FEASIBILITY OF PUSA ZERO ENERGY COOL CHAMBER AS LOW COST ON-FARM STORAGE STRUCTURE UNDER KERALA CONDITION

By

LEKSHMI S.G.

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"FEASIBILITY OF PUSA ZERO ENERGY COOL CHAMBER AS LOW COST ON FARM STORAGE STRUCTURE UNDER KERALA CONDITION"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship or other similar title, of any other University or Society.

Place : Vellayani
Date : 10/10/2019

LEKSHMI S.G.
(2017-12-015)

CERTIFICATE

Certified that this thesis entitled **"FEASIBILITY OF PUSA ZERO ENERGY COOL CHAMBER AS LOW COST ON FARM STORAGE STRUCTURE UNDER KERALA CONDITION"** is a record of research work done independently by Ms. LEKSHMI S.G under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Place : Vellayani

Date : 10/10/2019

Dr. Mini C.
Professor and Head
Department of Post Harvest Technology
College of Agriculture, Vellayani

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. LEKSHMI S.G. a candidate for the degree of **Master of Science in Horticulture** with major in Post Harvest Technology, agree that the thesis entitled **"FEASIBILITY OF PUSA ZERO ENERGY COOL CHAMBER AS LOW COST ON FARM STORAGE STRUCTURE UNDER KERALA CONDITION"** may be submitted by Ms. LEKSHMI S.G. in partial fulfilment of the requirement for the degree.

Dr. Mini. C
(Chairman, Advisory Committee)
Professor and Head
Department of Post Harvest Technology
College of Agriculture, Vellayani

Dr. Manju R.V.
(Member, Advisory Committee)
Professor
Department of Plant Physiology
College of Agriculture, Vellayani

Dr. P.R. Geetha Lekshmi
(Member, Advisory Committee)
Assistant Professor
Department of Post Harvest Technology
College of Agriculture, Vellayani

Dr. Anith K. N.
(Member, Advisory Committee)
Professor
Department of Agriculture Microbiology
College of Agriculture, Vellayani

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LIST OF ABBREVIATIONS

et al.	Co-workers/ Co-authors
%	Per cent
@	at the rate of
ANOVA	Analysis of variance
CRD	Completely Randomised Design
PLW	Physiological loss in weight
Eq.	Equivalent
Fig.	Figure
g	Gram
kg	Kilogram
KW	Kruskall-Wallis
m M	Millimolar
mg	Milligram
min	Minute
mL	Millilitre
mm	Millimetre
N	Newton
N	Normal
M	Molar
No.	Number
NS	Not significant
°C	Degree Celsius

V	Volume
viz.,	Namely
χ^2	Chi-square
OD	Optical density
rpm	Rotations per minute
°B	Degree brix
PZECC	Pusa Zero Energy Cool Chamber
IARI	Indian Agriculture Research Institute
RH	Relative Humidity
GI	Galvanised Iron
CPRS	Central Potato Research Station
$g\ g^{-1}$	Gram per gram
CD (0.05)	Critical difference at 5 % level
m^3	Meter cube

Introduction

1. INTRODUCTION

India is a rich horticultural country producing a wide variety of crops, and our production has been steadily increased due to advancement in production technology. India produced 90.2 million MT fruits and 169.1 million MT vegetables (NHB, 2016). Unfortunately, having such a huge production, major portion is being wasted at various stages from production till it reaches end-user, which is mainly due to improper post-harvest management.

Post-harvest loss is defined as measurable qualitative and quantitative loss along the supply chain, starting at the time of harvest till its consumption or other end uses (Hodges *et al.*, 2011). Post-harvest value chain has four critical phases, viz., harvesting and primary processing, storage, processing, and market linkage. Each of these has inefficiencies resulting in crop losses and 51% of this loss occurs during handling and storage in the food pipeline. The per cent post-harvest loss in fruits and vegetables is 4.58 – 15.88 % (CIPHET, 2015) with monetary value more than two trillion per year which adversely affect the Indian economy. Detailed analysis of our supply chain indicated that development of wholesale market together with enhancing storage capacities are keys for reducing post harvest losses of horticultural commodities and enhancing their market arrival.

Kerala, considered a consumer state, imports almost all fruits and vegetables from neighboring states and we have achieved great success in increasing the production of fruits and vegetables too. Post harvest loss and quality deterioration of horticultural commodities take place due to lack of several management practices including refrigerated storage. Setting up of cold storages will be ideal to reduce post harvest loss and manage price fluctuation considerably. Even then setting up of cold storages for storing horticultural produce has not gained pace in the state. Setting up of cold storages is not easily acceptable to small and marginal farmers of Kerala, as refrigeration is energy intensive, expensive, difficult to install and run in farmers' fields and not always environment friendly. In the absence of cold storages and related cold chain facilities, the farmers are being forced to sell their produce immediately after harvest which results in glut situations and low price realization. Sometime farmers do not even get their harvesting and transportation costs and our farmers continue to remain poor even though they take risk of cultivating high value fruits and vegetable crops year after year.

Considering acute energy crisis, a low cost storage facility accessible to them will go a long way in removing the risk of distress sale to ensure better returns. Unless there are systematic solutions to manage the surplus in horticulture perishables, time and money spent on cultivation will be a mere waste. Pusa Zero energy cool chamber (PZECC) is an accepted model of on-farm storage in Rural North India where high temperature and low humidity prevails. It is a low cost double walled storage structure made of bricks, developed at IARI, New Delhi, which operates on the principle of evaporative cooling.

Evaporation of water from the liquid phase into the vapour phase requires energy. This principle can be used to cool stores by first passing the air introduced into the storage room through a pad of water. The degree of cooling depends on the original humidity of the air and the efficiency of the evaporating surface. If the ambient air has low humidity and is humidified to around 100% RH, then a large reduction in temperature will be achieved. This can provide cool moist conditions during storage. Evaporative cooling is a natural phenomenon that occurs when moving air passes over a wetted medium or water source. When water evaporates, it draws energy from its surroundings which produce a considerable cooling effect.

If this structure is suited to humid tropics of Southern Kerala, it would be a satisfactory option for short term maintenance of horticultural perishables during glut period, reducing the wastage of perishable commodities and thus providing remunerative prices to the growers.

Hence the present study "Feasibility of Pusa Zero Energy Cool Chamber as low cost on-farm storage structure under Kerala condition" was carried out with the objective to evaluate the feasibility of Pusa Zero Energy Cool Chamber as a low cost on-farm storage structure for horticultural perishables during different seasons under humid tropical climate of Kerala.

Review of Literature

2. REVIEW OF LITERATURE

Post harvest loss and quality deterioration of horticultural commodities take place due to lack of several management practices. Due to postharvest losses, there is a considerable gap between gross production and net availability of fruits and vegetables to consumers at present and this loss has been attributed to several factors among which lack of refrigerated storage facilities and poor means of transportation are the major ones. Setting up of cold storages will be ideal to reduce post harvest loss and manage price fluctuation considerably. Relevant studies on importance of storage, low cost storage structures, zero energy cool chambers and the quality parameters influenced by storage in zero energy cool chambers are reviewed in this chapter.

IMPORTANCE OF STORAGE

Storage is defined as the process of keeping the commodity in safe condition with minimum of deteriorative changes for later use (Rathore *et al.*, 2012). It is the process which maintains food quality by retaining flavor, color, texture and nutrients, while reducing the chance of contracting a food-borne illness. (Khan *et al.*, 2017).

According to Widodo *et al.,* 2016, Rathore *et al.*, 2010, Kasso and Bekele, 2018, lack of storage facilities is a big issue in the supply chain of fruits and vegetables.

The capacity, availability and facilities of storage are very important requirements to reduce wastage and maintain food quality (Negi and Anand, 2015). Rais and Sheoran (2015) reported that India needs 10 million tons of cold storage capacity and its deficiency cause 30% wastage per year. According to Dey *et al.*, 2013, the storage structures should be strategically located so as to reduce the transportation time and the availability of the different modes of transport may also be considered for selection of storage location.

EFFECT OF STORAGE ON POST HARVEST QUALITY

Aziz *et al.*, 1975 reported an increased percentage weight loss of papaya fruits when stored for prolonged period, and the increase was greater in papaya stored at 15 compared to that at 10°C. The decay percentage was also greater at higher temperature. Total soluble solids showed a slight and gradual increase upto the end of the storage period. The high temperature in storage accelerated colour development in the peel and chlorophyll content was diminished. Increased carotenoids was noticed both in peel and pulp as the storage period increased.

Nazeeb and Broughton, 1978 reported that ascorbic acid contents decreased gradually as the papaya fruits ripened in storage.

The weight loss at which most fruits and vegetables become unmarketable due to shrinkage ranges from 3% to 10% (Burton, 1981). Hardenburg *et al.*, 1990 reported that low temperature storage is the most efficient method to maintain fruit and vegetable quality due to its influence on reducing rate of respiration, ethylene production, ripening, senescence, and rot development.

Weight loss during storage varied with the packaging conditions and storage temperature of spinach (Watada *et al.*, 1987). The types of fruit surfaces as well as underlying tissues of fruit have a marked effect on water loss and Wills *et al.*, 1981 observed the differences among the varieties.

Metabolism in fresh horticultural commodities continues even after harvest and rate of deterioration increases due to ripening, senescence and unfavourable environmental factors. Hence, preserving these commodities in fresh form demands that the chemical, bio-chemical and physiological changes are restricted to a minimum by control of temperature and humidity (Chandra *et al.*, 1999).

Bosland and Votava (2000) reported that differences in nutritional composition are decided by the cultivar, growing conditions and fruit maturity, and that changes occur later during postharvest handling and storage. High temperature increases enzymatic reaction leading to breakdown of biochemical compounds in fruit and vegetables (Yoshida *et al.*, 1984) which could be the reason for the low ascorbic acid content at ambient storage conditions.

Papaya fruits, when exposed to excessively hot temperatures during storage resulted in accelerated ripening, resulting in the depletion of organic acids and sugars due to increased respiration rate (Lam, 1989).

Increased TSS content during storage was associated with the conversion of pectic substances, starch, hemi cellulose or other polysaccharides in soluble sugar (Hoda *et al.*, 2000).

Fruit and vegetables quality is affected by water loss during storage, which is influenced by the temperature and RH during storage conditions (Aste *et al.*, 2017).

According to Agar *et al.*, 1997, vitamin C content of apples under controlled atmosphere reduced to a greater extent than those stored in air, but those in controlled atmosphere were stored for a longer period. Lee and Kader (2000) had classified different vegetables as good, moderate, or poor in their retention of ascorbic acid. Only 8% of the original ascorbic acid content was present in green beans after refrigerated storage of 16 days. Vitamin C content of spinach increased slightly between 3rd and 7th day during modified atmosphere storage. Ascorbic acid content decreased between 25% and 30% in apple cultivars during six months of conventional storage (Lachman *et al.*, 2000).

High storage temperature was responsible for accelerated water loss and subsequently to fruit shriveling and softening (Proulx *et al.*, 2005).

There is softening of fruits with progressive storage time and it could be due to textural modification through degradation of polysaccharides viz., pectins, cellulose and hemicellulose during ripening process (Irtwange, 2006).

Fruits and vegetables, need immediate post harvest attention to reduce their microbial load thereby increasing their shelf life, which can be achieved by storing them under low temperature and high relative humidity, which are usually achieved in cold storages (Basediya *et al.*, 2013)

Control of temperature and relative humidity during storage is important as they are the main reason for fruit and vegetable deterioration during ripening and storage. Reduction in temperature of the produce as well as surrounding air is possible by forced air-cooling, hydro cooling, vacuum cooling, ice cooling, and evaporative cooling (Awole *et al.*, 2011). The evaporative cooling was suggested to be a good alternative for the small-scale farmers, retailers, and wholesalers, as it requires low establishment and running cost compared to other cooling methods (Workneh and Woldetsadik, 2004, Tigist *et al.*, 2013, Workneh *et al.*, 2011 and Workneh *et al.*, 2012).

According to Jahun*et al.*, 2014 maintaining lower temperature and higher relative humidity during storage combined with selection of cultivars with long shelf life could maintain fruit quality and results in reduced loss.

LOW COST STORAGE STRUCTURES

Field storage clamp is a simple and low cost storage technique, used in agricultural fields for temporary storage of root crops which can be designed using local available materials (CIP, 1981).

A weight loss of 15-25% in yams stored in wind breaks compared to 60% in pit storage over a 5 months period was recorded in storage inside wind breaks (Ezeike, 1985).

One modification on the basic pot design is the Janata cooler that was developed by the Food and Nutrition Board of India (Roy and Khurdiya, 1985). The design consisted of a storage pot which was kept inside a bigger pot holding water.

The inner pot is used to store food that is maintained cool. A storage pot is placed in an earthenware bowl containing water and is then covered with a damp cloth which is dipped into the water reservoir. Water drawn up the cloth when evaporates, keep the storage pot cool. The bowl can be placed on wet sand, to isolate the pot from the ground. Mohammed Abbah, developed a small scale storage pot-in-pot system in Nigeria, that uses two pots of slightly different size (Longmone, 2003). The smaller pot is placed inside the large pot and the space between is filled with sand.

Underground storage structures called cellars were very useful in low cost storage for fruits and vegetables.Cellars helps in keeping the produce safe from freezing during winters and keep cool during summers (Mike and Bubel, 1991).

The indigenous low cost methods for storage of horticulture crops are less energy intensive involving less capital. Produces can be stored safely upto a few months without spoilage (Anon., 2004).

Modified pit storage system has been developed by Dr.Y.S. Parmar University of Horticulture & Forestry, Solan for ginger storage (Saraswathy *et al.*, 2008).

The charcoal cooler is made from an open timber frames covered with inside and outside meshes, leaving a 25 mm cavity and the cavity is filled with charcoal pieces. The charcoal pieces when sprayed with water provide evaporative cooling. (Odesola and Onyebuchi, 2009).

The efficacy of earthen pot cool chamber to store vegetables and fruits were studied by Murugan *et al.*, 2011 using tomato, grapes and brinjal. After 9 days of storage the products stored in earthen pot cool chamber remained fresh and less affected when compared to refrigeration and room temperature storage.

PRINCIPLE OF EVAPORATIVE COOLING

The farm level studies were initiated in the early eighties at CFTRI, Mysore, CPRS, Jalandhar and IARI, New Delhi (Rama and Narasimham, 1991).

Evaporative cooling provides an inexpensive, energy efficient, environment friendly and potentially attractive cooling system

Evaporative cooling (EC) occurs when air which is unsaturated with water vapour is blown across a wet surface. Thus evaporative coolers consisted of a wet porous bed through which air is drawn and cooled and humidified by water evaporation (Khader, 1999).

The process of evaporative cooling is an adiabatic heat exchange when ambient air passes through a saturated surface to obtain low temperature and high humidity, which are essential desirable to extend the storage life of fruits and vegetables (Dash and Chandra, 2001).

Evaporative cooling is a physical phenomenon where liquid evaporates to surrounding air there by cooling an object in contact with it. When water evaporation into air is considered, the wet-bulb temperature, as compared to the air's dry-bulb temperature, is a measure of the potential for evaporative cooling. The greater the difference between the two temperatures, the greater will be effect of evaporative cooling. Evaporation of water results in considerable cooling effect and the faster the evaporation the greater is the cooling. When the temperatures are the same, no net evaporation of water in air take place, thus there is no cooling effect. The principle of working of this system is when a particular space is conditioned and maintained at a temperature lower than the ambient temperature surrounding the space, there should be release of some moisture from outside the body. This maintains low temperature and high humidity in the space compared to the surrounding. The evaporative cool chamber fulfills all these requirements and is helpful to small farmers of rural areas (Dadhich *et al.*, 2008).

The evaporative cooled storage structure is found to be useful for short term, on-farm storage of fruits and vegetables in hot and dry regions (Jha and Chopra 2006). Evaporative cooling, which is an efficient and economical means for reducing temperature and increasing the relative humidity of an enclosure, has been extensively tried for enhancing the shelf life of horticultural commodities (Odesola and Onyebuchi, 2009) and for maintaining the freshness of the commodities (Dadhich *et al.*, 2008).

Evaporative cooling is an environmental friendly air conditioning system that operates using induced processes of heat and mass transfer where water and air are working fluids (Camargo, 2008).

The evaporative cooler has proved to be effective in minimizing the extremes of temperature and RH (Workneh and Woldetsadik, 2004), (Tefera *et al.*, 2007) and (Getenit *et al.*, 2008).

DESIGN AND FABRICATION OF EVAPORATIVE COOLERS

Roy and Khurdiya (1982) constructed four types of evaporative cool chambers for storage of vegetables. The first one was made of cheap quality porous bricks and riverbed sand and the other three chambers were earthen pots placed in three tanks: the first one was made of bricks, the second one a wooden box and the third, a fruit basket. Sand was used to fill the gap in all these cases. The sand and the gunny bags covering the top of the chambers were kept saturated with water. Temperature was maintained between 23-26.5°C and relative humidity between 94-97% in the cool chambers, where as it was 24.2-39.1°C and RH 9-36% at ambient temperature during May-June.

The design aspects of a solar-cum-wind aspirator ventilated evaporative cooling structure of 20-ton capacity for potatoes and other semi perishables were made by Chouksey (1985) at the Central Potato Research Station (CPRS), Jalandhar. The structure maintained a temperature of 21-25°C with 80-90% RH at ventilation rate of $24m^3$ /min where as the outside temperature and RH were 40-42°C and 30-35%, respectively.

Habibunnisa *et al.*, 1988 fabricated a metallic EC chamber of 45 x45 x 45 cm with a 2 mm GI sheet with the top side open. The four sides of the chamber were covered with a cloth and its top ends were immersed in water placed in the top tray. The cloth surrounding the metallic chamber was made to remain wet continuously by water and allowed to evaporate. A wire mesh basket of 30 x 30 x 30 cm size filled with fruits was kept inside the chamber, leaving adequate space all around the basket for air circulation.

Lawrence and Tiwari (1989) reported that an evaporative cooling system with 50%efficiency, has significant effect on room temperature of non-air-conditioned.

Rama *et al.*, 1990 evaluated the relative performance of two models of EC storage structures with respect to their efficiency in maintaining the temperature close to the ambient temperature and high RH. The first structure was the metallic EC chamber (approx. 0.1 m^3) with a 2 mm GI sheet with the top side open. In the second one the outer metallic wall was replaced by a weld wire mesh (2.5 x 2.5 cm) with evaporative sides covered with wet gunny cloth to help in free movement of evaporatively cooled air. The top tray was used to serve as water reservoir to wet the gunny cloth and was devoid of vents. The inside temperature for both the structures were close to the ambient wet bulb temperature and the relative humidities were 90 ±5%, respectively. The lower RH of the second system was attributed to the free air circulation through the structure.

