of Agricultural Engineering and Technology, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Studies on development and performance evaluation of solar powered cool chamber for short-term storage of okra

MK Ghosal and Jyoti Ranjan Rath

Abstract
Farmers in the rural areas often sell their products to the middleman or in the local market at low prices due to lack of transportation facility, shortage of electric supply and lack of investment on storage, lower price of vegetables during the harvesting season. They are not even able to get the return of the invested money in cultivating vegetables or fruits. Lack of on-farm storage facility, therefore, compels the growers to go for the distress sales of their produce, ultimately resulting into reduced net profit to them. There is therefore, the need of a low cost storage system which can be operated on a reliable and environment-friendly energy source for short-term storage of the perishable horticultural produces in a small scale at farmer's own level. An attempt has thus been made in this study to develop and evaluate a solar photovoltaic powered cool chamber of about 100 kg capacity for short term storage of vegetables especially most perishable one i.e. okra (hybrid variety, SARTAJ) in order to avoid distress sale among the growers, majority of them is coming under small and marginal farmers' category. The cool chamber was fabricated in the Dept. of Farm Machinery and Power, OUAT, Bhubaneswar, Odisha and its performance was evaluated for studying the storability of okra during peak summer period i.e. April-May 2018. It was found that the shelf-life of okra was enhanced to 12 days during summer season by maintaining temperatures in the range of 14-16 °C and humidity in the range of 83-94% in the cool chamber developed for the study.

Keywords: Storage of okra, solar photovoltaic system, shelf-life of vegetables, solar refrigeration, solar powered cool chamber

Introduction
Providing cooling by utilizing renewable energy such as solar energy is a key solution to the energy and environmental issues. In recent years, scientists have increasingly paid more attention to solar energy. One of the important applications of solar energy is the refrigeration system for the preservation of fruits and vegetables due to the major concern of about 30-35% of their annual post-harvest losses in the leading vegetable growing country like India (Economic Survey of India, 2013) [1]. India is the second largest producer of vegetables having 9.20 million ha under vegetable crops, with a production of 162 million tones (Jain 2007) [3]. Vegetables are required to be stored at lower temperature because they are highly perishable in nature. Preserving them in their fresh form demands the minimum possible chemical, bio-chemical and physiological changes by close control of space temperature and humidity. The high cost involved in developing cold storage or controlled atmosphere storage is a pressing problem in several developing countries. Several simple practices are useful for cooling and enhancing storage system efficiency wherever they are used, and especially in developing countries, where energy availability may be critical. The refrigeration and other commercial cold storage systems are the solution of the problem, but could not be fully exploited due to heavy initial cost and demand high input of energy. Mechanical refrigeration is also energy intensive and expensive, involves considerable initial capital investment, and requires uninterrupted supplies of electricity which are not always readily available, and cannot be quickly and easily installed. Available cold storage in India is used primarily for the storage of potatoes (Sharma and Samuel 2014) [7]. Appropriate cool storage technologies are therefore required in India for on farm storage of fresh horticultural produce in remote and inaccessible areas, to reduce losses. The favorable environment for storage of fruits and vegetables is low temperature and high humidity due to their high moisture contents (Singh and Satapathy 2006) [6]. Combination of both temperature and relative humidity to the recommended storage

condition is very important to enhance the shelf life of vegetables. Recommended temperature may be achieved due to mechanical refrigeration but desired humidity cannot be maintained. Hence to maintain both the parameters, mechanical refrigeration as well as evaporative method of cooling are required. But reliable source of power to operate such a system comprising mechanical refrigeration system and active evaporative cooler is a major constraint in rural and off-grid areas. To make the system sustainable with respect to energy independence and reliability in grid-isolated remote areas for short-term on-farm storage of vegetables, there is the necessity of a device integrating both mechanical compressor and passive or active evaporative cooling system which can be powered by an environment-friendly and renewable source of energy. Among the various renewable energy sources, application of solar energy may be a viable option because of its adequate availability in a tropical country like India (Anish *et al*. 2009) [5]. Hence, an attempt has been made in this study to develop a small capacity solar photo voltaic powered cool chamber at the farmer's level with the objectives of fabricating an experimental cool chamber of 100 kg capacity and to evaluate the performance of a stand-alone solar photovoltaic powered cool chamber for short-term storage of freshly harvested vegetables especially the most perishable vegetable i.e. okra in warm and humid climatic condition.