Sharma and Kachru, 1990 said sand stores cooled by evaporative cooling, where a 5 cm thick potato layer was placed on floor in between two sand layers each of 20 cm thickness. Water @2.1 m^3 was sprinkled daily to wet the sand for allowing evaporative cooling. It was seen that under low atmospheric RH conditions, wet sand was found suitable for storing potatoes up to three months as compared to two months in jute bags and it was still less in bamboo baskets and heaps.

Umbarkar *et al.*, 1991 made a 25 kg capacity double brick walled EC storage structure of size, 0.75 x 0.75 x 0.75 m under a shed for extending the shelf life of oranges using structural materials brick, cement, mortar, gunny bag, bamboo.

Umbarkar *et al.*, 1998 constructed an EC structure of two tonne capacity based on previous results. The walls were constructed with 10 cm thick brick batt pad sandwiched between two 10 cm thickness brick perforated walls. 8 mm diameter mild steel reinforcement anchored the latter with each other to add to the structural strength. 50 x 40 mm holes were provided between two successive brick layers for air circulation throughout the structure height. A thatched roof with bamboo mat and dry grass was provided as top cover. At the bottom of storage stacks, a free board of 10 cm was left for flow of water from walls. The chamber temperature varied between 23- 26.5°C as against ambient temperature between 25-44°C on a test day. The RH in the structure was 85-97%.

Taha *et al.*, 1994 designed a special type of evaporative cooler and evaluated for its performance under different conditions and concluded that the ambient temperature was reduced by 10–13 °C.

Dash, (1999) formulated a mathematical model for analysis of time dependent thermal environment in evaporative coolers. It was proved that the RH inside the evaporative cooler would remain close to 100%, throughout the year and maximum advantage of evaporative cooling could be obtained under low ambient relative humidity. The orientation of structure had a negligible effect on the inside thermal environment. Shading the structure during the month of January, April, July and October could lower the cumulative heat units by 8.1, 8.23, 3.2 and 4.8%, respectively.

The design, construction and measurement of performance of a porous evaporative cooler for preservation of fruits and vegetables were carried out by Anyanwu, 2004.

Babarinsa, 2006 constructed a double-walled rectangular 1.38 m^3 capacity evaporative cool storage structure of size 108 x 108x 120 cm for tomato with bricks, sand, cement, particle board as the structural material.

Jain (2007) developed a two-stage evaporative cooler (TSEC) to improve the efficiency of evaporative cooling for high humidity and low temperature air conditioning.

According to Zhao *et al.*, 2008, several types of materials, viz.,metals, fibres, ceramics, zeolite and carbon, have potential to be used as heat and mass transfer medium in the indirect evaporative cooling systems.

ROLE OF WATER IN EVAPORATIVE COOLERS

Water has a critical role in regulating relative humidity and temperature inside the cool chamber. Too moist and too dry cool chamber could lead to unwanted microbial growth and spoil the stored commodities. Since the moisture content in the cool chamber is regulated by the water added to the sand, it is necessary to find the optimum water quantity to be added for improving performance of the cool chamber.

Muthiah *et al.*, 2004 conducted a storage study of brinjal (cv. Pattabiram) in cool chambers at room temperature using three different levels of water (100, 75 and 50 litres per day) added through drip irrigation system to moisten the sand in the cool chamber. The PLW and rotting percentage decreased with increasing water level up to 100 litres per day. shelf-life of brinjal at room temperature was enhanced from three to 9 days with the addition of 100 litres of water per day.

Rayaguru *et al*., 2010 analysed that optimum water level of 75 litre per day and 90 itre per day were required to achieve a steady and conducive storage environment in summer and winter months, respectively in coastal districts of Orissa.

ZERO ENERGY COOL CHAMBERS

Roy and Khurdiya (1982) constructed an evaporative cool chamber made of cheap quality porous bricks and river bed sand for storage of vegetables, later known as Zero energy cool chamber. The gap was filled with sand, the sand and the gunny bags covering the top of the chamber were kept saturated with water to maintain enclosed air temperature between 23-25.2˚C and relative humidity (RH) between 94-97%. Zero energy cool chamber performed best among the available four types of Evaporative coolers.

Roy (1984) constructed a six tonne capacity cool chamber, where the side wall with two layers of bricks was constructed leaving approx. 7.5 cm gap in between them. This gap was filled with sand and the floor made of wooden planks. Below the floor, a 33 cm deep tank was constructed with 4 air ducts made of bricks opening at the center and submerged under wet sand. The sand in the wall and surrounding the ducts were saturated with a drip system. The chamber top was insulated and incorporated with an exhaust fan. The air while passing through saturated duct and walls cooled sufficiently and took away heat from the commodities. The desired temperature and humidity was maintained by sprinkling of water twice daily.

Roy and Khurdiya (1986) have detailed construction method of a Zero energy cool chamber capable of storage of about 100 kg horticultural commodities. The top of the storage space was covered with khaskhas/ gunny cloth in a bamboo-framed structure. There was no provision for mechanical ventilation. The sidewall and top cover were kept completely wet during the storage period. It was observed that the cool chamber had a temperature of less than 28˚C during summer, when the maximum outside temperature was 44˚C..

The cooler made of bricks with a mixture of moistened sand and zeolite maintained a low inside temperature and high relative humidity (Islam and Morimoto, 2012).

Islam and Morimoto (2014) recommended a new ZECC with two cooling systems, a solar-driven adsorption refrigerator and an evaporative cooling system as low-cost, energy-saving and useful for storing fruit and vegetables in areas where there is no electricity.

WAETHER PARAMETERS AND ZECC

Dirpan *et al.*, 2017 evaluated temperature and relative humidity (RH) in two types of zero energy cool chamber constructed in South Sulawesi, Indonesia. The first type was kept underground and the second one was on the surface. It was that the ZECC constructed on the surface produced lower temperature and higher RH compare to ZECC which placed underground. On an average, outside temperature was 28.0°C and inside temperature was 26.2°C. The outside relative humidity (72.9%) was less than in inside (87.2%) of the chamber. The ZECC constructed on the surface is more suitable for decreasing temperature and increasing relative humidity.

EFFECT OF ZECC ON SHELF LIFE AND MARKETABILITY

Kaithli, Umran and Gola cultivars of Ber fruits could be stored in PZEC chambers for 14, 15 and 18 days, respectively (Roy, 1989). Siddiqui and Gupta (1990) stored fruits in these chambers up to 6–10 days. The fruits of cultivar Gola were found to be in acceptable condition up to 12 days of storage in ZECC.

Storage of horticultural products inside the cool chamber has showed reduction in physiological loss in weight and extended shelf life by 1–2 weeks . Cool chambers are reported to be effective in minimizing the weight loss while storage (Bhatnagar *et al*., 1990).

Roy and Pal (1991) could obtain an additional shelf life of 3-4 days for mature green mangoes kept in cool chamber as compared to ambient storage. But, ripe mangoes when stored in cool chamber had 9 days shelf life as against 6 days under ambient condition. The chamber was more efficient during the dry season.

Physiological loss in weight of tubers of potato cultivars remained less than 10% until 12 weeks of storage under ECS (Mehta and Kaul, 1997).

On farm evaporative cool storage was technically feasible on reducing potato storage losses by as much as 50% over farmer's methods (Fuglie *et al*., 1997).

Bhardwaj and Sen (2003) evaluated storage of Mandarin cv. 'Nagpur Santra' in zero energy cool chamber and reported reduction in the PLW (17.88%), rotting (18.07%), loss in juice content (11.08%) and reduction in diameter (11.54%).

Ramesh (2003) reported that coleus tubers stored under ZECC exhibited minimum spoilage with least physiological loss in weight compared to those stored under room temperature and pit storage

Mordi and Olorunda (2003) reported a higher marketability for the evaporative cooler samples than those stored under ambient conditions.

Singh and Satapathy (2006) evaluated the performance of IARI design Zero Energy Cool Chamber (ZECC) at ICAR Research Complex, Meghalaya and observed an enhanced shelf life of 5 days for bitter gourd, capsicum, and cauliflower whereas; shelf life of tomato and pineapple was increased for about 6 and 9 days respectively, inside the cool chamber as compared to room temperature storage.

The shelf life of mangoes kept in the evaporative cooling unit was increased from 3 to 28 days, compared to storage at ambient conditions (Tefera *et al.*2007). The Storage temperature greatly affected all postharvest quality parameters tested in mangoes during storage and higher temperatures rapidly deteriorated the physiological and chemical quality of stored mangoes.

The significant reduction in PLW under cool chamber was due to prevailing higher humidity and lower temperature, which lowered the transpiration rate as well as ethylene production at the lower temperatures. (Pareek *et al.*, 2009)

Rayaguru *et al.* (2010) reported the suitability of ZECC for extension of storage life of potato, tomato, brinjal, mango, banana and spinach by 3 to 15 days as against ambient conditions in coastal Orissa.

After 16 days of storage, all pepper fruits stored at ambient condition were unmarketable while those stored in evaporative cooler were kept up to 28 days (Samira *et al.*, 2013). The highest weight loss was recorded in bell peppers stored at ambient condition and the lowest weight loss in bell peppers stored in evaporative cooler.

Verma (2014) observed an enhanced shelf life for brinjal, tomato and potato stored in ZECC during summer compared to ambient condition storage.

The shelf life of tomatoes and pepper stored in the evaporative cooler was improved when compared with ambient storage (Jahun *et al.*, 2014).

EFFECT OF ZECC ON CHEMICAL QUALITY PARAMETERS

Dhaka *et al.*, 2001 reported a slower increase in TSS of the mango fruit at cool chamber conditions than ambient temperature storage which could be attributed to the lower temperature and higher humidity resulting in slower rate of ripening. Retention of ascorbic acid in cool chamber could be attributed to low temperature and high humidity prevalent in cool chamber condition. The similar trend in cool chamber storage was observed by Naik (1985).

Sandooja *et al.*, (1987) reported least deterioration in quality parameters of tomato viz., TSS, acidity and ascorbic acid content when stored in zero energy cool chamber.

Potatoes tubers stored in evaporative cool store were better suited to processing into chips and french fries due to low reducing sugar content (Mehta and Kaul, 1997)

Wasker *et al.* (1999) reported slower rate of change of physicochemical constituents in fruits when stored in cool chamber.

Kanak and Sanjay, 2013 conducted an experiment to evaluate the efficacy of zero energy cool chamber along with packaging on fruit quality of jamun cv Goma Priyanka and reported that packed fruits in perforated polythene bag when stored in zero energy cool chamber retained maximum total soluble solids, total sugar and reduction in titratable acidity, ascorbic acid.

The higher retention of TSS, ascorbic acid and acidity content of fruits at zero energy cool chamber might be due to lowering of temperature and respiration rate. (Sindhu and Singhrot, 1994) and Roy and Khurdia (1986). Organoleptic rating (test) revealed that the fruits stored at cool chamber were acceptable even after 12 days of storage period, whereas, at ambient temperature, fruits were acceptable upto the 4th day of storage.

Compared to fruits stored in the evaporative cooler, the higher TSS contents was reported in pepper at ambient storage condition and it could be related to the higher temperature that resulted in faster conversion of starch into water-soluble sugars (Getenit *et al.*, 2008)

Reducing sugar content increased by 52.4–242.1% in tubers stored in EC storage as compared to 90.5–484.2% increase in tubers stored in refrigerated storage until 14 weeks.(Mehta and Kaul, 1997)

Increase in TSS content was reported during storage of grapes (Singh *et al.*, 1987) and Indian gooseberry fruits (Singh *et al.*, 2010a) when stored in ZECC.

Azene *et al.*, (2014) reported that as the storage time advanced, papaya stored in the evaporative cooler had high TSS, ascorbic acid, titrable acidity , reducing and total sugar content and lower pH values.

Bell pepper fruits stored in evaporative cooler (Samira *et al.*, 2013) had highest ascorbic acid content compared to the one stored in ambient temperature.

EFFECT OF ZECC ON SENSORY QUALITY PARAMETERS

Storage of horticultural products inside the cool chamber has showed optimum colour, and better firmness. Cool chambers are reported to be effective in maintaining the fruit acceptability for a longer period (Bhatnagar *et al.*, 1990).

Mature green mangoes scored high organoleptic values when stored under ZECC (Roy and Pal, 1991)

Mitra *et al.*, (2003) observed more acceptability with better appearance, texture, taste and flavour for mango, litchi, guava, banana, sapota and mandarin stored in zero energy cool chambers than those maintained in ambient conditions.

Ramesh (2003) reported that coleus tubers stored under ZECC had high sensory score compared to those stored under room temperature and pit storage

Decreased organoleptic score with a corresponding increase in acidity was reported in fruits stored under ZECC (Ramkrishnan and Godara, 1993). The Umran cultivar of ber stored in ZECC after 12 days of storage were organoleptically acceptable (Fageria *et al.*, 1999 and Dhaka *et al.*, 2000).

Mordi and Olorunda (2003) reported that samples in evaporative cooler had higher rate for visual quality attributes than those stored under ambient conditions.

Papaya fruits stored in evaporative cooler were firmer till 9th day, while those under ambient storage were less firm and became soft after 6th day of storage. The relatively higher firmness in cooler might be due to the higher relative humidity and lower temperature which help to retard the fruit respiration and transpiration rate (Azene *et al.*, 2014).

Quality attributes of tomatoes and pepper was found to be best which was stored in the evaporative cooler (Jahun *et al.*, 2014)

Verma (2014) observed an excellent texture for brinjal, tomato and potato stored in ZECC during summer compared to ambient condition storage.

EFFECT OF ZECC ON MICROBIAL QUALITY PARAMETERS

High temperature and moderate humidity at the time of fruit maturity (February to March) leads to the attack of different micro-flora that caused decay, increased PLW and reduced shelf-life and quality of ber fruits. These factors lead to heavy losses which can be minimized by storing ber fruits in a zero energy cool chamber (Pareek *et al.*, 2009)

Roy and Khurdiya (1983) reported that spoilage in mango could be prevented to a great extent by storing the fruits in zero energy cool chamber.

IMPORTANCE OF PACKAGING IN ZECC

The storage life of fresh tomatoes without packaging stored in evaporative cooler was 11 days when compared to four days under ambient storage. In combination with perforated polyethylene bags the fresh tomatoes could be kept for over 18 days in the evaporative cooler as against 13 days under ambient conditions. For the completely sealed samples however, the storage life of tomatoes under ambient storage and evaporative cooler conditions were 6 and 8 days, respectively (Mordi and Olorunda, 2003)

Packaged amaranth and fenugreek samples stored in walk-in cooler conditions had higher amounts of ascorbic acid throughout the storage (Negi and Roy, 2003).

Sharma *et al.* (2010) found cryovac film (9μ) as the best for shrink-wrapping of Royal Delicious apples for storing in ZECC for 45 days without any adverse effect on quality parameters. Individual shrink-wrapping and storage under zero energy cool chamber exhibited the least physiological loss in weight and decay loss and higher juice recovery and total soluble solids over other films or control. Apples wrapped in cryovac films had higher sensory acceptability over the other films or control.

The evaporatively cooled storage combined with packaging improved the shelf life of papaya by more than two fold. The polyethylene packaging combined with evaporative cooling could maintain the superior quality fruit for a period of 21 days (Azene *et al.*, 2014). Similar results were reported in mango (Workneh and Woldetsadik, 2004) and in tomato (Getenit *et al.*, 2008)

Zero energy cool chamber along with perforated polythene bag was found economically viable for on farm storage of jamun fruits (Kanak and Sanjay, 2013). They also revealed that jamun cv Goma Priyanka fruits packed in perforated polythene bag when stored in zero energy cool chamber exhibited 4 days economic shelf-life, where as samples under ambient condition had shown one day economic life. Percentage of marketable fruits was 82.50% on 5th day of storage in perforated polythene bag and stored in zero energy cool chamber, while it was only zero per cent under ambient storage.

Singh *et al.* (2017) reported that Pear fruits individually packed in PE 0.05 or 0.01mm and stored at ZECC effectively maintained quality parameters up to 10th day of storage.

PRE-STORAGE TREATMENTS AND ZECC

Islam and Morimoto (2012) showed that tomato fruits treated with 60°C hot water for three minutes and eggplant with 45°C hot water for one hour when stored inside silver-ion-coated containers in the ZECC exhibited extended shelf life up to 28 and 15 days, respectively

Prabha *et al.*, 2006 and Arun *et al.* (2006) showed that extent of decrease in ascorbic acid contents in the stored fruits was lesser when treated in chlorine water and stored in zero energy cool chambers.

The fruits with fine coating of 10% sago and stored in ZECC had shown gradual ripening, retained excellent fruit quality with high TSS, total and reducing sugars, acidity and ascorbic acid even up to 9th day of storage (Jholgiker and Reddy, 2007)

Application of $CaCl_2$ 1.5% and ZECC is considered as an ideal on-farm storage facility for maintaining the quality of Ber fruits (Singh *et al.*, 2010b) and Indian gooseberry (Singh *et al.*, 2010a) under semiarid environment of Western India.

Materials and Methods

3. MATERIALS AND METHODS

The study entitled “Feasibility of Pusa Zero Energy Cool Chamber as low cost on- farm storage structure under Kerala condition” was undertaken at Department of Post Harvest Technology, College of Agriculture Vellayani from 2017-2019 with the objective to evaluate the feasibility of Pusa Zero Energy Cool Chamber as a low cost on-farm storage structure for horticultural perishables during different seasons under humid tropical climate of Kerala. The materials used and methods adopted during the research programme are described in this chapter.

3.1. CONSTRUCTION OF PUSA ZERO ENERGY COOL CHAMBER

A levelled land with good air circulation and sunlight having a nearby source of water supply was selected for construction of three numbers of zero energy cool chambers (Roy and Kurdiya, 1985), each with dimension of 165cm length, 115 cm breadth and 75 cm height. Floor was built with a single layer of bricks and a cavity wall was constructed of bricks around the outer edge of the floor with a gap of 75 mm between the inner wall and the outer wall. This cavity was filled with river sand and thoroughly saturated with water. Once the chamber was completely wet, a daily sprinkling of water was given to maintain 85-95% relative humidity inside the chamber and this was continued throughout the period of study. A covering for the chamber was made with wet jute sacks mounted on a wooden frame. The whole structure was protected from sunlight or rain by making a roof with green coconut fronds. (Plate.1)

3.2. COLLECTION OF COMMODITIES

The following six different fruits and vegetables of good quality and uniform maturity were harvested immediately after harvest from farmers’ fields of Kalliyur Panchayat through Farmer Producers Groups viz. Sanghamytri and Harithamitra and transported carefully and immediately for storage without affecting the produce quality. (Plate 2.)

Plate 1. Construction of Pusa Zero Energy Cool Chamber

(a) (b)

(c) (d)

(e) (f)

Plate 2. Commodities for storage study

(a) Papaya (b) snake gourd (c) cucumber
(d) bitter gourd (e) amaranth (f) cowpea

1. Papaya (*Carica papaya*) (local)

2. Snake gourd(*Trichosanthes cucumerina*)(local)

3. Cucumber (*Cucumis sativus*) (Sambar vellari)

4. Bitter gourd (*Momordica charantia*) (Preethi)

5. Amaranth (*Amaranthus viridis*) (Arun)

6. Cowpea (*Vigna unguiculata*) (Jyothika)

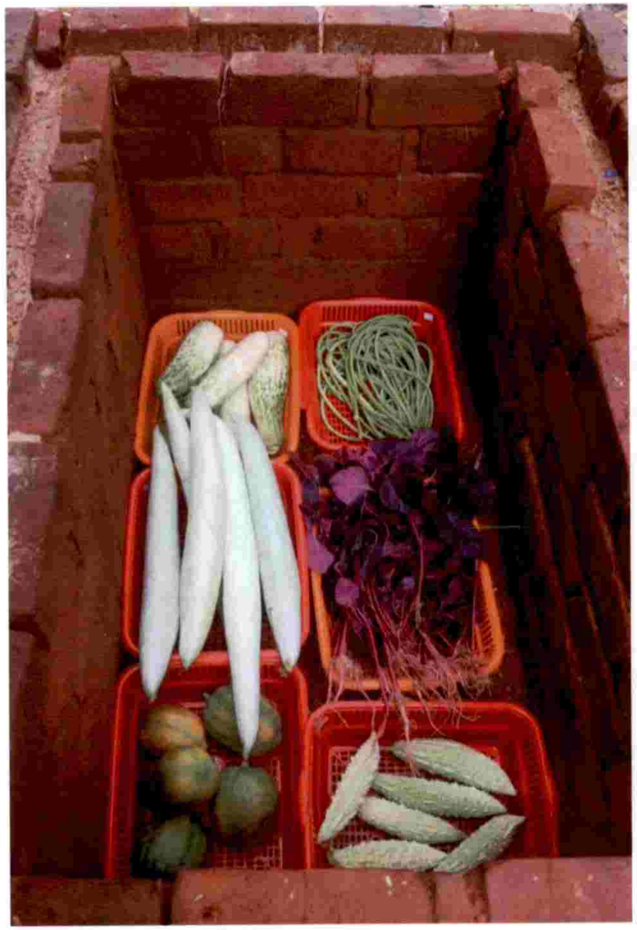
3.3. STORAGE STUDIES

The collected commodities were kept in perforated plastic crates and stored inside the zero energy cool chambers for storage studies. The commodities kept in each chamber formed each replication. Same set of commodities were kept under ambient storage conditions as control. (Plate 3.)

Experiment was conducted during the following three different seasons.

S1- June - September
S2- October - February
S3- March - May
Storage conditions (Z) – 2 Z_0:ZECC
Z_1:Ambient storage
Number of seasons (S) - 3
Total number of treatments - 6
Replication - 3
Design of experiment - CRD

The study was conducted as six separate experiments for six different commodities and possibility of storage of each commodity during different seasons was assessed based on the following quality parameters.



(a)

(b)

Plate 3. Storage conditions
(a) PZECC (b) Ambient condition

3.3.1. Physiological parameters

1. Shelf life (days)

Shelf life of commodities was assessed as the number of days from harvest till they remained fresh and marketable. Freshness assessment was based on the physical appearance as judged by retention of quality, color variation, level of pathogenic decay, shriveling and desiccation. (Nanda *et al.*, 2000)

2. Physiological loss in weight (%)

Physiological loss in weight was calculated on intial weight basis by weighing the commodities intially at the time of storage and subsequently at a constant interval till the end of shelf life using a laboratory level digital electronic balance having 0.01g accuracy. Cumulative weight loss was calculated using the formula and expressed as percentage.

$$\text{PLW (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \text{X } 100$$

3. Marketability

Marketability of stored commodities was assessed according to the scoring method described by Mohammed et al. (1999).

A 1 to 9 rating scale with 1 = unusable; 3= unsalable; 5= good; 7= very good; and 9= excellent was used to evaluate the marketability. The descriptive quality attributes were determined by the sensory panellists by observing level of decay, colour, firmness, shrivelling and surface defects as visual parameters and over all acceptability. The number of fruits receiving a rating of 5 and above was considered marketable, while those rated less than 5 were considered unmarketable. The number of marketable commodity was used as a measure to calculate the percentage of marketable commodities during storage, by using the following formula and expressed as percentage.

$$Marketability = \frac{Number\ of\ marketable\ commodities}{Total\ number\ of commodities} X\ 100$$

3.3.2. Physical parameters

1. Color

The external colour of commodities was examined daily and assessed using the modified colour chart (Zong et al.,1993).

Excellent uniform colour -9

Good colour -7

Fair and non uniform colour - 5

Poor colour for market -3

Un-acceptable colour -1

2. Texture

The texture of commodities stored under two different conditions were measured in firmness using texture analyzer TA.HD plus (Stable Microsystems, England) (Plate 4.) using compression mode. Two types of probes were utilised for analyzing texture of commodities adopting pear penetration model.

1) P/2 dia cylinder: It is a 2mm cylindrical stainless steel probe, used for cucumber, papaya, bitter gourd and snake gourd.

2) P/2N needle: It is a 2mm needle probe, used for amaranth and cowpea.

The machine was calibrated using the following test conditions.

Mode – compression

Pretest speed – 1 mm/sec

Test speed – 2mm/sec

Post test speed – 10mm/sec

Plate 4. Texture analyser

Distance – 5mm (P/N needle)

15mm (P/2 cylinder)

Trigger force – 0.049 N

Data acquisition – 200pps

After calibration of the equipment different commodities were positioned centrally on the blank plate of the platform and the compression test was carried out using suitable probes to plot the corresponding force determination curves.

3.3.3. Chemical quality parameters

The following chemical quality parameters of the commodities stored under two conditions were analyzed initially at the time of storage and at periodic intervals till the end of shelf life.

The parameters for analysis were selected based on the major chemical constituents present in each commodity as shown below.

Papaya -TSS (ºB), Sugars (%), Titratable acidity (%), Total carotene (mg/100gm), Vitamin C (mg/100gm)
Snake gourd - Total carotene (mg/100gm)
Cucumber - Vitamin C (mg/100gm)
Bitter gourd - Total carotene (mg/100gm), Vitamin C (mg/100gm)
Amaranth -Total carotene (mg/100gm), Vitamin C (mg/100gm), Oxalate(mg/100gm)
Cowpea - Total carotene (mg/100gm), Vitamin C (mg/100gm)

1. TSS (ºB)

Total Soluble Solids (TSS) of papaya fruits stored under both storage conditions were recorded using digital refractometer (Atago-0 to 53%) and expressed in degree brix (^{0}B).

2. Sugars (%)

A) Reducing Sugar (%)

The titrimetric method of Lane and Eynon described by Ranganna (1986) was adopted for the estimation of reducing sugar in papaya. Percentage of reducing sugar was calculated according to the following formula.

$$Reducing\ Sugar(\%) = \frac{Glucose\ Eq.(0.05)\ X\ Total\ volume\ made\ up(mL)}{Titre\ value(mL)\ X\ Weight\ of\ the\ sample}$$

B) Total Sugar (%)

The total sugar content in papaya was expressed as percentage in terms of invert sugar according to the following formula (Ramganna, 1986).

$$Total\ Sugar = \frac{\begin{matrix} Glucose\ Eq.(0.05) X\ Total\ volume\ made\ up(mL) X \\ Volume\ made\ after\ inversion(mL) \end{matrix}}{\begin{matrix} Titre\ value(mL) X\ Weight\ of\ pulp\ taken(g) X \\ Aliquot\ taken\ for\ inversion(mL) \end{matrix}} X\ 100$$

3. Titratable acidity (%)

The method described by Ranganna (1986) was followed to measure titrable acidity. The titrable acidity of papaya was expressed in terms of citric acid equivalent using following formula.

$$Acidity = \frac{\begin{matrix} Titre\ value\ XNormality\ of\ NaOH(0.1N) X \\ Volume\ make\ up(100\ mL) X \\ Equivelent\ weight\ of\ citric\ acid((0.064) \end{matrix}}{Volume\ of\ aliqot\ (25mL) X\ Weight\ of\ sample\ (5g)}$$

4. Total carotene (mg/100gm)

Carotene content in papaya, amaranth, bitter gourd, snake gourd, cowpea was estimated as total carotenoids using spectrophotometer (Sadasivam and Manickam, 1992).

One gram sample was cut into small bits and ground it with addition of 20 ml of 80% acetone thoroughly in mortar and pestle. It was centrifuged at 5000 rpm for five minutes and transferred the supernatant to a 100 ml volumetric flask. The residue was ground with 20 ml of 80% acetone, centrifuged and transferred the supernatant to the same volumetric flask. This procedure was repeated until the residue became colourless. The volume was made up to 100 ml with 80% acetone and the absorbance of solution was read at 480 nm and 510 nm against the solvent (80% acetone) blank.

$$Total\ carotenoids(mg\ 100g^{-1}) = \frac{(7.6X\ OD_{480} - 1.49X\ OD_{510})X\ V}{Weight\ of\ sample\ X\ 1000}$$

5. Vitamin C (mg/100gm)

Vitamin C content in papaya, amaranth, bitter gourd, cowpea and cucumber were estimated by 2, 6-dichloro phenol indophenol (DCPIP) dye method (Sadasivam and Manickam, 1992) and expressed as mg/100g.

Working standard solution (5 ml) was pipetted out into a 100 ml conical flask, oxalic acid 4% was added and titrated against the dye (V1 ml). End point was noted as appearance of pink color which persisted for a few minutes. The sample (1 g) was weighed and ground in a mortar and pestle in 15 ml of 4 % oxalic acid. The homogenate was filtered through a double layered cheese cloth. The filtrate was made up to a known volume and centrifuged at 10,000 rpm for 10 minutes. The supernatant was collected and made up to 25 ml using oxalic acid. 5 ml aliquot was pipette into a conical flask to which 10 ml of 4 % oxalic acid was added. This was titrated against 2, 6 – dichlorophenol indophenol (DCPIP) solution, until the appearance of pink color (V2 ml). The amount of ascorbic acid was calculated as follows.

$$Vitamin\ C\ (mg\ 100g^{-1}) = \frac{\frac{Titrevalue(V1) X Dye\ factor X}{Volume\ made\ up(mL)}}{\frac{Aliqot\ of\ extract\ taken(mL) X}{Weightof\ sample(g)}} X100$$

6. Oxalate (%)

Oxalate content in amaranth was calculated by titration method (Day and Underwood, 1986). One gram of dried powdered sample was taken in 100 ml conical flask; 75 ml of sulphuric acid (3 M) was added and stirred for 1 h with a magnetic stirrer. The mixture was filtered and 25 ml of the filtrate was titrated while hot against KMnO4 solution (0.05 M) to the end point. The oxalate content was calculated by taking 1mL 0f 0.05M KMnO4 as equivalent to 2.2mg oxalate (Chinma and Igyor, 2007).

3.3.4. Organoleptic parameters (hedonic rating)

Colour, texture, appearance, flavour and taste of the selected commodities were evaluated initially and at regular intervals till it lost its shelf life by conducting organoleptic scoring/hedonic rating performed by a 10 member semi-trained panel. The panel constituted the research students and staff members of College of Agriculture Vellayani and they were asked to score the ripe fruit and cooked vegetables for different sensory attributes on a numerical scoring method (Amerine *et al.*, 1965) using a nine point hedonic scale (Annexure I) descending order of acceptability, which was briefly described to the panel members before evaluation.

3.3.5. Microbial load

The commodities were subjected to quantitative assay of the micro flora by serial dilution spread plate techniques (Somashegaran and Hoben, 1985) intially and regular intervals till they lost their shelf life. Nutrient agar and Rose Bengal medium were used for the enumeration of bacterial and fungal population respectively.

Sample piece of 1cm^2 area was suspended in 100mL distilled water and shaken thoroughly for 2 minutes to get a 10^{-1} dilution. 100μL of the supernatant was accurately pipette out into eppendoff tube containing 900μL of sterile water to get 10^{-2} dilution and this procedure was repeated to get 10-4 dilution according to trial observations.

100 μL each of 10^{-2}, 10^{-3}, 10^{-4} was used for enumeration of total bacterial count and 100 μL each of 10^{-1}, 10^{-2}, 10^{-3} was used for enumeration of total fungal count.

Number of microorganisms (bacteria and fungi) per cm^2 was counted and results were expressed as log of colony forming units (cfu) per cm^2 as per the following formula.

$$No. of\ colony\ forming\ units/cm^2 = \frac{Total\ number\ of\ colony\ formed\ X\ dilution\ factor}{Aliquot\ taken}$$

3.3.6. Temperature and humidity inside the storage structure

Temperature (^{0}C) and relative humidity (%) inside the PZECC was periodically recorded using digital thermo-hygrometer during the storage of commodities.

3.3.7. Weather data

Weather data during the period of research work (October 2018 to July 2019) was collected at monthly intervals from Meteorological observatory in College of Agriculture Vellayani. (Appendix II).

3.3.8. Statistical analysis

The data generated from the experiment were statistically analysed using Completely Randomised Design (CRD). The sensory score of different commodities were statistically analysed using Kruskall-Wallis test (Chi- Square value) and ranked (Shamrez et al., 2013).

Results

4. RESULT

The experimental data collected for the study "Feasibility of Pusa Zero Energy Cool Chamber as low cost on-farm storage structure under Kerala condition" were analysed statistically and the results tabulated and are presented in this chapter.

4.1. PAPAYA

Physical, physiological, chemical, organoleptic and microbial parameters of papaya as influenced by two storage conditions in three different seasons are described below.

4.1. 1.Physiological quality parameters

Physiological quality parameters like shelf life, PLW and marketability of papaya fruits stored under PZECC and at ambient condition in three different seasons were recorded and described below. The fruits stored under PZECC during S_1, June-September were rotten and hence discarded after 4th day after storage and hence comparison was made on 6th day after storage between the treatments other than those stored under PZECC during S_1, June-September.

1. Shelf life

Papaya fruits stored under PZECC had better shelf life (6.30 days) than those stored in ambient conditions (5.80 days) and the fruits stored in S_3 (March-May) had maximum (6.39 days) shelf which was on par with fruits stored in S_2, October-February (6.33 days). Fruits stored in S_1, June-September had least (5.40 days) shelf life (Table 1).

When interaction effects were considered, shelf life of papaya fruits stored under PZECC during March- May (S_3) had maximum (7.22 days) shelf life which was on par with the fruits kept under the same condition during S_2, October-February

Table 1. Effect of season and storage condition on shelf life of stored papaya.

Treatments	Shelf life (days)		
S_1Z_0	4.56		
S_1Z_1	6.22		
S_2Z_0	7.11		
S_2Z_1	5.56		
S_3Z_0	7.22		
S_3Z_1	5.56		
Mean	S_1- 5.40 Z_0-6.30	S_2-6.33 Z_1-5.80	S_3-6.39
CD (0.05)	S-0.302	Z-0.246	S X Z-0.427

Table 2. Effect of season and storage condition on physiological loss in weight of stored papaya.

Treatments	Physiological loss in weight (%)			
	Days after storage		Treatment mean	6th day after storage
	2nd day	4th day		
S_1Z_0	0.89	0.93	0.91	-
S_1Z_1	2.06	1.76	1.91	0.88
S_2Z_0	0.89	0.87	0.88	0.72
S_2Z_1	1.60	1.70	1.65	2.16
S_3Z_0	0.93	1.40	1.17	1.04
S_3Z_1	2.11	2.84	2.48	1.04
Days mean	1.41	1.58		
Mean	S_1- 1.41 Z_0- 0.99	S_2- 1.26 Z_1- 2.01	S_3- 1.82	CD- 0.51
CD (0.05)	D-NS S X Z-NS	S-0.25	Z- 0.20 D X S X Z- NS	

(7.11 days). The papaya fruits stored in PZECC during S_1 (June-September) had the least (4.56 days) shelf life.

2. Physiological loss in weight

Papaya fruits kept under PZECC had less physiological loss in weight (0.99%) than those kept under ambient storage condition (2.01%) (Table 2.) Fruits stored during S_2, October-February had least physiological loss in weight (1.26%) which was on par with S_1 (June- September). Fruits stored during S_3 (March-May) had highest physiological loss in weight (1.82%). Physiological loss in weight increased from 1.41% on 2nd day after storage to 1.58% on 4th day after storage.

Interaction has no significant effect on physiological loss in weight of papaya. The fruits stored under PZECC during S_1 June-September were discarded after 4th day after storage.

Papaya fruits stored in PZECC during S2, October-February had least physiological loss in weight (0.72%) on 6th day after storage and fruits stored under ambient storage condition during S2, October-February had the highest (2.16%) physiological loss in weight.

3. Marketability

Papaya fruits stored under PZECC had higher marketability (96.30%) than those stored under ambient storage condition (Table 3.). There was no significant effect of seasons on marketability of papaya fruits. Marketability decreased from 100% on the day of storage to 81.48% on 4th day after storage.

Interaction effect of seasons and storage condition on marketability of papaya showed that, fruits kept under PZECC during S_3 (March-May) and S_2 (October-February) had highest marketability (100%) which were on par with those stored under ambient storage condition during S_1, June-September (96.30%). Fruits stored under ambient storage condition during S_2 (October-February) had least marketability (85.19%).

Papaya fruits stored under PZECC during S_3 (March-May) had highest marketability (66.67%) which was on par with those stored under ambient condition during S_1, June-September (55.56%) on 6th day after storage.

4.1.2. Physical quality parameters

Physical quality parameters like colour and texture of the stored papaya fruits under two conditions and three seasons are described below.

1. Colour

There was no significant effect of storage conditions on colour score of papaya fruits. Papaya fruits stored during S_3 (March-May) had higher colour score (7.10) which was on par with those stored during S_2, October-February (6.97) (Table 4.). Fruits stored during S_1, June-September had least colour score (5.90). Colour score of papaya increased from 6.17 on the day of storage to 7.00 on the second day and then decreased to 6.80 on the 4th day.

When considering interaction effect, papaya fruits stored under PZECC during S_2, October-February had highest colour score (7.33) which was on par with those stored under same condition during S_3, March-May (7.20) and fruits stored under ambient condition during S_3, March – May (7.00). Papaya fruits stored under PZECC during S_1, June-September had the least colour score (5.67).

Colour score recorded at 6th day after storage revealed that the papaya fruits stored under PZECC during S_2 (October-February) had the maximum (8.20) colour score which was on par with colour score of those stored under same condition during S_3, March-May (7.60) and fruits stored in ambient condition during S_1, June-September had the minimum (5.20) on 6th day after storage.

Table 3. Effect of season and storage condition on marketability of stored papaya.