Studies have been undertaken through development and performance evaluation of an environment-friendly and affordable solar powered refrigeration system for short term storage of okra considering the necessities of growers, vendors and consumers together.

Freshly harvested, tender green okra fruits of hybrid variety SARTAJ has captured a permanent position among vegetable crops in Odisha because of prolong period of cultivation, almost cultivated throughout the year except a few winter months. Okra has also been classified as a vegetable of high respiratory activity (>120 mg CO2/kg/hr). The fruit thus, losses its marketability and become unfit for consumption within 2 days of picking under ambient condition. At higher temperature of storage, moisture loss, shrinkage, toughening, yellowing and decay are rapid in fruits of okra. If the rates of these activities are reduced, the shelf-life of this commodity can be increased (Ghai, 2002) [2]. Okra "*Abelmoschus esculuntus* L. Moenth" belongs to family Malvaceae and considers one of favorite summer/rainy vegetable crops in Odisha, India, due to the highest nutritive value of fruits such as carbohydrates, calcium and phosphorus in addition to thiamine, niacin, vitamin C. Due to the lack of studies on storage ability of okra fruit of SARTAJ variety (Fig. 1), the present study was conducted to improve the storage behavior of okra fruits by developing sustainably a low capacity solar power cool chamber viable for small and marginal category of farmers of Odisha.

Fig 1: Variety Sartaj

Materials and methods

The experiments were carried out in the premises of College of Agricultural Engineering and Technology, OUAT, Bhubaneswar, Odisha during 2017-2018, which lies at the latitude of 20^0 15' N and longitude of 85^0 52' E and coming under warm and humid climatic condition. Studies on SPV powered cooling system for storage of vegetables are based on the sizing and installation of solar photovoltaic modules, power conversion (power conditioning) unit, battery, cooling system, storage structure and storability of okra. The cool chamber was fabricated in the Workshop of College of Agricultural Engineering and Technology, OUAT, Bhubaneswar and placed in the experimental site. The dimensions of the cool chamber are as follows (Fig. 2).

- Outside dimension of about 0.9 m length X 0.9 width X 1.05 m height.
- Inside dimensions of about 0.78 m length X 0.78 m width X 0.93 m height.
- Square shape and white surface walls.