Treatments	Marketability (%)				
	Days after storage			Treatment mean	6^{th} day after storage
	0^{th} day	2^{nd} day	4^{th} day		
S_1Z_0	100	100	66.67	88.89	-
S_1Z_1	100	100	88.89	96.30	55.56
S_2Z_0	100	100	100	100	22.22
S_2Z_1	100	100	55.55	85.19	0
S_3Z_0	100	100	100	100	66.67
S_3Z_1	100	100	77.78	92.59	22.22
Days mean	100	100	81.48		
Mean	S_1- 92.59 Z_0 -96.30	S_2- 92.59 Z_1- 91.40	S_3- 96.29		CD- 38.85
CD (0.05)	D-5.31 S X Z-7.51	S-NS	Z-4.34 D X S X Z- 13.014		

Table 4. Effect of season and storage condition on colour of stored papaya.

Treatments	Colour score				
	Days after storage			Treatment mean	6^{th} day after storage
	0^{th} day	2^{nd} day	4^{th} day		
S_1Z_0	5.00	6.60	5.40	5.67	-
S_1Z_1	5.40	6.80	6.20	6.13	5.20
S_2Z_0	6.60	7.60	7.80	7.33	8.20
S_2Z_1	6.80	7.00	6.00	6.60	3.80
S_3Z_0	6.60	7.00	8.00	7.20	7.60
S_3Z_1	6.60	7.00	7.40	7.00	4.80
Days mean	6.17	7.00	6.80		
Mean	S_1- 5.90 Z_0- 6.73	S_2- 6.97 Z_1- 6.58	S_3- 7.10		CD-1.28
CD (0.05)	D-0.42 S X Z-0.59	S-0.42	Z-NS D X S X Z- NS		

2. Texture

a. Bio-yield point

Papaya fruits stored under PZECC had higher bio yield point (1267.93 N) compared to the fruits stored under ambient condition (1153.80 N) (Table 5.). Bio-yield point of papaya fruits stored in S_3 (March-May) was highest (1488.58 N) which was significantly different from fruits stored in other two seasons. The papaya fruits stored during S_1, June-September had the least bio-yield point (1069.58 N). Bio-yield point decreased with days after storage; it was 1470.89 N on the day of storage and 734.72 N on 4th day after storage.

Considering the interaction effect of seasons and storage conditions, the papaya fruits stored under PZECC during S_3, March-May had highest bio-yield point (1742.31 N) which was significantly different from all other treatments. The papaya fruits stored under the same condition during S_1, June-September had the least bio-yield point (965.63 N).

Bio-yield point recorded on 6th day after storage revealed that the papaya fruits stored under PZECC during S_2 (October-February) had the maximum (939.97 N) bio-yield point and fruits stored in ambient condition during S_1, June-September had the minimum (409.86 N).

b. Flesh firmness

Effect of seasons, storage conditions and their interaction on flesh firmness of stored papaya fruits is shown in Table 6. Papaya fruits stored under the PZECC had higher flesh firmness (410.11 N) than those stored under ambient conditions. Texture of papaya fruits in terms of flesh firmness was highest (456.71 N) for those stored during S_3 (March-May) which was on par with those stored during S1 (444.29 N). Papaya fruits stored during S_2 had the least flesh firmness (180.36 N).

Table 5. Effect of season and storage condition on bio-yield point of stored papaya.

Treatments	Bio-yield point (N)				
	Days after storage			Treatment mean	6^{th} day after storage
	0^{th} day	2^{nd} day	4^{th} day		
S_1Z_0	1,453.43	1,385.19	58.25	965.63	-
S_1Z_1	1,411.41	1,508.36	600.84	1,173.54	409.86
S_2Z_0	1,199.28	1,128.54	959.70	1,095.84	939.97
S_2Z_1	1,147.60	1,186.71	824.71	1,053.01	668.62
S_3Z_0	1,953.17	1,883.16	1,390.60	1,742.31	421.51
S_3Z_1	1,660.47	1,469.90	574.20	1,234.86	474.35
Days mean	1,470.89	1,426.98	734.72		
Mean	S_1- 1,069.58 S_2- 1,074.43 S_3- 1,488.58 Z_0- 1,267.93 Z_1- 1,153.80				
CD (0.05)	D-59.77 S-59.77 Z-48.81 S X Z-84.53 D X S X Z-146.42				CD-156.20

Table 6. Effect of season and storage condition on flesh firmness of stored papaya.

Treatments	Flesh firmness (N)				
	Days after storage			Treatment mean	6^{th} day after storage
	0^{th} day	2^{nd} day	4^{th} day		
S_1Z_0	650.21	594.59	16.77	420.52	-
S_1Z_1	757.76	563.02	83.40	468.06	50.63
S_2Z_0	297.03	350.55	129.83	259.14	77.73
S_2Z_1	128.83	66.27	109.65	101.58	75.99
S_3Z_0	690.87	733.83	227.34	550.68	15.00
S_3Z_1	432.63	595.12	60.45	362.74	24.42
Days mean	492.89	483.90	104.57		
Mean	S_1- 444.29 S_2- 180.36 S_3- 456.71 Z_0 -410.11 Z_1- 310.79				
CD (0.05)	D-62.23 S-62.23 Z- 50.81 S X Z- 88.01 D X S X Z- NS				CD- 19.10

The flesh firmness decreased with the days after storage and it ranged from 492.89 N on the day of storage to 104.57 N on 4th day after storage.

When the interaction effect of seasons and storage conditions were considered, the papaya fruits stored under PZECC during S_3 (March-May) had the highest flesh firmness (550.68 N) which was on par with those stored under ambient condition during S_1, June-September (468.06 N). The fruits stored under ambient condition during S_2, October- February had the minimum (101.58 N) flesh firmness.

Fruits stored under PZECC during S_2 (October-February) had the maximum (77.73 N) bio-yield point on 6th day after storage, which was on par with fruits stored under ambient condition during S_2, October-February (75.99 N).

4.1.3. Chemical quality parameters

Effect of seasons, storage conditions and their interaction on chemical quality parameters of stored papaya fruits is shown in Table 7-12.

1. Total soluble solids

Papaya fruits stored under ambient condition had higher total soluble solids (13.85^{0}B) than those stored under PZECC (13.06^{0}B) (Table 7.). Total soluble solids of papaya fruits stored during S_3, March-May was maximum (13.93^{0}B) which was significantly different from those stored during the other two seasons. The fruits stored during S_1, June-September had least (13.09^{0}B) total soluble solid content. Total soluble solids of papaya increased with the days after storage; it ranged from 10.24^{0}B on the day of storage to 16.56^{0}B at 4th day after storage.

When the interaction effect of season and storage condition were considered, it was seen that the fruits stored under ambient condition during S_3, March-May had the highest total soluble solids (14.78^{0}B) which was on par with those stored under same condition during S_1, June-September(14.07^{0}B) and those stored under PZECC during S_2, October- February (14.00^{0}B). Papaya fruits stored under PZECC during S_1, June-September had least (12.11^{0}B) total soluble solids.

Papaya fruits stored in PZECC during S_2 (October-February) had maximum TSS (20.33^{0}B) on 6th day after storage, which was on par with those stored under ambient condition during S_3, March-May (19.37^{0}B).

2. Sugars

a. Reducing sugar

Storage condition had no significant effect on reducing sugar content of papaya fruits (Table 8.). Papaya fruits stored during S_3, March-May had highest reducing sugar (9.55 mg/100g) which was on par with S_2, October-February (9.52 mg/100g). The papaya fruits stored during S_1, June – September had the least (8.75 mg/100g) reducing sugar content. The reducing sugar content of papaya fruits increased from 8.55 mg/100g on the day of storage to 10.27mg/100g on 4th day after storage.

While considering the interaction effect of seasons and storage conditions, papaya fruits stored under PZECC during S_2, October-February had highest reducing sugar content (9.80 mg/100g) which was on par with the fruits stored during S_3, March-May irrespective of storage condition. The papaya fruits stored under PZECC during S_1, June-September had the least (8.57 mg/100g) reducing sugar content.

When the reducing sugar content of fruits on 6th day after storage was analysed, it was seen that, papaya fruits stored in PZECC during S_3 (October-February) had maximum (11.64 mg/100g) reducing sugar content on 6th day after storage, and the fruits stored during S_1, June-September under ambient storage had the minimum (9.68 mg/100g) reducing sugar.

Table 7. Effect of season and storage condition on total soluble solids of stored papaya.

Treatments	Total soluble solids (^{0}B)				
	Days after storage			Treatment mean	6^{th} day after storage
	0^{th} day	2^{nd} day	4^{th} day		
S_1Z_0	9.47	12.27	14.60	12.11	-
S_1Z_1	10.03	15.07	17.10	14.07	18.63
S_2Z_0	10.27	13.87	17.87	14.00	20.33
S_2Z_1	10.03	11.90	16.17	12.70	18.50
S_3Z_0	10.77	12.57	15.90	13.08	18.50
S_3Z_1	10.87	15.73	17.73	14.78	19.37
Days mean	10.24	13.57	16.56		
Mean	S_1- 13.09 S_2- 13.35 S_3-13.93 Z_0- 13.06 Z_1- 13.85				
CD (0.05)	D-0.56 S-0.56 Z-0.46 S X Z-0.79 D X S X Z-1.37				CD-0.856

Table 8. Effect of season and storage condition on reducing sugars of stored papaya.

Treatments	Reducing sugars (mg.100g^{-1})				
	Days after storage			Treatment mean	6^{th} day after storage
	0^{th} day	2^{nd} day	4^{th} day		
S_1Z_0	8.15	8.57	8.98	8.57	-
S_1Z_1	8.38	9.05	9.38	8.94	9.68
S_2Z_0	8.83	9.59	10.95	9.80	11.54
S_2Z_1	8.43	9.15	10.14	9.24	10.64
S_3Z_0	8.57	9.56	10.49	9.54	11.64
S_3Z_1	8.93	9.56	10.21	9.56	10.65
Days meån	8.55	9.25	10.27		
Mean	S_1- 8.75 S_2- 9.52 S_3-9.55 Z_0- 9.30 Z_1- 9.25				
CD (0.05)	D- 0.20 S-0.20 Z- NS S X Z- 0.28 D X S X Z- NS				CD- 0.66

b. Total sugars

Storage condition had no significant effect on total sugar content of papaya fruits (Table 9.). Papaya fruits stored during S_3. March-May had the highest (32.54 mg/100g) total sugar content. Fruits stored in S_2, October-February had the least (31.51 mg/100g) total sugar content which was on par with papaya fruits stored during S_1, June-September (31.54 mg/100g). Total sugar content of papaya increased from 31.18 mg/100g on the day of storage to 32.48 mg/100g on 4^{th} day after storage.

There was no interaction effect of seasons and storage condition on total sugar content of papaya fruits.

There was no significant difference between the total sugar content of fruits on 6^{th} day after storage.

3. Titrable acidity

Storage condition had no significant effect on titrable acidity of papaya fruits (Table 10.). When considering the individual effect of seasons, papaya fruits stored during S_3, March-May had the least titrable acidity (0.15%) which was on par with those stored during S_2, October-February (0.17%). Papaya fruits stored during S_1 June-September had maximum titrable acidity (0.19 %). Titrable acidity of papaya increased with the days after storage and it ranged from 0.12% on the day of storage to 0.22% on 4^{th} day after storage.

While considering the interaction effect of storage condition and seasons on titrable acidity, papaya fruits stored under PZECC during S_1, June-September had least titrable acidity (0.13%) which was on par with those stored under ambient condition during S_3, March-May and S_2, October - February (0.14%) and under PZECC during S_3, March-May (0.15%). The papaya fruits stored under ambient condition during S_1 June-September had maximum titrable acidity (0.25%)

Table 9. Effect of season and storage condition on total sugars of stored papaya.

Treatments	Total sugars (mg.100g^{-1})				
	Days after storage			Treatment mean	6th day after storage
	0th day	2nd day	4th day		
S_1Z_0	30.86	31.58	32.26	31.57	-
S_1Z_1	30.86	31.52	32.12	31.50	32.82
S_2Z_0	30.99	31.52	32.33	31.61	33.95
S_2Z_1	30.49	31.74	31.99	31.41	33.90
S_3Z_0	32.19	32.75	33.18	33.18	34.01
S_3Z_1	31.65	32.47	32.97	32.97	33.56
Days mean	31.18	31.93	32.48		
Mean	S_1-31.54 Z_0-31.96	S_2- 31.51 Z_1-31.76		S_3- 32.54	
CD (0.05)	D-0.28 S X Z-NS	S- 0.28		Z-NS D X S X Z- NS	CD- NS

Table 10. Effect of season and storage condition on titrable acidity of stored papaya.

Treatments	Titrable acidity (%)				
	Days after storage			Treatment mean	6th day after storage
	0th day	2nd day	4th day		
S_1Z_0	0.09	0.12	0.18	0.13	-
S_1Z_1	0.21	0.25	0.30	0.25	0.29
S_2Z_0	0.13	0.19	0.25	0.19	0.29
S_2Z_1	0.09	0.16	0.18	0.14	0.23
S_3Z_0	0.11	0.14	0.21	0.15	0.23
S_3Z_1	0.07	0.18	0.18	0.14	0.23
Days mean	0.12	0.17	0.22		
Mean	S_1- 0.19 Z_0-0.16		S_2- 0.17 Z_1- 0.18	S_3-0.15	
CD (0.05)	D-0.03 S X Z-0.04		S-0.03	Z-NS D X S X Z- NS	CD-NS

Papaya fruits stored in PZECC during S_2, October-February and those stored under ambient during S_1 June-September had maximum (0.29%) titrable acidity on 6^{th} day after storage. All other treatments had 0.23% titrable acidity.

4. Total carotene

The papaya fruits stored under ambient condition had greater (0.77 mg/100g) total carotene content than those stored under PZECC (0.65 mg/100g) (Table 11.). Papaya fruits stored during S_1, June-September had the highest total carotene content (0.77 mg/100g) which was on par with those stored during S_3, March-May (0.74 mg/100g). Papaya fruits stored during S_2, October-February had the least total carotene content (0.62 mg/100g). Total carotene content of papaya increased with the days after storage; it ranged from 0.24 mg/100g on the day of storage to 1.13 mg/100g at 4^{th} day after storage.

While considering interaction effect of seasons and storage conditions on total carotene content, the papaya fruits stored under ambient condition during S_3 March-May had the highest total carotene content (0.94 mg/100g) which was on par with those stored under PZECC during S_1, June-September (0.89 mg/100g). The papaya fruits stored under PZECC during S_2, October-February had the least total carotene content (0.53 mg/100g) which was on par with the fruits stored under PZECC during S_3, March-May (0.54 mg/100g).

Papaya fruits stored under ambient condition during S_2, October-February had maximum (1.50 mg/100g) total carotene on 6^{th} day after storage which was on par with all other conditions except those stored under PZECC during S_3, March-May.

5. Vitamin C/ Ascorbic acid

Storage condition had no significant effect on vitamin C content of papaya fruits. (Table 12.) Papaya fruits stored during S_2, October-February had highest

Table 11. Effect of season and storage condition on total carotene content of stored papaya.

Treatments	Total carotene (mg.100g^{-1})				
	Days after storage			Treatment mean	6th day after storage
	0th day	2nd day	4th day		
S_1Z_0	0.20	1.11	1.34	0.89	-
S_1Z_1	0.21	0.85	0.93	0.66	1.33
S_2Z_0	0.26	0.45	0.90	0.53	1.22
S_2Z_1	0.25	0.52	1.35	0.70	1.50
S_3Z_0	0.28	0.38	0.94	0.54	1.10
S_3Z_1	0.26	1.23	1.32	0.94	1.44
Days mean	0.24	0.76	1.13		
Mean	S_1- 0.77 Z_0- 0.65	S_2- 0.62 Z_1- 0.77		S_3-0.74	
CD (0.05)	D-0.04 S X Z-0.06	S-0.04		Z-0.04 D X S X Z- 0.11	CD-0.29

Table 12. Effect of season and storage condition on vitamin C of stored papaya.

Treatments	Vitamin C (mg.100 g^{-1})				
	Days after storage			Treatment mean	6th day after storage
	0th day	2nd day	4th day		
S_1Z_0	50.48	52.86	55.24	52.86	-
S_1Z_1	50.95	52.86	55.71	53.18	57.62
S_2Z_0	58.09	58.57	58.57	58.41	60.00
S_2Z_1	55.71	60.00	61.90	59.21	63.81
S_3Z_0	54.76	57.14	58.57	56.82	60.95
S_3Z_1	55.71	57.62	60.48	57.94	
Days mean	54.28	56.51	58.41		
Mean	S_1- 53.02 Z_0 -56.03	S_2- 58.81 Z_1- 56.77		S_3- 57.38	
CD (0.05)	D- 1.24 S X Z- NS	S-1.24		Z- NS D X S X Z- NS	CD-2.64

vitamin C content (58.81 mg/100g) and those stored during S_1, June-September had the least vitamin C content (53.02 mg/100g). Vitamin C content increased from 54.28 mg/100g on the day of storage to 58.41 mg/100g on 4th day after storage.

There was no interaction effect for seasons and storage condition on Vitamin C content of papaya fruits.

Papaya fruits stored under ambient condition during S_2, October-February had maximum (63.81mg/100g) total carotene on 6th day after storage.

4.1.4. Organoleptic quality parameters

Effect of seasons and storage conditions on organoleptic quality parameters of stored papaya fruits are shown in Table 13.

1. Appearance

Appearance of papaya fruits was significantly affected by the treatments. Mean score was higher for fruits stored under PZECC during S_2, October-February and under ambient condition during S_1, June-September on 4th day after storage.

2. Colour

Colour score obtained by hedonic rating was significantly affected by the treatments. Mean scores obtained for colour were highest (7.3) for fruits stored under PZECC during S_2, October-February and under PZECC during S_3, March-May on second day after storage.

3. Texture

There was no significant effect of treatments on texture of papaya fruits

Table 13. Effect of season and storage condition on organoleptic quality parameters of stored papaya.

Treatments	Appearance (mean score)			Colour (mean score)		
	0th day	2nd day	4th day	0th day	2nd day	4th day
S_1Z_0	5.3	6	3.9	4.8	5.4	6.3
S_1Z_1	5.6	6.5	7.3	5.1	6	6.4
S_2Z_0	5.6	6.1	7.3	6.1	7.3	7.1
S_2Z_1	5	5.9	4.7	6.2	5.7	6.7
S_3Z_0	6	6.7	7.2	6	7.3	6.5
S_3Z_1	6.4	7.3	5.7	6.3	6.7	6.6
k value	16.04	15.94	38.54	15.69	22.53	5.30
Treatments	Texture (mean score)			Taste (mean score)		
	0th day	2nd day	4th day	0th day	2nd day	4th day
S_1Z_0	5.4	5.3	5.1	4.5	5	4.5
S_1Z_1	6	5.7	5.4	4.9	5.3	4.7
S_2Z_0	5.9	4.8	5.4	5.2	5.3	5.1
S_2Z_1	5.6	5.7	6	5.2	5.1	4.9
S_3Z_0	6.6	6.4	6.2	5.6	5.9	5.1
S_3Z_1	6.5	6.4	4.9	5.4	5.7	5.1
k value	9.4	10.34	10.22	9.8	7.19	3.9
Treatments	Flavour (mean score)			Overall acceptability (mean score)		
	0th day	2nd day	4th day	0th day	2nd day	4th day
S_1Z_0	4.1	5.3	5	4.7	5.6	5
S_1Z_1	4.2	5.4	4.9	4.9	5.7	5.2
S_2Z_0	4.7	5.3	5.1	5.3	5.8	5.1
S_2Z_1	4.9	4.9	4.9	5.1	5.4	5.5
S_3Z_0	5.1	5.5	5.2	5.1	6.5	5.9
S_3Z_1	5	5.6	5.2	5	5.6	5.3
k value	8.32	4.30	1.70	3.66	5.64	4.02
$\chi 2$	11.07					

4. Taste

Seasons and storage conditions had no significant effect on taste of stored papaya fruits.

5. Flavour

Seasons and storage conditions had no significant effect on flavour of stored papaya fruits.

6. Overall acceptability

There was no significant effect of treatments on overall acceptability of papaya fruits.

4.1.5. Microbial load

1. Bacterial load

Storage conditions had no significant effect on bacterial load of papaya fruits (Table 14). The effect of seasons showed that, papaya fruits stored during S_3, March-May had least bacterial load (4.44 log cfu/cm^2) and fruits stored during S_1, June-September and S_2, October-February had higher bacterial load (4.56 log cfu/cm^2). Bacterial load increased from 4.44 log cfu/cm^2 on the day of storage to 4.60 log cfu/cm^2 on 4th day after storage.

No significant interaction effect was noticed on the bacterial load of papaya.

2. Fungal load

Storage conditions, season and their interaction had no significant effect on fungal load of papaya fruits (Table 15.). Fungal load increased from 0.67 log cfu/cm^2 on the day of storage to 1.58 log cfu/cm^2 on 4th day after storage. However the fungal load was least (0.33 log cfu/cm^2) for fruits kept in PZECC during S_3 (March-May).

Table14. Effect of season and storage condition on bacterial load of stored papaya.

Treatments	Bacterial load (Log colony forming units/cm^2)		
	Days after storage		Treatment mean
	0^{th} day	4^{th} day	
S_1Z_0	4.47	4.38	4.60
S_1Z_1	4.47	4.37	4.52
S_2Z_0	4.52	4.65	4.59
S_2Z_1	4.45	4.61	4.53
S_3Z_0	4.38	4.50	4.44
S_3Z_1	4.37	4.52	4.44
Days mean	4.44	4.60	
Mean	S_1- 4.56 Z_0 -4.54	S_2-4.56 Z_1-4.50	S_3-4.44
CD (0.05)	D-0.06 S X Z- NS	S-0.07	Z - NS D X S X Z- NS

Table 15. Effect of season and storage condition on fungal load of stored papaya.

Treatments	Fungal load (Log colony forming units/cm^2)		
	Days after storage		Treatment mean
	0^{th} day	4^{th} day	
S_1Z_0	0.00	2.96	1.48
S_1Z_1	0.67	2.26	1.46
S_2Z_0	1.33	1.49	1.41
S_2Z_1	0.67	1.43	1.05
S_3Z_0	0.00	0.67	0.33
S_3Z_1	1.33	0.67	1.00
Days mean	0.67	1.58	
Mean	S_1- 1.47 Z_0-1.08	S_2-1.23 Z_1-1.17	S_3- 0.67
CD (0.05)	D-0.67 S X Z-NS	S-NS	Z- NS D X S X Z- NS

4.2. SNAKE GOURD

Physical, physiological, chemical, organoleptic and microbial parameters of snake gourd as influenced by two storage conditions in three different seasons are described below.

4.2.1. Physiological quality parameters

Physiological quality parameters like shelf life, PLW and marketability of snake gourd stored under PZECC and at ambient condition in three different seasons were analysed statistically, results tabulated and described below.

1. Shelf life

Storage conditions or seasons individually had no significant effect on shelf life of snake gourd. (Table 16.)

While considering interaction effect of seasons and storage conditions, snake gourd stored under PZECC during S_2 had highest shelf life (7.66 days) which was on par with those stored under the same condition during S_3, March- May (7.56 days) and those kept under ambient storage condition during S_1, June-September (7.44), S_2, October-February and S_3, March-May (7.00 days)

2. Physiological loss in weight

Snake gourd kept under PZECC had less physiological loss in weight (0.71 %) than those kept under ambient storage condition (1.56%) (Table 17.). Snake gourd stored during S_1, June- September had least (0.88%) physiological loss in weight which was on par with those stored during S_3, March-May (0.95%). Physiological loss in weight was highest (1.56%) when stored during S_2 (October-February). Physiological loss in weight increased from 0.83% on 2nd day after storage to 1.42% on 6th day after storage.

Table 16. Effect of season and storage condition on shelf life of stored snake gourd.

Treatments	Shelf life(days)		
S_1Z_0	6.44		
S_1Z_1	7.44		
S_2Z_0	7.66		
S_2Z_1	7.00		
S_3Z_0	7.56		
S_3Z_1	7.00		
Mean	S1-6.94 Z_0-7.22	S2-7.33 Z_2-7.15	S3-7.27
CD (0.05)	S- NS	Z-NS	S X Z- 0.78

Table 17. Effect of season and storage condition on physiological loss in weight of stored snake gourd.

Treatments	Physiological loss in weight (%)			
	Days after storage			Treatment mean
	2^{nd} day	4^{th} day	6^{th} day	
S_1Z_0	0.32	0.68	0.80	0.60
S_1Z_1	0.84	1.35	1.27	1.15
S_2Z_0	0.43	0.74	1.20	0.79
S_2Z_1	2.02	2.23	2.77	2.34
S_3Z_0	0.44	0.75	1.00	0.73
S_3Z_1	0.92	1.15	1.46	1.18
Days mean	0.83	1.15	1.42	
Mean	S_1- 0.88 Z_0 -0.71		S_2-1.56 Z_1 - 1.56	S_3-0.95
CD (0.05)	D-0.07 S X Z-0.10		S- 0.07	Z-0.06 D X S X Z- NS

Snake gourd stored under PZECC during S_1, June-September had least physiological loss in weight (0.60%) and those stored in ambient condition during S2 had the highest (2.34).

3. Marketability

Storage conditions or seasons individually had no significant effect on marketability of snake gourd (Table 18.).

When interaction effect of seasons and storage condition on marketability of snake gourd was analysed, it was seen that, snake gourd kept under PZECC during S_3 (March-May), S_2 (October-February) and under ambient condition during S_1, June-September had highest marketability (72.22%). Snake gourd stored under ambient storage condition during S_3 (March- May) had least marketability (55.56%).

4.2.2. Physical quality parameters

Physical quality parameters like colour and texture of the stored snake gourd under two conditions and three seasons are described below.

1. Colour

Effect of storage condition on colour of stored snake gourd showed that, those stored under PZECC had better colour (6.18) compared to those stored under ambient storage condition (5.67) (Table 19.). Snake gourd stored during S_3 (March-May) had higher colour score (6.27) which was on par with those stored during S_2, October-February (5.95). Snake gourd stored during S_1, June-September had least colour score (5.55). Colour score of snake gourd decreased from 7.80 on the day of storage to 5.67 on the 6th day after storage.

Snake gourd stored under PZECC during S_3, March-May had highest colour score (6.95) which was on par with those stored under same condition during S_2,

Table 18. Effect of season and storage condition on marketability of stored snake gourd.

Treatments	Marketability (%)				
	Days after storage				Treatment mean
	0^{th} day	2^{nd} day	4^{th} day	6^{th} day	
S_1Z_0	100	77.78	55.56	11.11	61.11
S_1Z_1	100	88.89	66.67	33.33	72.22
S_2Z_0	100	88.89	66.67	33.33	72.22
S_2Z_1	100	77.78	44.44	22.22	61.11
S_3Z_0	100	100	66.67	22.22	72.22
S_3Z_1	100	77.78	33.33	11.11	55.56
Days mean	100	85.19	55.56	22.22	
Mean	S_1- 66.67 Z_0 -68.52		S_2- 66.67 Z_1- 62.96		S_3-63.89
CD (0.05)	D-8.73 S X Z- 10.70		S-NS		Z – NS D X S X Z- NS

Table 19. Effect of season and storage condition on colour of stored snake gourd.

Treatments	Colour score				
	Days after storage				Treatment mean
	0^{th} day	2^{nd} day	4^{th} day	6^{th} day	
S_1Z_0	7.60	5.00	4.60	3.00	5.05
S_1Z_1	7.80	6.00	6.00	4.40	6.00
S_2Z_0	8.00	7.00	6.40	4.80	6.55
S_2Z_1	7.40	5.20	5.20	3.60	5.35
S_3Z_0	8.40	7.40	6.80	5.20	6.95
S_3Z_1	7.60	6.00	5.00	3.80	5.60
Days mean	7.80	6.10	5.67		
Mean	S_1-5.55 Z_0 -6.18		S_2- 5.95 Z_1-5.67		S_3-6.27
CD (0.05)	D-0.55 S X Z- 0.67		S-0.48		Z -0.39 D X S X Z- NS

October-February (6.55). Snake gourd stored under PZECC during S_1, June-September had the least colour score (5.05).

2. Texture

a. Bio-yield point

Storage condition had no significant effect on bio- yield point of stored snake gourd during storage (Table 20.). Bio-yield point of snake gourd stored in S_2 (October-February) was highest (876.49 N) which was significantly different from those stored in other two seasons. The snake gourd stored during S_1, June-September had the least bio-yield point (631.80 N). Bio-yield point decreased with days after storage; it was 920.28 N on the day of storage and 471.75 N on 6^{th} day after storage.

Considering the interaction effect of seasons and storage conditions, the snake gourd stored under PZECC during S_2, October-February had highest bio-yield point (955.26 N) which was significantly different from all other treatments. The snake gourd stored under the same condition during S_1, June-September had the least bio-yield point (519.71 N).

b. Flesh firmness

Effect of seasons, storage conditions and their interaction on flesh firmness of stored snake gourd is shown in Table 21. Snake gourd stored under the ambient condition had higher flesh firmness (246.93 N) than those stored under PZECC (210.39 N). Flesh firmness was highest (287.13 N) for those stored during S_2 (October-February). Snake gourd stored during S_1, June-September had the least flesh firmness (170.93 N). The flesh firmness decreased with the days after storage and it ranged from 341.51 N on the day of storage to 136.79 N on 6^{th} day after storage.

Table 20. Effect of season and storage condition on bio-yield point of stored snake gourd.

Treatments	Bio-yield point (N)				
	Days after storage				Treatment mean
	0^{th} day	2^{nd} day	4^{th} day	6^{th} day	
S_1Z_0	980.75	917.50	84.05	96.54	519.71
S_1Z_1	909.17	879.63	868.40	318.31	743.88
S_2Z_0	1,019.44	1,177.14	1,074.78	549.67	955.26
S_2Z_1	969.54	551.09	840.93	829.28	797.71
S_3Z_0	744.40	724.84	646.20	622.48	684.48
S_3Z_1	898.36	803.07	756.05	414.20	717.92
Days mean	920.28	842.21	711.74	471.75	
Mean	S_1-631.80 Z_0 -719.82		S_2-876.49 Z_1- 753.17		S_3-701.20
CD (0.05)	D-62.73 S X Z- 76.83		S- 54.33		Z - NS D X S X Z- 153.66

Table 21. Effect of season and storage condition on flesh firmness of stored snake gourd.

Treatments	Flesh firmness (N)				
	Days after storage				Treatment mean
	0^{th} day	2^{nd} day	4^{th} day	6^{th} day	
S_1Z_0	284.28	182.08	24.82	19.35	127.63
S_1Z_1	272.64	241.02	241.02	102.19	214.22
S_2Z_0	531.52	256.17	329.70	136.74	313.53
S_2Z_1	493.27	143.98	227.35	178.33	260.73
S_3Z_0	146.40	142.89	238.74	231.97	190.00
S_3Z_1	320.92	311.22	279.13	152.13	265.85
Days mean	341.51	212.89	223.46	136.79	
Mean	S_1- 170.93 Z_0 -210.39		S_2- 287.13 Z_1- 246.93		S_3-227.93
CD (0.05)	D-35.95 S X Z- 44.03		S-31.13		Z - 25.42 D X S X Z- 88.06

Snake gourd stored under PZECC during S_2, October- February had the highest flesh firmness (313.53 N)and the one stored under ambient condition during S_1, June-September had the minimum (127.63 N) flesh firmness.

4.2.3. Chemical quality parameters

1. Total carotene

Storage condition, season and their interaction had no significant effect on total carotene content of stored snake gourd (Table 22.). Total carotene content of snake gourd increased with the days after storage; it ranged from 0.52 mg/100g on the day of storage to 1.76 mg/100g at 6^{th} day after storage.

4.2.4. Organoleptic quality parameters

Effect of seasons and storage conditions on organoleptic quality parameters of stored snake gourd is shown in Table 23.

1. Appearance

There was no significant effect of seasons and storage conditions on appearance of stored snake gourd.

2. Colour

Colour score obtained by hedonic rating was significantly affected by the treatments on 2^{nd}, 4^{th}, 6^{th} day after storage. Mean scores obtained for colour were highest (5.1) for snake gourd stored under PZECC during during S_3, March-May. Least colour score was obtained for those stored under PZECC during S_1, June-September (3.4) on 6^{th} day after storage.

3. Texture

There was no significant effect of treatments on texture of stored snake gourd.

Table 22. Effect of season and storage condition on total carotene content of stored snake gourd.

Treatments	Total carotene (mg.100g^{-1})				
	Days after storage				Treatment mean
	0^{th} day	2^{nd} day	4^{th} day	6^{th} day	
S_1Z_0	0.48	0.53	0.57	0.60	0.55
S_1Z_1	0.53	0.57	0.77	3.59	1.37
S_2Z_0	0.50	0.60	0.60	0.64	0.59
S_2Z_1	0.55	0.63	0.87	1.49	0.88
S_3Z_0	0.52	0.53	0.60	0.65	0.57
S_3Z_1	0.53	0.59	0.80	3.59	1.38
Days mean	0.52	0.57	0.70	1.76	
Mean	S_1-0.96 Z_0 -0.57		S_2-0.73 Z_1- 1.21		S_3-0.98
CD (0.05)	D-0.91 S X Z- NS		S- NS		Z - NS D X S X Z- NS

4. Taste

Seasons and storage conditions had no significant effect on taste of stored snake gourd.

5. Flavour

Seasons and storage conditions had no significant effect on flavour of snake gourd during storage exept on 2nd and 4th day after storage. Snake gourd stored under PZECC during S_3, March-May had highest score for flavor and those stored under the same condition during S_1, June-September had least score.

6. Overall acceptability

There was no significant effect of treatments on overall acceptability of snake gourd during storage.

4.2.5. Microbial load

1. Bacterial load

Storage conditions had no significant effect on bacterial load of stored snake gourd (Table 24.). Snake gourd stored during S_3 (March-May) had least bacterial load (4.24 log cfu/cm^2) which was on par with those stored during S_2, October-February (4.31 log cfu/cm^2). Snake gourd stored during S_1, June-September and had higher bacterial load (4.47 log cfu/cm^2). Bacterial load increased from 4.24 log cfu/cm^2 on the day of storage to 4.44 log cfu/cm^2 on 6th day after storage.

There was no significant effect of interaction between seasons and storage on bacterial load of snake gourd.

Table 23.Effect of season and storage condition on organoleptic quality parameters of stored snake gourd.

Treatments	Appearance (mean score)				Colour (mean score)			
	0^{th} day	2^{nd} day	4^{th} day	6th day	0^{th} day	2^{nd} day	4^{th} day	6th day
S_1Z_0	7.1	5.5	4.9	3.3	7.0	5.1	4.9	3.4
S_1Z_1	7.4	5.9	5.6	4.1	7.4	6.0	5.7	4.5
S_2Z_0	7.6	6.6	5.8	4.3	7.4	6.7	6.1	5.0
S_2Z_1	7.2	5.5	5.2	3.8	7.1	5.3	5.0	4.0
S_3Z_0	7.9	6.6	6	5.1	8.0	6.8	6.3	5.1
S_3Z_1	7.2	5.6	5.3	4	7.3	5.7	5.1	4.1
k value	4.19	8.73	7.27	10.1	4.00	13.31	14.80	11.28
Treatments	Texture (mean score)				Taste (mean score)			
	0^{th} day	2^{nd} day	4^{th} day	6th day	0^{th} day	2^{nd} day	4^{th} day	6th day
S_1Z_0	7.2	5.5	4.7	3.1	6.8	5.4	4.7	2.9
S_1Z_1	7.2	5.5	4.9	4	7.4	5.9	5.5	4.2
S_2Z_0	7.9	6.6	5.8	4.5	7.5	6.3	5.9	4.5
S_2Z_1	7.6	5.9	5.4	4.2	7.1	5.6	4.8	3.9
S_3Z_0	7.6	6.3	5.5	4.3	8	6.5	6.1	4.6
S_3Z_1	7.3	5.6	5.3	4.1	7.2	5.7	5.4	4.1
k value	3.47	6.85	4.96	4.85	6.42	5.28	8.03	5.40
Treatments	Flavour (mean score)				Overall (mean score)			
	0^{th} day	2^{nd} day	4^{th} day	6th day	0^{th} day	2^{nd} day	4^{th} day	6th day
S_1Z_0	6.7	5.2	4.2	2.4	7.4	5.4	5	3.4
S_1Z_1	7.6	6	5.3	4	8	6.1	5.4	3.8
S_2Z_0	7.7	6.2	5.9	4.1	8.2	6.7	5.6	4.1
S_2Z_1	7.1	5.6	4.8	3.1	7.7	5.7	5.1	3.5
S_3Z_0	8.1	7.2	6.1	4.4	8.3	6.9	6	4.4
S_3Z_1	7.2	5.9	5.1	3.8	7.6	5.9	5.3	3.6
k value	7.2	11.71	15.85	10.26	3.65	10.56	7.7	3.38
$\chi 2$	11.07							

2. Fungal load

Storage conditions, season and their interaction had no significant effect on fungal load of snake gourd (Table 25.). Fungal load increased from 0.78 log cfu/cm^2 on the day of storage to 2.07 log cfu/cm^2 on 6th day after storage. However the fungal load was least (1.05 log cfu/cm^2) for those kept in PZECC during S_3 (March-May).

4.3. CUCUMBER

Physical, physiological, chemical, organoleptic and microbial parameters of cucumber as influenced by two storage conditions in three different seasons are described below.

4.3.1. Physiological quality parameters

Physiological quality parameters like shelf life, PLW and marketability of cucumber stored under PZECC and at ambient condition in three different seasons were recorded and described below.

Cucumbers stored under PZECC during S_1 (June-September) were rotten and hence discarded after 4th day after storage and comparison was made on 6th day after storage between the treatments other than those stored under PZECC during S_1 (June-September).