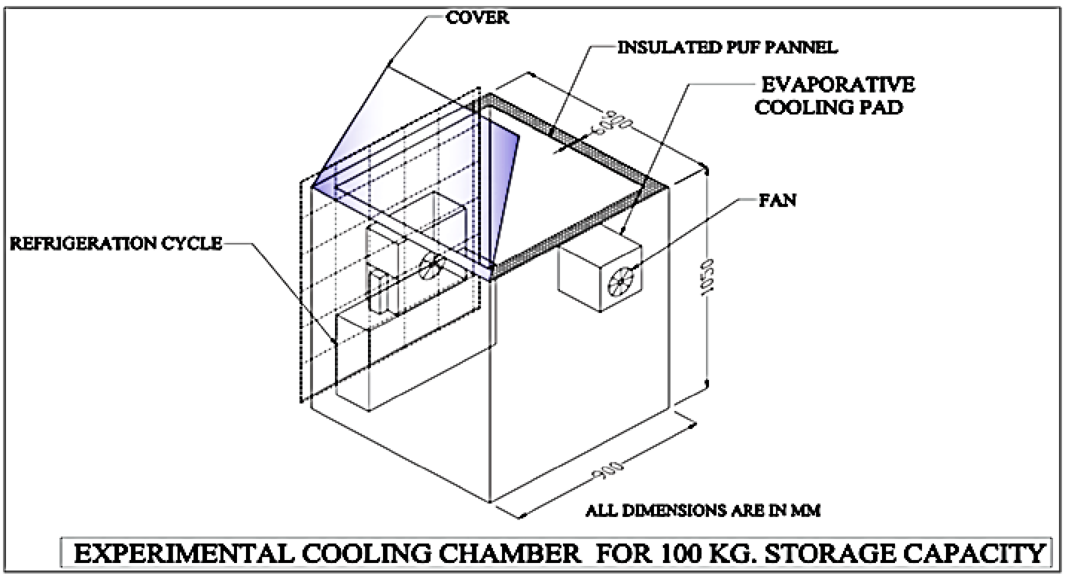

Fig 2: Photograph of solar powered cool chamber

Insulation: Polyurethane foam (PUF) of 60 mm thickness was attached to all the walls, ceiling (roof) and base, because it is light in weight, low thermal conductivity, non-hygroscopic, high strength and high resistance to fire. Dark condition was maintained in the cool chamber (without diffused light) to avoid additional thermal energy gain. The complete set-up of the present study has been shown in the fig. 3.

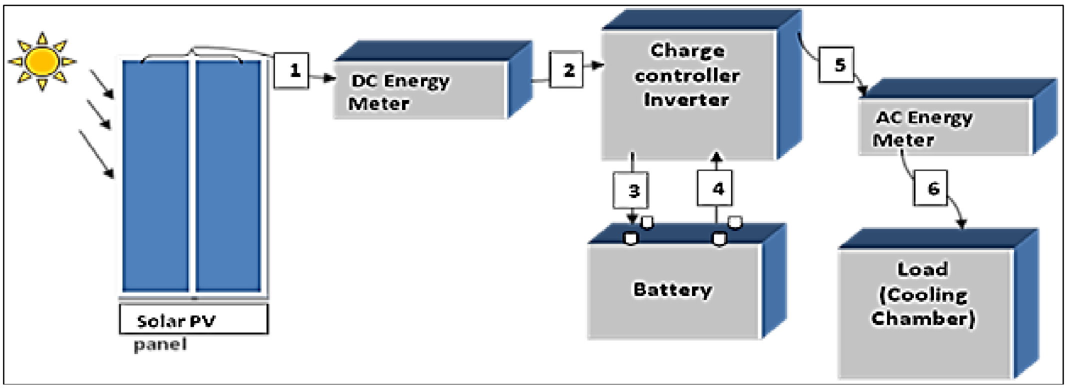

Fig 3: Line Diagram of Experimental Set-up

Quality Parameters Study of Stored Vegetable

The following physical parameters were tested during the experiment.

Firmness Test

Shrinking and discoloration of okra has a direct relationship with their firmness and since respiration continues even after harvest, the fruits have the tendency of becoming blackened. As a result of continued chemical activity within the fruits tissues even after harvest, it becomes hard and blackened. It is therefore required to slow down the rate of respiration and will ultimately reduce the fruit firmness change. This may be possible by storing the harvested vegetables at low temperature.

The freshly harvested tender okra generally go from fully softened to moderately softened, slightly softened and becomes very slightly softened and hard during storage. The firmness of the stored vegetables is determined by a vegetable firmness tester in the unit of kg/cm^2. The firmness index of vegetables is determined by the extent of their softening stages on the basis of visual observation and is scored as follows;

Fully softened = 1
Moderately softened = 2
Slightly softened = 3
Very slightly softened = 4

Where

Fully softened indicates fresh green, edible and good condition, moderately softened indicates green, edible and good condition, slightly softened indicates edible and yellowing starts and very slightly softened indicates not edible, blackening starts and rotten.

Physiological Loss in Weight (PLW)

Physiological loss in weight is expressed in percent with the following formula by weighing the stored vegetables before and after storage.

Percent PLW = $(w_1-w_2)/(w_1) \times 100$

Where

w_1 = weight of vegetable before storage

w_2 = weight after storage in certain days interval of storage.

For good and edible condition, physiological loss in weight is up to 10 percent. For the present study, the observations were recorded at two days' interval for each treatment of physiological loss in weight.

Moisture Content (MC)

The moisture content of a product is the amount of moisture present in it on weight basis and is usually expressed in percent. It is represented by two methods, wet basis and dry basis.