1. Shelf life

Storage conditions had no significant effect on shelf life of cucumber and those stored in S_3 (March-May) had maximum (7.33 days) shelf life which was on par with cucumbers stored in S_2, October- February (7.28 days). Cucumbers stored in S_1, June-September had least (6.22 days) shelf life (Table 26.).

When interaction effects were considered, shelf life of cucumber was maximum (8.11 days) when stored under PZECC during March-May (S_3). The

Table 24. Effect of season and storage condition on bacterial load of stored snake gourd

Treatments	Bacterial load(Log colony forming units/cm^2)		
	Days after storage		Treatment mean
	0^{th} day	6^{th} day	
S_1Z_0	4.45	4.56	4.51
S_1Z_1	4.19	4.43	4.43
S_2Z_0	4.07	4.41	4.31
S_2Z_1	4.38	4.48	4.31
S_3Z_0	4.24	4.39	4.24
S_3Z_1	4.09	4.37	4.23
Days mean	4.24	4.44	
Mean	S1- 4.47 Z_0-4.35	S2- 4.31 Z_1-4.32	S3-4.24
CD (0.05)	D-0.07 S X Z-NS	S-0.08	Z-NS D X S X Z-NS

Table 25. Effect of season and storage condition on fungal load of stored snake gourd.

Treatments	Fungal load (Log colony forming units/cm^2)		Treatment mean
	Days after storage		
	0^{th} day	6^{th} day	
S_1Z_0	0.67	2.98	1.82
S_1Z_1	0.67	2.16	1.21
S_2Z_0	0.67	1.43	1.41
S_2Z_1	0.00	2.42	1.72
S_3Z_0	1.33	2.10	1.05
S_3Z_1	1.33	1.33	1.33
Days mean	0.78	2.07	
Mean	S1- 1.52 Z_0-1.43	S2-1.57 Z_1-1.42	S3-1.19
CD (0.05)	D- 0.62 S X Z-NS	S-NS	Z- NS D X S X Z-NS

cucumbers stored in PZECC during S_1 (June-September) had the least (5.56 days) shelf life.

2. Physiological loss in weight

Cucumbers kept under PZECC had less physiological loss in weight (0.59%) than those kept under ambient storage condition (1.13%) (Table 27.). Cucumbers stored during S_1 (June- September) had least physiological loss in weight (0.74%) and those stored during S_3, March-May and S_2, October-February had highest physiological loss in weight (0.92%). Physiological loss in weight increased from 0.72% on 2^{nd} day after storage to 0.99% on 4^{th} day after storage.

While considering interaction of season and storage condition, cucumbers stored under PZECC during S_1, June-September and S_2 (October-February) had least (0.53%) physiological loss in weight. Cucumbers stored at ambient condition during S_2 (October-February) had highest (1.32%) physiological loss in weight.

Cucumbers stored in PZECC during S_2 (October-February) and S_3 (March-May) had least physiological loss in weight (0.91%) on 6^{th} day after storage and those stored under ambient storage condition during S_2 (October-February) had the highest (1.98%) physiological loss in weight.

3. Marketability

Seasons or storage conditions individually had no significant effect on marketability of stored cucumbers (Table 28.). Marketability decreased from 100% on the day of storage to 68.52% on 4^{th} day after storage.

Interaction effect of seasons and storage condition on marketability of cucumber showed that, cucumbers kept under PZECC during S_3 (March-May), S_2 (October-February) and in ambient storage condition during S_1, June-September had

Table 26. Effect of season and storage condition on shelf life of stored cucumber.

Treatments	Shelf life (days)		
S_1Z_0	5.56		
S_1Z_1	6.89		
S_2Z_0	7.67		
S_2Z_1	6.89		
S_3Z_0	8.11		
S_3Z_1	6.56		
Mean	S1-6.22 Z_0- 7.11	S2-7.28 Z_1- 6.78	S3-7.33
CD (0.05)	S- 0.66	Z-NS	S X Z- 0.94

Table 27. Effect of season and storage condition on physiological loss in weight of stored cucumber.

Treatments	Physiological loss in weight (%)		Treatment mean	6^{th} day after storage
	Days after storage			
	2^{nd} day	4^{th} day		
S_1Z_0	0.43	0.64	0.53	-
S_1Z_1	0.83	1.034	0.93	1.45
S_2Z_0	0.38	0.68	0.53	0.91
S_2Z_1	1.19	1.44	1.32	1.98
S_3Z_0	0.56	0.83	0.70	0.91
S_3Z_1	0.95	1.34	1.15	1.61
Days mean	0.72	0.99		
Mean	S_1- 0.74 Z_0- 0.59	S_2- 0.92 Z_1- 1.13	S_3- 0.92	
CD (0.05)	D-0.043 S X Z-0.07	S-0.05	Z- 0.04 D X S X Z- NS	CD- 0.19

highest marketability (92.59%). Cucumbers stored under PZECC during S_1, June-September had least marketability (81.48%).

There was no significant effect of treatments on marketability of cucumbers on 6th day after storage.

4.3.2. Physical quality parameters

Physical quality parameters like colour and texture of the stored cucumbers under two conditions and three seasons are described below.

1. Colour

Cucumbers stored under PZECC had better colour score (6.93) when compared to those stored under ambient storage condition (6.53) (Table 29.) Cucumbers stored during S_1, June-September had higher colour score (7.57) and cucumbers stored during S_3 (March-May) had least colour score (5.87). Colour score of cucumber decreased from 7.83 on the day of storage to 5.70 on the 4th day.

When considering interaction effect, cucumbers stored under PZECC during S_1, June-September had highest colour score (7.80) which was on par with those stored under ambient condition during S_1, June-September (7.33). Cucumbers stored under ambient condition during S_3 (March-May) had the least colour score (5.40).

Cucumber stored under PZECC during S_2 (October-February) had the maximum (6.80) colour score on 6th day after storage which was on par with colour score of those stored under ambient condition during S_1, June-September (6.60). Cucumbers stored in ambient condition during S_3, March-May had the minimum (3.00) on 6th day after storage.

Table 28. Effect of season and storage condition on marketability of stored cucumber.

Treatments	Marketability (%)				
	Days after storage			Treatment mean	6th day after storage
	0th day	2nd day	4th day		
S_1Z_0	100	88.89	55.56	81.48	-
S_1Z_1	100	100	77.78	92.59	77.78
S_2Z_0	100	100	77.78	92.59	66.67
S_2Z_1	100	100	55.56	85.18	33.33
S_3Z_0	100	100	77.78	92.59	55.56
S_3Z_1	100	100	66.67	88.89	33.33
Days mean	100	98.15	68.52		
Mean	S_1- 87.04 S_2- 88.89 S_3- 90.74 Z_0 -88.89 Z_1- 88.89				
CD (0.05)	D-7.51 S- NS Z- NS S X Z-10.63 D X S X Z- NS				CD- NS

Table 29. Effect of season and storage condition on colour of stored cucumber.

Treatments	Colour score				
	Days after storage			Treatment mean	6th day after storage
	0th day	2nd day	4th day		
S_1Z_0	8.80	7.80	5.40	7.33	-
S_1Z_1	8.40	7.40	7.60	7.80	6.60
S_2Z_0	7.40	7.00	7.00	7.13	6.80
S_2Z_1	7.60	6.40	5.20	6.40	3.60
S_3Z_0	7.80	5.80	5.80	6.33	5.20
S_3Z_1	7.40	5.60	3.20	5.40	3.00
Days mean	7.83	6.67	5.70		
Mean	S_1- 7.57 S_2- 6.77 S_3- 5.87 Z_0- 6.93 Z_1- 6.53				
CD (0.05)	D-0.46 S-0.46 Z-0.37 S X Z-0.64 D X S X Z- 1.11				CD-1.06

2. Texture

a. Bio-yield point

Storage conditions had no significant individual effect on bio-yield point of cucumber (Table 30.). Bio-yield point of cucumbers stored in S_3 (March-May) was highest (1132.46 N) which was significantly different from cucumbers stored in other two seasons. The cucumbers stored during S_1, June-September had the least bio-yield point (810.77N). Bio-yield point decreased with days of storage; it was 1,132.20 N on the day of storage and 847.84 N on 4^{th} day after storage.

Considering the interaction effect of seasons and storage conditions, the cucumbers stored under PZECC during S_3, March-May had highest bio-yield point (1200.86N) which was significantly different from all other treatments. The cucumbers stored under the same condition during S_1, June-September had the least bio-yield point (698.21 N).

Cucumbers stored under PZECC during S_3, March-May had the maximum (1291.15 N) bio-yield point on 6^{th} day after storage and those stored in ambient condition during S_2 (October-February) had the minimum (255.90 N).

b. Flesh firmness

Effect of seasons, storage conditions and their interaction on flesh firmness of stored cucumbers is shown in Table 31. Cucumbers stored under the ambient condition had higher flesh firmness (297.76 N) than those stored under PZECC (234.83 N). Seasons individually had no significant effect on flesh firmness of stored cucumbers. The flesh firmness decreased with the days of storage and it ranged from 297.68 N on the day of storage to 227.65 N on 4^{th} day after storage.

When the interaction effect of seasons and storage conditions were considered, the cucumbers stored under ambient condition during S_1, June-September

Table 30. Effect of season and storage condition bio-yield point of stored cucumber.

Treatments	Bio-yield point (N)				
	Days after storage			Treatment mean	6^{th} day after storage
	0^{th} day	2^{nd} day	4^{th} day		
S_1Z_0	941.22	689.06	464.36	698.21	-
S_1Z_1	970.34	791.42	1,008.21	923.32	743.15
S_2Z_0	1,142.60	977.42	864.70	994.91	805.84
S_2Z_1	1,051.48	994.34	833.31	959.71	255.90
S_3Z_0	1,331.93	1,175.89	1,094.76	1,200.86	1,291.15
S_3Z_1	1,355.65	1,014.81	821.70	1,064.05	1,000.72
Days mean	1,132.20	940.49	847.84		
Mean	S_1- 810.77 Z_0 - 964.66		S_2- 977.31 Z_1- 982.36	S_3- 1,132.46	
CD (0.05)	D- 85.72 S X Z- 121.23		S- 85.72	Z- NS D X S X Z- 209.98	CD- 277.91

Table 31. Effect of season and storage condition on flesh firmness of stored cucumber

Treatments	Flesh firmness (N)				
	Days after storage			Treatment mean	6^{th} day after storage
	0^{th} day	2^{nd} day	4^{th} day		
S_1Z_0	231.46	203.87	115.19	183.51	-
S_1Z_1	325.98	331.19	313.19	323.45	288.87
S_2Z_0	295.68	252.60	238.81	262.36	209.50
S_2Z_1	346.13	347.04	211.43	301.53	29.68
S_3Z_0	298.61	250.66	226.60	258.62	288.93
S_3Z_1	288.25	255.94	260.70	268.30	297.18
Days mean	297.68	273.55	227.65		
Mean	S_1- 297.68 Z_0 - 234.83		S_2- 273.55 Z_1 - 297.76	S_3- 227.66	
CD (0.05)	D-40.61 S X Z-57.43		S- NS	Z- 33.15 D X S X Z- NS	CD- 124.61

had the highest flesh firmness (323.45 N) which was on par with those stored under ambient condition during S_2, October- February (301.53 N) and S_3, March-May (268.30 N). The cucumbers stored under PZECC during S_1, June-September had the minimum (183.51 N) flesh firmness.

Cucumbers stored under ambient condition during S_3, March-May had the maximum (297.18 N) flesh firmness on 6^{th} day of storage, which was on par with those stored under all other treatments except those stored under ambient condition during S_2 ,October-February (29.68 N).

4.3.3. Chemical quality parameters

1. Vitamin C

Storage condition, seasons or their interaction had no significant influence on vitamin C content of stored cucumbers (Table 32.). Vitamin C did not show any significant change with days after storage. There was no significant effect of treatments on Vitamin C content of stored cucumber on 6^{th} day after storage.

4.3.4. Organoleptic quality parameters

Effect of seasons and storage conditions on organoleptic quality parameters of stored cucumbers are shown in Table 33.

1. Appearance

Appearance of cucumber was significantly affected by the treatments on 2^{nd} and 4^{th} day of storage. Mean score was higher for cucumbers stored under PZECC during S_3, March-May on 2^{nd} day (6.80) and 4^{th} day (6.10) of storage.

Table 32. Effect of season and storage condition on vitamin C of stored cucumber.

Treatments	Vitamin C ($mg.100^{-1} g$)				
	Days after storage			Treatment mean	6^{th} day after storage
	0^{th} day	2^{nd} day	4^{th} day		
S_1Z_0	0.52	0.62	0.52	0.55	-
S_1Z_1	0.62	0.43	0.62	0.55	0.57
S_2Z_0	0.62	0.62	0.67	0.63	0.62
S_2Z_1	0.71	0.48	0.62	0.60	0.66
S_3Z_0	0.57	0.62	0.52	0.57	0.57
S_3Z_1	0.66	0.52	0.62	0.60	0.52
Days mean	0.62	0.55	0.59		
Mean	S_1- 0.55 Z_0 - 0.59		S_2- 0.62 Z_1- 0.59	S_3- 0.59	
CD (0.05)	D- NS S X Z- NS		S- NS	Z- NS D X S X Z- NS	CD - NS

2. Colour

Colour score obtained by hedonic rating was significantly affected by the treatments. Mean scores obtained for colour were highest (7.3) for cucumbers stored under PZECC during S_1, June-September on 2nd day and 6.5 on 4th day after storage.

3. Texture

Score obtained for texture of cucumber by hedonic rating was significantly affected by treatments. The score was higher (5.9) for those stored under ambient condition during S_3, March-May on 4th day and those stored under same condition during S_2 , October-February on 2nd day (7.0).

4. Taste

Taste; an organoleptic parameter was significantly affected by the treatments. The mean score was higher (6.2) for cucumbers stored under PZECC during S_1, June-September on 4th day after storage. It was higher (7.5) for cucumbers stored under PZECC during S_1, June-September on 2nd day after storage.

5. Flavour

Seasons and storage conditions had significant effect on flavour of stored cucumbers. Cucumbers stored under ambient condition during S_1, June-September had maximum mean score (7.00, 5.70) on 2nd and 4th day after storage respectively.

6. Overall acceptability

Seasons and storage conditions had significant effect on overall acceptability of stored cucumbers. Cucumbers stored under ambient condition during S_1, June-September had maximum mean score (6.00) on 4th day after storage and 7.40 on 2nd day after storage.

Table 33. Effect of season and storage condition on organoleptic quality parameters of stored cucumber.

Treatments	Appearance (mean score)			Colour (mean score)		
	0th day	2nd day	4th day	0th day	2nd day	4th day
S_1Z_0	5.70	4.50	3.60	7.9	7.3	6.5
S_1Z_1	5.90	5.00	4.40	7.1	6.5	6.0
S_2Z_0	6.20	5.60	4.70	6.5	6.4	5.1
S_2Z_1	6.40	5.40	5.10	6.7	5.7	5.6
S_3Z_0	7.10	6.80	6.10	6.3	6.6	4.6
S_3Z_1	6.90	6.00	5.50	6.0	6.0	4.0
k value	9.67	18.41	21.53	16.53	13.74	22.57
Treatments	Texture (mean score)			Taste (mean score)		
	0th day	2nd day	4th day	0th day	2nd day	4th day
S_1Z_0	5.8	4.7	3.3	8.1	7.5	6.2
S_1Z_1	7.3	6.3	6	8.1	7.2	5.9
S_2Z_0	6.4	5.5	5.5	8.0	6.8	5.4
S_2Z_1	7.7	7	4.5	7.7	5.7	5.2
S_3Z_0	6.8	5.2	5.2	7.8	5.3	4.9
S_3Z_1	6.1	6.1	5.9	7.6	4.8	4.1
k value	17.4	25.05	22.18	2.40	32.37	16.96
Treatments	Flavour (mean score)			Overall acceptability (mean score)		
	0th day	2nd day	4th day	0th day	2nd day	4th day
S_1Z_0	7.20	4.60	3.90	7.70	4.60	3.60
S_1Z_1	7.60	7.00	5.70	7.90	7.40	6.00
S_2Z_0	7.40	5.40	4.70	7.70	5.70	4.50
S_2Z_1	7.50	6.80	5.20	7.60	7.20	5.40
S_3Z_0	7.20	5.00	4.40	7.80	5.40	4.30
S_3Z_1	7.50	6.30	5.00	7.70	6.50	5.00
k value	1.4	27.56	17.56	1.21	30.73	27.67
$\chi2$	11.07					

4.3.5. Microbial load

1. Bacterial load

Storage conditions had no significant effect on bacterial load of stored cucumbers (Table 34). Cucumbers stored during S_3, March-May had least bacterial load (4.37 log cfu/cm^2) and cucumbers stored during S_1, June-September a had the highest bacterial load (4.54 log cfu/cm^2). Bacterial load increased from 4.43 log cfu/cm^2 on first day to 4.51 log cfu/cm^2 on 4th day after storage.

No significant interaction effect of season and storage condition was noticed on the bacterial load of cucumber.

2. Fungal load

Storage conditions individually had no significant effect on fungal load of stored cucumbers (Table 35.). Cumbers stored during S_2 , October-February had least fungal load (1.21 log cfu/cm^2) and cucumbers stored during S_1, June-September a had highest fungal load (2.24 log cfu/cm^2). Fungal load increased from 0.89 log cfu/cm^2 on the day of storage to 2.32 log cfu/cm^2 on 4th day after storage.

Considering the interaction effect of seasons and storage conditions, fungal load was least (1.00 log cfu/cm^2) for cucumbers kept in ambient condition during S_3 (March-May) which was on par with those stored under PZECC during same season and cucumbers stored during S_2 ,October-February irrespective of storage conditions. Cucumbers stored under PZECC during S_1, June-September had higher fungal load (2.47 log cfu/cm^2).

4.4. BITTER GOURD

Physical, physiological, chemical, organoleptic and microbial parameters of bitter gourd as influenced by two storage conditions in three different seasons are described below.

Table 34. Effect of season and storage condition on bacterial load of stored cucumber.

Treatments	Bacterial load (Log colony forming units/cm^2)		
	Days after storage		Treatment mean
	0th day	4th day	
S_1Z_0	4.52	4.54	4.53
S_1Z_1	4.47	4.57	4.55
S_2Z_0	4.33	4.47	4.52
S_2Z_1	4.50	4.60	4.45
S_3Z_0	4.44	4.47	4.40
S_3Z_1	4.30	4.40	4.35
Days mean	4.43	4.51	
Mean	S1-4.54 Z_0-4.48	S2-4.49 Z_1-4.45	S3-4.37
CD (0.05)	D-0.06 S X Z-NS	S-0.07	Z-NS D X S X Z-NS

Table 35. Effect of season and storage condition on fungal load of stored cucumber.

Treatments	Fungal load (Log colony forming units/cm^2)		
	Days after storage		Treatment mean
	0th day	4th day	
S_1Z_0	2.00	2.95	2.47
S_1Z_1	0.00	2.32	2.01
S_2Z_0	1.33	2.10	1.16
S_2Z_1	1.33	2.69	1.26
S_3Z_0	0.00	2.52	1.72
S_3Z_1	0.67	1.33	1.00
Days mean	0.89	2.32	
Mean	S1- 2.24 Z_0-1.78	S2-1.21 Z_1-1.42	S3-1.36
CD (0.05)	D- 0.46 S X Z-0.80	S-0.57	Z- NS D X S X Z-NS

4.4.1. Physiological quality parameters

Physiological quality parameters like shelf life, PLW and marketability of bitter gourd stored under PZECC and at ambient condition in three different seasons were analysed statistically, results tabulated and described below.

1. Shelf life

Bitter gourd stored under PZECC had better shelf life (6.96 days) than those stored under ambient condition (6.60 days) (Table 36.). Seasons had no significant effect on shelf life of bitter gourd.

While considering interaction effect of seasons and storage conditions, bitter gourd stored under PZECC during S_2 had highest shelf life (7.33 days) which was on par with those stored under the same condition during S_3, March- May (7.22 days) and those kept under ambient storage condition during S_1, June-September (7.00). Shelf life was least for those stored under PZECC during S_1, June-September (6.33 days).

2. Physiological loss in weight

Bitter gourd kept under PZECC had less physiological loss in weight (1.61 %) than those kept under ambient storage condition (2.92%) (Table 37.). Bitter gourd stored during S_1, June- September had least (2.19%) physiological loss in weight which was on par with those stored during S_2 (October-February). Bitter gourd stored during S_3, March- May had highest (2.40%) physiological loss in weight. Physiological loss in weight increased from 1.23% on 2nd day after storage to 3.27% on 6th day after storage.

Interaction effect of seasons and storage conditions effect on physiological loss in weight of bitter gourd was non-significant.

Table 36. Effect of season and storage condition on shelf life of stored bitter gourd

Treatments	Shelf life (days)		
S_1Z_0	6.33		
S_1Z_1	7.00		
S_2Z_0	7.33		
S_2Z_1	6.44		
S_3Z_0	7.22		
S_3Z_1	6.56		
Mean	S_1- 6.67 Z_0- 6.96	S_2-6.89 Z_1- 6.6	S_3- 6.89
CD (0.05)	S- NS	Z-0.28	S X Z- 0.49

Table 37. Effect of season and storage condition on physiological loss in weight of stored bitter gourd

Treatments	Physiological loss in weight (%)			
	Days after storage			Treatment mean
	2nd day	4th day	6th day	
S_1Z_0	0.80	1.61	2.24	1.55
S_1Z_1	1.80	2.39	4.31	2.83
S_2Z_0	0.75	1.69	2.40	1.61
S_2Z_1	1.49	2.87	4.09	2.82
S_3Z_0	0.83	1.67	2.55	1.68
S_3Z_1	1.72	3.56	4.05	3.11
Days mean	1.23	2.30	3.27	
Mean	S_1- 2.19 Z_0 -1.61		S_2- 2.21 Z_1- 2.92	S_3-2.40
CD (0.05)	D-0.14 S X Z- NS		S- 0.14	Z- 0.11 D X S X Z- 0.34

3. Marketability

Bitter gourd stored inside PZECC had better marketability (67.59%) when compared to bitter gourd stored in ambient conditions (49.07%). (Table 38.). Bitter gourd stored during S_3, March- May had highest marketability (63.89%) which was on par with those stored during S_2, October-February (56.94%). Bitter gourd stored during S_1, June-September had least (54.17%) marketability. Marketability decreased from 100% on the day of storage to 22.22% on 6^{th} day after storage.

Bitter gourd kept under PZECC during S_3 (March-May) had highest marketability (77.77%) which was on par with bitter gourd stored under same condition during S_2, October-February (72.23%). Bitter gourd stored under ambient storage condition during S_2, October-February had least marketability (41.66%).

4.4.2. Physical quality parameters

1. Colour

Effect of storage condition on colour of stored bitter gourd showed that, those stored under PZECC had better colour (5.91) compared to those stored under ambient storage condition (5.17) (Table 39.). Seasons had no effect on colour of bitter gourd. Colour score of bitter gourd decreased from 8.20 on the day of storage to 3.40 on the 6^{th} day after storage.

When considering interaction effect, bitter gourd stored under PZECC during S_2, October-February had highest colour score (6.25) which was on par with gourd stored under same condition during S_3, March-May and those stored under ambient condition during S_1, June-September (5.95). Bitter gourd stored under PZECC during S_1, June-September had the least colour score (5.53).

Table 38. Effect of season and storage condition on marketability of stored bitter gourd

Treatments	Marketability (%)				
	Days after storage				Treatment mean
	0^{th} day	2^{nd} day	4^{th} day	6^{th} day	
S_1Z_0	100	77.78	33.33	0.00	52.78
S_1Z_1	100	55.56	33.33	33.33	55.55
S_2Z_0	100	88.89	66.67	33.33	72.23
S_2Z_1	100	44.44	22.22	0.00	41.66
S_3Z_0	100	88.89	66.67	55.56	77.77
S_3Z_1	100	55.56	33.33	11.11	50.00
Days mean	100	68.52	42.59	22.22	
Mean	S_1- 54.17 Z_0 -67.59		S_2- 56.94 Z_1- 49.07		S_3- 63.89
CD (0.05)	D-9.12 S X Z- 11.17		S-7.90		Z -6.45 D X S X Z- 22.35

Table 39. Effect of season and storage condition on colour of stored bitter gourd

Treatments	Colour score				
	Days after storage				Treatment mean
	0^{th} day	2^{nd} day	4^{th} day	6^{th} day	
S_1Z_0	8.80	6.70	3.80	2.80	5.53
S_1Z_1	8.20	6.60	5.00	4.00	5.95
S_2Z_0	8.00	7.20	5.60	4.20	6.25
S_2Z_1	8.00	5.60	3.40	2.40	4.85
S_3Z_0	8.20	5.80	5.00	4.80	5.95
S_3Z_1	8.00	5.40	3.20	2.20	4.70
Days mean	8.20	6.22	4.33	3.40	
Mean	S_1- 5.74 Z_0 -5.91		S_2- 5.55 Z_1-5.17		S_3-5.33
CD (0.05)	D-0.49 S X Z-0.60		S- NS		Z - 0.35 D X S X Z-1.21

2. Texture

a. Bio-yield point

Bitter gourd stored under PZECC had higher bio-yield point (1235.06 N) when compared to bitter gourd stored under ambient conditions (955.71 N) (Table 40.). Bio-yield point of bitter gourd stored in S_2 (October-February) was highest (1.251.52 N) which was significantly different from those stored in other two seasons. The bitter gourd stored during S_3, March-May had the least bio-yield point (998.39 N). Bio-yield point decreased with storage and it was 1508.30 N on the day of storage and 484.83 N on 6^{th} day after storage.

Interaction of seasons and storage was non-significant effect on bio-yield point of bitter gourd.

b. Flesh firmness

Effect of seasons, storage conditions and their interaction on flesh firmness of stored bitter gourd is shown in Table 41. Bitter gourd stored under the PZECC had higher flesh firmness (367.70 N) than those stored under ambient conditions (292.16 N). Flesh firmness was highest (360.02 N) for those stored during S_2 (October-February). Bitter gourd stored during S_1, June-September had the least flesh firmness (286.65 N). The flesh firmness decreased with the days after storage and it ranged from 395.16 N on the day of storage to 162.84 N on 6^{th} day after storage.

Interaction of seasons and storage conditions had no significant effect on flesh firmness of stored bitter gourd.

Table 40. Effect of season and storage condition on bio-yield point of stored bitter gourd

Treatments	Bio-yield point (N)				
	Days after storage				Treatment mean
	0^{th} day	2^{nd} day	4^{th} day	6^{th} day	
S_1Z_0	1,549.13	1,430.54	1,583.25	175.59	1184.63
S_1Z_1	1,304.05	1,100.16	828.87	318.31	887.85
S_2Z_0	1,655.35	1,442.61	1,091.01	1,176.31	1341.32
S_2Z_1	1,630.21	1,282.00	1,105.16	629.56	1161.73
S_3Z_0	1,460.92	1,415.15	1,468.82	371.99	1179.22
S_3Z_1	1,450.10	1,222.08	360.85	237.19	817.56
Days mean	1,508.30	1,315.42	1,072.99	484.83	
Mean	S_1-1,036.24 Z_0 -1,235.06		S_2-1,251.52 Z_1- 955.71		S_3-998.39
CD (0.05)	D-129.78 S X Z- NS		S- 112.39		Z - 91.77 D X S X Z- 317.89

Table 41. Effect of season and storage condition on flesh firmness of stored bitter gourd

Treatments	Flesh firmness (N)				
	Days after storage				Treatment mean
	0^{th} day	2^{nd} day	4^{th} day	6^{th} day	
S_1Z_0	460.66	374.71	336.23	44.23	303.96
S_1Z_1	325.51	423.61	226.02	102.19	269.33
S_2Z_0	321.94	494.96	314.91	507.65	409.86
S_2Z_1	293.19	507.77	313.71	126.05	310.18
S_3Z_0	466.48	498.58	453.45	138.62	389.28
S_3Z_1	503.18	500.78	125.63	58.30	296.97
Days mean	395.16	466.73	294.99	162.84	
Mean	S_1-286.65 Z_0 -367.70		S_2- 360.02 Z_1-292.16		S_3-343.13
CD (0.05)	D- 68.24 S X Z- NS		S-59.10		Z - 48.25 D X S X Z- 167.15

4.4.3. Chemical quality parameters

1. Total carotene

Storage conditions had significantly affected total carotene content of stored bitter gourd (Table 42.). Bitter gourd stored at ambient conditions had higher (1.32 mg/100g) total carotene content compared to bitter gourd stored inside PZECC. Seasons had no significant individual effect on total carotene content of stored bitter gourd. Total carotene content of bitter gourd increased with storage; it ranged from 1.18 mg/100g on the day of storage to 1.39 mg/100g at 6^{th} day after storage.

While considering interaction effect, bitter gourd stored under PZECC during S_2, October-February had higher (1.33 mg/100g) total carotene which was on par with gourd stored under same condition during S_3, March-May (1.31 mg/100g) and those stored under ambient condition during S_1, June-September (1.32 mg/100g). Bitter gourd stored under PZECC during S_1, June-September had least (1.21 mg/100g) total carotene content.

2. Vitamin C

Storage condition, seasons and their interaction had no significant effect on vitamin C content of bitter gourd. (Table 43.). Vitamin C content decreased from 30.95 mg/100g on the day of storage to 28.63 mg/100g on 6^{th} day after storage.

There was no interaction effect for seasons and storage condition on vitamin C content of bitter gourd.

4.4.4. Organoleptic quality parameters

Effect of seasons and storage conditions on organoleptic quality parameters of stored bitter gourd are shown in Table 44.

Table 42. Effect of season and storage condition on total carotene content of stored bitter gourd

Treatments	Total carotene (mg.100g^{-1})				Treatment mean
	Days after storage				
	0th day	2nd day	4th day	6th day	
S_1Z_0	1.11	1.16	1.25	1.31	1.21
S_1Z_1	1.20	1.27	1.36	1.44	1.32
S_2Z_0	1.20	1.20	1.25	1.26	1.23
S_2Z_1	1.22	1.26	1.34	1.49	1.33
S_3Z_0	1.21	1.25	1.28	1.33	1.27
S_3Z_1	1.16	1.23	1.34	1.49	1.31
Days mean	1.18	1.23	1.30	1.39	
Mean	S_1- 1.26 Z_0 -1.23		S_2- 1.28 Z_1- 1.32		S_3-1.29
CD (0.05)	D-0.02 S X Z- 0.03		S- NS		Z - 0.02 D X S X Z- NS

Table 43. Effect of season and storage condition on vitamin C of stored bitter gourd

Treatments	Vitamin C (mg.100g^{1})				
	Days after storage				Treatment mean
	0th day	2nd day	4th day	6th day	
S_1Z_0	32.29	31.19	29.57	26.33	29.84
S_1Z_1	31.05	31.48	29.33	28.28	30.04
S_2Z_0	30.24	31.00	30.62	31.00	30.72
S_2Z_1	31.05	30.90	29.380	28.28	29.60
S_3Z_0	30.00	31.24	31.428	29.76	30.61
S_3Z_1	31.05	30.67	28.571	28.10	29.60
Days mean	30.95	31.08	29.817	28.63	
Mean	S_1- 29.94 Z_0 -30.39		S_2- 30.31 Z_1 -29.85		S_3- 30.10
CD (0.05)	D- 1.015 S X Z- NS		S- NS		Z - NS D X S X Z- NS

1. Appearance

There was no significant effect of seasons and storage conditions on appearance of stored bitter gourd.

2. Colour

There was no significant effect of treatments on colour of stored bitter gourd.

3. Texture

Scores obtained by hedonic rating for texture was significantly affected by the treatments on 2^{nd}, 4^{th}, 6^{th} days after storage. Mean scores obtained for texture were highest (4.90) for bitter gourd stored under PZECC during S_2 (October-February) and least score for those stored under PZECC during S_1, June-September (3.10) on 6^{th} day after storage.

4. Taste

Mean scores obtained for taste was significant only 4^{th} day of storage and were highest (5.90) for bitter gourd stored under PZECC during S_2 (October-February) and least score for those stored under PZECC during S_1, June-September (3.90) on 4^{th} day after storage.

5. Flavour

Seasons and storage conditions had no significant effect on flavour of bitter gourd during storage.

6. Overall acceptability

Score obtained by hedonic rating for overall acceptability was significantly affected by the treatments on 2^{nd}, 4^{th}, 6^{th} days after storage. Mean scores obtained for overall acceptability were highest (5.10) for bitter gourd stored under PZECC during

Table 44. Effect of season and storage condition on organoleptic quality parameters of stored bittergourd

Treatments	Appearance (mean score)				Colour (mean score)			
	0^{th} day	2^{nd} day	4^{th} day	6th day	0^{th} day	2^{nd} day	4^{th} day	6th day
S_1Z_0	7.30	6.10	4.80	2.90	7.20	5.50	5.00	3.10
S_1Z_1	8.00	6.80	5.30	3.80	7.80	6.30	5.10	4.00
S_2Z_0	8.20	7.00	5.50	3.90	8.00	7.00	5.90	4.60
S_2Z_1	7.90	6.60	5.10	3.50	7.60	6.10	4.80	3.70
S_3Z_0	8.10	6.90	5.90	4.30	7.90	6.80	5.50	3.80
S_3Z_1	7.80	6.20	5.00	3.10	7.50	5.80	4.60	3.30
k value	3.98	5.05	5.72	6.56	2.52	10.04	8.58	5.04

Treatments	Texture (mean score)				Taste (mean score)			
	0^{th} day	2^{nd} day	4^{th} day	6th day	0^{th} day	2^{nd} day	4^{th} day	6th day
S_1Z_0	7.20	5.10	4.30	3.10	7.10	5.60	3.90	2.50
S_1Z_1	7.20	6.20	4.90	3.80	7.60	6.10	4.40	3.40
S_2Z_0	7.10	7.00	5.90	4.90	8.10	6.90	5.90	4.00
S_2Z_1	6.70	6.50	5.40	4.60	7.50	6.00	4.30	3.20
S_3Z_0	7.40	6.40	5.30	4.10	7.80	6.80	4.60	3.60
S_3Z_1	8.10	5.20	4.40	3.50	7.30	5.90	4.10	3.10
k value	7.33	17.43	12.76	14.80	4.70	8.33	13.34	6.18

Treatments	Flavour (mean score)				Overall (mean score)			
	0^{th} day	2^{nd} day	4^{th} day	6th day	0^{th} day	2^{nd} day	4^{th} day	6th day
S_1Z_0	7.60	5.80	4.20	2.70	6.70	5.10	4.80	3.40
S_1Z_1	7.90	6.80	5.20	3.50	7.30	6.00	5.70	4.50
S_2Z_0	8.20	6.90	5.40	4.60	8.00	6.90	6.40	5.10
S_2Z_1	7.80	6.50	4.80	3.40	6.90	5.90	5.10	4.10
S_3Z_0	8.10	6.90	5.30	3.80	7.40	6.40	6.10	5.00
S_3Z_1	7.60	6.30	4.60	3.10	7.20	5.30	5.00	3.80
k value	3.52	6.08	8.39	9.68	5.53	11.98	15.05	11.17
$\chi 2$	11.07							

S_2 (October-February) and least score for those stored under PZECC during S_1, June-September (3.40) on 6^{th} day after storage.

4.4.5. Microbial load

1. Bacterial load

Storage conditions had no significant effect on bacterial load of stored bitter gourd (Table 45.). The effect of seasons showed that, bitter gourd stored during S_2, October-February had least bacterial load (4.33 log cfu/cm^2) which was on par with those stored during S_3, March-May (4.32). Bitter gourd stored during S_1, June-September and had higher bacterial load (4.45 log cfu/cm^2). Bacterial load increased from 4.29 log cfu/cm^2 on first day to 4.44 log cfu/cm^2 on 6^{th} day after storage.

All the bitter gourd stored under S_2 (October-February) and S_3 (March-May) had least bacterial load irrespective of storage condition. Highest bacterial load (4.49 log cfu/cm^2) was noticed in bitter gourd stored under PZECC during S_1 (June-September).

2. Fungal load

Storage conditions had no significant effect on fungal load of bitter gourd (Table 46.). Bitter gourd stored during S_2 (October-February) had least fungal load which was on par with those stored during S_3 (March-May). Fungal load was highest during S_1, June-September. Fungal load increased from 0.92 log cfu/cm^2 on first day to 1.98 log cfu/cm^2 on 6^{th} day after storage. However the fungal load was least (0.72 log cfu/cm^2) for those kept in PZECC during S_2 (October-February).

4.5. AMARANTH

Physical, physiological, chemical, organoleptic and microbial parameters of amaranth as influenced by two storage conditions in three different seasons are described below.

Table 45. Effect of season and storage condition on bacterial load of stored bitter gourd

Treatments	Bacterial load(Log colony forming units/cm^2)		
	Days after storage		Treatment mean
	0^{th} day	6^{th} day	
S_1Z_0	4.43	4.56	4.49
S_1Z_1	4.20	4.41	4.40
S_2Z_0	4.27	4.43	4.30
S_2Z_1	4.32	4.48	4.35
S_3Z_0	4.32	4.39	4.35
S_3Z_1	4.22	4.37	4.30
Days mean	4.29	4.44	
Mean	S1-4.45 Z_0-4.38	S2-4.33 Z_1-4.35	S3-4.32
CD (0.05)	D-0.03 S X Z-0.06	S-0.04	Z-NS D X S X Z-NS

Table 46. Effect of season and storage condition on fungal load of stored bitter gourd

Treatments	Fungal load (Log colony forming units/cm^2)		
	Days after storage		Treatment mean
	0^{th} day	6^{th} day	
S_1Z_0	1.33	2.94	2.14
S_1Z_1	0.00	1.43	2.01
S_2Z_0	1.43	1.33	0.72
S_2Z_1	1.43	2.59	1.46
S_3Z_0	0.67	2.26	1.38
S_3Z_1	0.67	1.33	1.00
Days mean	0.92	1.98	
Mean	S_1-2.08 Z_0- 1.41	S_2-1.09 Z_1-1.49	S_3-1.19
CD (0.05)	D- 0.67 S X Z-NS	S-0.82	Z- NS D X S X Z-NS

4.5.1. Physiological quality parameters

Physiological quality parameters like shelf life, PLW and marketability of amaranth stored under PZECC and at ambient condition in three different seasons were recorded and described below. Amaranth stored under ambient condition irrespective of season were wilted and discarded after one day after storage and hence comparison was made on 3rd day after storage between the treatments except for those stored under ambient condition during 3 seasons.