Wet Basis: (Weight of water in product / Weight of product sample) × 100

Dry Basis: (Weight of water in product / weight of dry matter of product sample) × 100

Experimental Results

The variety SARTAJ which is at present the most prevailing variety of okra in Odisha was taken for the study. To start with the work, a small capacity (100 kg) cool chamber was fabricated and fitted with solar powered vapour compression refrigeration system and an active evaporative cooler. The performance of the developed solar powered cool chamber was evaluated with respect to physiological weight loss, rotten percentage, colour change and firmness condition during the storage of okra both in winter and summer period. The freshly harvested okra was stored in the cool chamber by keeping them in the perforated polythene packet. The physiological weight loss in the range of 10-15 percent and rotten percentage to be in the range of 20-30 are allowable for maintaining the freshness and marketability of vegetables (Olosunde 2006) [4]. The data regarding percentage physiological loss in weight, rotten percentage, prevailing temperatures, relative humidity in the cool chamber and in the ambient condition along with the shelf-life of okra under the present investigation were recorded both during peak winter and summer period and are presented in the tables 1-4.

From Table-1, it was observed that the temperature and relative humidity variations in the solar cool chamber were in the range of 12.2-14.7 ºC and 86-93% respectively in a winter day. The decrease of temperature and increase of relative humidity were found to be in the range of about 4-12 ºC and 5-12% respectively compared to the ambient conditions. This may be due to the lower rate of evaporation of the ambient air with more relative humidity in winter days. Similarly, from Table-2, it was found that in a summer day, the temperatures and relative humidity variations in the solar cool chamber were in the range of 14.3-15.9 ºC and 83-94% respectively. The decrease of temperature and increase of relative humidity were found to be in the range of about 12-16 ºC and 16-49% respectively compared to the ambient conditions. This may be due to the higher rate of evaporation of the prevailing dry ambient air in summer days.

Considering the allowable physiological weight loss in the range of 10-15 percent and rotten percentage to be in the range of 20-30 for the vegetables (Olosunde 2006) [4], it was found from Tables-3 and 4 that the okra was safely stored up to 17 days and 12 days respectively in winter and summer period. The score for colour index is given on the basis of visual observations. The rating of colour index is defined as,

Fresh green = 1
Green = 2
Yellow = 3
Blackened = 4

Table 1: Experimental observations of temperature and relative humidity in ambient condition and inside developed cool chamber with stored okra during a winter day

Date: 11-1-18 Time ↓	Ambient		Developed cool chamber		Solar Radiation
	Temp (ºC)	Rh (%)	Temp (ºC)	Rh (%)	(w/m²)
6 am	16.3	82	12.2	93	0
8 am	19.7	80	12.2	91	181
10 am	23.7	78	12.6	91	630
12 noon	25.6	75	13.9	89	731
2 pm	26.5	73	14.7	86	590
4 pm	20.4	77	14.7	87	184
6 pm	18.4	80	14.6	88	0
8 pm	17.9	81	14.5	89	0
10 pm	15.6	85	14.5	90	0
12 mid night	15.4	86	13.3	92	0

Table 2: Experimental observations of temperature and relative humidity in ambient condition and inside developed cool chamber with stored okra during a summer day

Date: 6-5-18 Time ↓	Ambient		Developed cool chamber		Solar Radiation
	Temp (ºC)	Rh (%)	Temp (ºC)	Rh (%)	(W/m²)
6 am	28.3	75	14.3	91	28
8 am	29.1	71	14.5	88	408
10 am	33.8	41	14.5	85	871
12 noon	35.5	36	14.7	85	922
2 pm	39.6	32	15.9	83	882
4 pm	36.8	40	15.5	86	414
6 pm	31.8	48	15.0	86	0
8 pm	31.4	59	14.8	87	0
10 pm	30.0	67	14.6	90	0
12 mid night	26.6	73	14.5	94	0

Table 3: Quality analysis of storage of okra in developed cool chamber during winter period (initial moisture content 88%)

Date	Storage (days)	% Physiological Weight Loss	Rotten/Unmarketable (%)	Colour Change	Firmness Conditionb (kg/cm²)
3-1-18	Initial (0)	--	--	1	1.4
5-1-18	2	---	---	1	2.0
7-1-18	4	2.6	---	1	2.3
9-1-18	6	4.8	---	2	2.5
11-1-18	8	6.2	3.8	2	2.8
13-1-18	10	8.8	7.5	3	3.0
15-1-18	12	10.2	9.5	3	3.2
17-1-18	14	13.5	15.8	3	3.4
19-1-18	16	15.8	19.8	3	3.8
20-1-18	17	17.4	20.8	3	4.0
21-1-18	18	Spoiled	30.8	4	4.3

Table 4: Quality analysis of storage of okra in developed cool chamber during summer period (initial mc 92%)

Date	Storage (days)	% Physiological Weight Loss	Rotten/Unmarketable (%)	Colour Change	Firmness Condition (kg/cm²)
4-5-18	Initial (0)	--	--	1	1.3
6-5-18	2	2.4	---	1	2.1
8-5-18	4	3.6	---	2	2.4
10-5-18	6	5.8	4.5	2	2.7
12-5-18	8	7.2	6.8	3	3.1
14-5-18	10	10.8	9.5	3	3.4
16-5-18	12	17.3	10.5	3	3.7
18-5-18	14	Spoiled	30.8	4	1.3

Where

Fresh green indicates just harvested, edible and good condition. Green indicates few hours after harvest, edible and good in condition. Yellow indicates starting of deteriorating condition, not edible, black color indicates not edible, and rotten. The score of colour index for 17 and 12 days of storage in winter and summer days was given 2 for okra from visual a observation which was in the green, edible and in good conditions. Hence, from the data collected in the storability of okras in the solar cool chamber under study during the course of the research work, the following conclusions have been drawn.

1. The shelf life of okra in the developed cool chamber was found to be 12 and 17 days respectively during summer and winter period when it was covered with the perforated polythene packet and then stored inside the cool chamber.
2. The shelf life of okra in the developed cool chamber was found to be 11 and 14 days respectively during summer and winter period when it was not covered with the perorated polythene packet and kept in exposed condition in the crates during storage inside the cool chamber.
3. The shelf life of okra when covered with perforated polythene packet during storage inside the various cooling devices under study was observed to be 2-4 days more than without polythene cover both during summer and winter period.
4. The average efficiency of module for the experimental solar PV system was found to be 12% as against 15.7% under standard condition, mentioned by the manufacturer.
5. The temperatures and relative humidity were maintained in the range of 14-16 ^{o}C and 83-94% respectively during summer period inside the developed cool chamber as against the recommended values for storage of okra to be 10-15 ^{o}C and 85-95%.

References

1. Anonymous. Economic Survey of India, Govt. of India, 2013
2. Ghai TR. Post-harvest physiology of okra. In: Post-harvest Handling of Fruits and Vegetables. Sandhu AS, Bal JS. (Ed.). Super Natural Design, 1808, Maharaj Nagar, Ludhiana, 2002, 100-104.
3. Jain D. Development and testing of two-stage evaporative cooler. Building and Environment, 2007, 2549-2554.
4. Olosunde WA. Performance Evaluation of Absorbent Materials in the Evaporative Cooling System for the Storage of Fruits and Vegetable M.Sc. Thesis, Department of Agricultural Engineering, University of Ibadan, Ibadan, 2006.
5. Modi Anish, Anirban Chaudhuri, Bhavesh Vijay, Jyotirmay Mathur. Performance analysis of a solar photovoltaic operated domestic refrigerator. Applied Energy. 2009; 86:2583-2591.
6. Singh RKP, Satpathy KK. Performance evaluation of zero energy cool chamber in hilly region. Agricultural Engineering Today. 2006; 30(5&6):47-56.
7. Sharma PK, Samuel DVK. Solar Photovoltaic (PV) powered system for lighting and refrigeration for use in rural areas. Agricultural Engineering Today. 2014; 38(2):18-21.