1. Shelf life

Effect of storage condition on shelf life of amaranth showed that, amaranth stored under PZECC had 3 days shelf life and those stored under ambient condition had 1 day only (Table 47.). Seasons individually had no effect on shelf life of amaranth.

There was no significant interaction effect of seasons and storage conditions on shelf life of amaranth.

2. Physiological loss in weight

Amaranth kept under PZECC had less physiological loss in weight (12.15%) than those kept under ambient storage condition (27.40%) (Table 48.). Amaranth stored during S_1 (June- September) had least physiological loss in weight (16.75%) and those stored during S_3, March-May had highest physiological loss in weight (21.85%).

While considering interaction of season and storage condition, amaranth stored under PZECC during S_2 (October-February) had least (11.40%) physiological loss in weight which was on par with amaranth stored under same condition during S_1, June-September (11.52%) and S_3, March-May (13.53%). Amaranth stored at ambient condition during S_3, March-May had highest (30.17%) physiological loss in

Table 47. Effect of season and storage condition on shelf life of stored amaranth.

Treatments	Shelf life (days)		
S_1Z_0	3		
S_1Z_1	1		
S_2Z_0	3		
S_2Z_1	1		
S_3Z_0	3		
S_3Z_1	1		
Mean	S_1- 2 Z_0- 3	S_2- 2 Z_1- 1	S_3- 2
CD(0.05)	S- NS	Z- 0.52	S X Z- NS

Table 48. Effect of season and storage condition on physiological loss in weight of stored amaranth.

	Physiological loss in weight(%)			
Treatments	1 day after storage			3rd day after storage
S_1Z_0	11.52			17.76
S_1Z_1	21.98			-
S_2Z_0	11.40			11.21
S_2Z_1	30.05			-
S_3Z_0	13.53			16.71
S_3Z_1	30.17			-
Mean	S_1- 16.75 Z_0 -12.15	S_2- 20.73 Z_1- 27.40	S_3-21.85	
CD (0.05)	S-2.38	Z - 1.94	S X Z- 3.36	CD - NS

weight. Amaranth stored under ambient condition irrespective of season were wilted and discarded after one day after storage.

There was no significant effect of treatments on physiological loss in weight of amaranth on 3rd day after storage.

3. Marketability

Amaranth stored under PZECC had better marketability (87.04%) when compared to those stored under ambient storage conditions (51.85%). Seasons had no significant individual effect on marketability of stored amaranth (Table 49.). Marketability decreased from 100% on the day to 38.89% on first day after storage.

There was no significant interaction effect of seasons and storage conditions on marketability of amaranth and there was no significant effect of treatments on marketability of amaranth on 3rd day after storage.

4.5.2. Physical quality parameters

1. Colour

Amaranth stored under PZECC had better colour (8.40) when compared to those stored under ambient storage condition (7.40) (Table 50.). Amaranth stored during S_1, June-September had higher colour score (8.25) and amaranth stored during S_3 (March-May) had least colour score (7.35). Colour score of amaranth decreased from 8.87 on the day to 6.93 on the first after day.

There was no significant interaction effect of seasons and storage conditions on colour of amaranth and the treatments had not significantly influenced the colour score of amaranth on 3rd day of storage.

Table 49. Effect of season and storage condition on marketability of stored amaranth.

Treatments	Marketability (%)			
	Days after storage		Treatment mean	3rd day after storage
	0th day	1st day		
S_1Z_0	100.00	77.78	88.89	11.11
S_1Z_1	100.00	11.11	55.56	-
S_2Z_0	100.00	77.78	88.89	0.00
S_2Z_1	100.00	0.00	50.00	-
S_3Z_0	100.00	66.67	83.33	11.11
S_3Z_1	100.00	0.00	50.00	-
Days mean	100.00	38.89		
Mean	S_1- 72.22 Z_0 -87.04	S_2- 69.45 Z_1-51.85	S_3- 66.67	
CD (0.05)	D-9.36 S X Z- NS	S- NS	Z - 9.36 D X S X Z- NS	CD - NS

Table 50. Effect of season and storage condition on colour of stored amaranth.

Treatments	Colour score			
	Days after storage		Treatment mean	3rd day after storage
	0th day	1st day		
S_1Z_0	9.00	8.40	8.70	3.60
S_1Z_1	8.80	6.80	7.50	
S_2Z_0	9.00	8.40	7.80	3.00
S_2Z_1	8.80	6.20	6.90	
S_3Z_0	8.80	6.80	7.80	3.20
S_3Z_1	8.80	5.00	6.90	
Days mean	8.87	6.93		
Mean	S_1- 8.25 Z_0 -8.40	S_2- 8.10 Z_1- 7.40	S_3- 7.35	
CD (0.05)	D-0.37 S X Z- NS	S-0.45	Z - 0.37 D X S X Z- NS	CD - NS

2. Texture

a. Bio-yield point

Storage conditions individually had no significant effect on bio-yield point of amaranth (Table 51.). Bio-yield point of amaranth stored during S_1, June-September was highest (316.13N) which was significantly different from amaranth stored in other two seasons. The amaranth stored during S_2 (October-February) had the least bio-yield point (203.91N). Bio-yield point decreased with storage; it was 276.82 N on the day of storage and 222.54N on first day after storage.

Considering the interaction effect of seasons and storage conditions, the amaranth stored under ambient during S_1, June-September had highest bio-yield point (343.70N) which was significantly different from all other treatments. The amaranth stored under the same condition during S_2 (October-February) had the least bio-yield point (177.72N).

There was no significant effect of treatments on bio-yield point of amaranth on 3rd day after storage.

b. Flesh firmness

Storage conditions individually had no significant effect on flesh firmness of amaranth (Table 52.). Flesh firmness of amaranth stored during S_1, June-September was highest (166.51N) which was significantly different from amaranth stored in other two seasons. The amaranth stored during S_2 (October-February) had the least flesh firmness (97.29N). Flesh firmness decreased with days after storage; it was 140.04 N on the day of storage and 112.06 N on first day after storage.

Considering the interaction effect of seasons and storage conditions, the amaranth stored under ambient during S_1, June-September had highest flesh firmness (180.34 N) which was significantly different from all other treatments. The amaranth

Table 51. Effect of season and storage condition on bio-yield point of stored amaranth.

Treatments	Bio-yield point (N)			
	Days after storage		Treatment mean	3rd day after storage
	0th day	1st day		
S_1Z_0	263.81	313.32	288.56	177.33
S_1Z_1	364.50	322.89	343.70	-
S_2Z_0	218.87	241.34	230.10	140.23
S_2Z_1	217.30	138.15	177.72	-
S_3Z_0	296.68	153.12	224.90	123.17
S_3Z_1	299.76	166.44	233.10	-
Days mean	276.82	222.54		
Mean	S_1- 316.13 Z_0-247.86	S_2- 203.91 Z_1-251.51	S_3-229.00	
CD (0.05)	D-19.10 S X Z- 33.08	S-23.39	Z- NS X S X Z- 46.78	CD - NS

Table 52. Effect of season and storage condition on flesh firmness of stored amaranth.

Treatments	Flesh firmness (N)			
	Days after storage		Treatment mean	3rd day after storage
	0th day	1st day		
S_1Z_0	143.87	161.50	152.68	82.84
S_1Z_1	194.25	166.43	180.34	-
S_2Z_0	108.74	119.74	114.24	68.40
S_2Z_1	105.00	55.70	80.35	-
S_3Z_0	143.99	81.84	112.91	62.64
S_3Z_1	144.38	87.14	115.76	-
Days mean	140.04	112.06		
Mean	S_1-166.51 Z_0-126.61	S_2- 97.29 Z_1-125.48	S_3-114.34	
CD (0.05)	D-14.33 S X Z-24.82	S-17.55	Z - NS D X S X Z- NS	CD - 12.17

stored under the same condition during S_2 (October-February) had the least flesh firmness (80.35 N).

Amaranth stored under PZECC during S_1, June-September had the maximum (82.84 N) flesh firmness on 3rd day after storage and least (62.64 N) for those stored under same condition during S_3, March-May.

4.5.3. Chemical quality parameters

1. Total carotene

Storage conditions had no significant effect on total carotene content of stored amaranth (Table 53.). Amaranth stored during S_2 (October-February) had higher (10.23 mg/100g) total carotene content. Least total carotene content (9.65 mg/100g) was observed during S_3, March-May. Total carotene content of amaranth decreased with the days after storage; it was 10.54 mg/100g on the day of storage and 9.44 mg/100g on first day after storage.

While considering interaction effect, amaranth stored under ambient condition during S_2, October-February had higher (10.32 mg/100g) total carotene and those stored under ambient condition during S_3, March-May (9.56 mg/100g) had least total carotene content.

Amaranth stored under PZECC during S_1, June-September had the maximum (8.78 mg/100g) total carotene content on 3rd day after storage which was on par with those stored under PZECC during S_2, October-February (8.75 mg/100g). Least total carotene content (8.03 mg/100g) was observed for those stored under same condition during S_3, March-May.

2. Vitamin C

Amaranth stored under ambient condition had better vitamin C content (23.29) when compared to those stored under PZECC (22.48 mg/100g) (Table 54.).

Table 53. Effect of season and storage condition on total carotene content of stored amaranth.

Treatments	Total carotene ($mg.100g^{-1}$)			
	Days after storage		Treatment mean	3rd day after storage
	0th day	1st day		
S_1Z_0	10.57	9.48	10.03	8.78
S_1Z_1	10.61	9.69	10.15	-
S_2Z_0	10.72	9.55	10.13	8.75
S_2Z_1	10.74	9.91	10.32	-
S_3Z_0	10.25	9.24	9.75	8.03
S_3Z_1	10.33	8.80	9.56	-
Days mean	10.54	9.44		
Mean	S_1-10.09 Z_0 -9.97	S_2-10.23 Z_1-10.01	S_3-9.65	
CD (0.05)	D-0.04 S X Z- 0.08	S-0.05	Z - NS D X S X Z-0.11	CD - 0.14

Table 54. Effect of season and storage condition on vitamin C of stored amaranth.

Treatments	Vitamin C ($mg.100g^{-1}$)			
	Days after storage		Treatment mean	3rd day after storage
	0th day	1st day		
S_1Z_0	27.43	20.62	24.03	7.713
S_1Z_1	26.57	21.95	24.26	
S_2Z_0	27.86	20.48	24.17	8.383
S_2Z_1	26.38	22.19	24.29	
S_3Z_0	23.62	14.86	19.24	7.143
S_3Z_1	24.81	17.81	21.31	
Days mean	26.11	19.65		
Mean	S_1- 24.14 Z_0 -22.48	S_2- 24.23 Z_1- 23.29	S_3- 20.27	
CD (0.05)	D- 0.17 S X Z- 0.29	S-0.21	Z -0.17 D X S X Z- 0.41	CD - 0.31

Amaranth stored during S_2 (October-February) had highest vitamin C content (24.23 mg/100g) which was on par with those stored during S_1, June-September (24.14 mg/100g). Least (20.27 mg/100g) vitamin C content was observed during S_3, March-May. Vitamin C content of amaranth decreased with storage; it was 26.11 mg/100g on the day of storage to 19.65 mg/100g at first day after storage.

Amaranth stored during S_1, June-September and S_2, October-February irrespective of storage condition had high an similar vitamin C content. Amaranth stored under PZECC during S_3, March-May had least (19.24 mg/100g) vitamin C content.

There was no significant difference between the vitamin C content of amaranth evaluated on 3rd day after storage.

3. Oxalate

Storage conditions had no significant effect on oxalate content of stored amaranth (Table 55.). Amaranth stored during S_3, March-May had least (3.16 mg/100g) oxalate content and highest (3.42 mg/100g) oxalate content was observed during S_1, June-September. Oxalate content of amaranth decreased with storage; it was 3.40 mg/100g on the day of storage to 3.22mg/100g on first day after storage.

There was no significant interaction effect of seasons and storage conditions on oxalate content of amaranth.

Amaranth stored in PZECC during S_3, March-May had least (2.71 mg/100g) oxalate content and those stored in same condition during S_2, October-February had highest (3.01 mg/100g) on 3rd day after storage.

4.5.4. Organoleptic quality parameters

Effect of seasons and storage conditions on organoleptic quality parameters of stored amaranth are shown in Table 56.

Table 55. Effect of season and storage condition on oxalate content of stored amaranth.

Treatments	Oxalate ($mg.100g^{-1}$)			
	Days after storage		Treatment mean	3rd day after storage
	0th day	1st day		
S_1Z_0	3.48	3.37	3.43	2.93
S_1Z_1	3.45	3.37	3.41	-
S_2Z_0	3.48	3.30	3.39	3.01
S_2Z_1	3.52	3.08	3.30	-
S_3Z_0	3.19	3.30	3.14	2.71
S_3Z_1	3.26	3.08	3.19	-
Days mean	3.40	3.22		
Mean	S_1- 3.42 Z_0 -3.32	S_2-3.35 Z_1-3.30	S_3-3.16	
CD (0.05)	D- 0.10 S X Z- NS	S-0.12	Z - NS D X S X Z- NS	CD - 0.13

1. Appearance

Appearance of amaranth was significantly affected by the treatments. Mean score was highest for amaranth stored under PZECC during S_1, June-September on 2^{nd} day (6.3) and of storage.

2. Colour

Colour score obtained by hedonic rating was significantly affected by the treatments. Mean scores obtained for colour were highest (6.9) for amaranth stored under PZECC during S_1, June-September on 2^{nd} day after storage.

3. Texture

Score obtained for texture of amaranth by hedonic rating was significantly affected by treatments. The score was highest (5.5) for those stored under ambient condition during S_1, June-September on 2^{nd} day.

4. Taste

Taste was significantly affected by the treatments. The mean score was highest (6.3) for amaranth stored under PZECC during S_3, March-May on 2^{nd} day after storage.

5. Flavour

Seasons and storage conditions had significant effect on flavour of stored amaranth. Amaranth stored under PZECC during S_3, March-May had maximum mean score (5.80) on 2^{nd} day after storage.

Table 56. Effect of season and storage condition on organoleptic quality parameters of stored amaranth.

Treatments	Appearance (mean score)		Colour (mean score)	
	0^{th} day	2^{nd} day	0^{th} day	2^{nd} day
S_1Z_0	8.0	6.3	8.6	6.9
S_1Z_1	7.9	4.0	8.1	4.5
S_2Z_0	8.3	5.5	7.9	6.4
S_2Z_1	7.6	2.8	7.1	4.1
S_3Z_0	7.9	5.1	8.3	5.8
S_3Z_1	7.7	3.4	7.6	3.4
k value	2.1	33.61	10.04	40.13
Treatments	Texture (mean score)		Taste (mean score)	
	0^{th} day	2^{nd} day	0^{th} day	2^{nd} day
S_1Z_0	7.8	5.0	8.7	5.3
S_1Z_1	7.9	5.5	8.2	3.8
S_2Z_0	7.7	3.1	8.2	5.9
S_2Z_1	7.4	2.5	8.2	3.7
S_3Z_0	7.5	2.9	8.3	6.3
S_3Z_1	7.7	4.5	7.8	3.0
k value	1.62	36.71	6.4	34.56
Treatments	Flavour (mean score)		overall (mean score)	
	0^{th} day	2^{nd} day	0^{th} day	2^{nd} day
S_1Z_0	7.8	4.9	6.9	4.5
S_1Z_1	7.6	2.8	7.4	2.8
S_2Z_0	7.7	5.2	7.4	4.6
S_2Z_1	7.8	3.0	7.7	3.1
S_3Z_0	8.0	5.8	7.6	5.5
S_3Z_1	7.5	3.3	7.4	3.0
k value	2.19	33.8	2.3	30.84
$\chi 2$	11.07			

6. Overall acceptability

Seasons and storage conditions had significant effect on overall acceptability of stored amaranth. Amaranth stored under PZECC during S_3, March-May had maximum mean score (5.50) on 2^{nd} day after storage.

4.5.5. Microbial load

1. Bacterial load

Storage conditions, seasons and their interaction had no significant effect on bacterial load of stored amaranth (Table 57). Bacterial load increased from 4.35 log cfu/cm^2 on the day of storage to 4.43 log cfu/cm^2 on first day after storage.

2. Fungal load

Storage conditions, seasons and their interaction had no significant effect on fungal load of stored amaranth (Table 58). However fungal load increased from 0.67 log cfu/cm^2 on the day of storage to 1.58 log cfu/cm^2 on first day after storage.

4.6. COWPEA

Physical, physiological, chemical, organoleptic and microbial parameters of cowpea pods as influenced by two storage conditions in three different seasons are described below.

4.6.1. Physiological quality parameters

Physiological quality parameters like shelf life, PLW and marketability of cowpea stored under PZECC and at ambient condition in three different seasons were recorded and described below. Cowpea pods stored under ambient condition irrespective of season were wilted and discarded after one day of storage and hence comparison was made on second day after storage between the treatments stored under PZECC during 3 seasons.

Table 57. Effect of season and storage condition on bacterial load of stored amaranth.

Treatments	Bacterial load(Log colony forming units/cm^2)		
	Days after storage		Treatment mean
	0^{th} day	1st day	
S_1Z_0	4.44	4.42	4.43
S_1Z_1	4.39	4.41	4.40
S_2Z_0	4.23	4.45	4.40
S_2Z_1	4.38	4.42	4.39
S_3Z_0	4.36	4.41	4.34
S_3Z_1	4.28	4.47	4.38
Days mean	4.35	4.43	
Mean	S1-4.42 Z_0-4.39	S2-4.39 Z_1-4.39	S3-4.36
CD (0.05)	D-0.06 S X Z-NS	S- NS	Z-NS D X S X Z-NS

Table 58. Effect of season and storage condition on fungal load of stored amaranth.

Treatments	Fungal load (Log colony forming units/cm^2)		
	Days after storage		Treatment mean
	0^{th} day	1st day	
S_1Z_0	0.00	2.96	1.48
S_1Z_1	1.33	1.49	1.46
S_2Z_0	0.00	0.67	1.41
S_2Z_1	0.667	2.26	1.05
S_3Z_0	0.667	1.43	0.33
S_3Z_1	1.333	0.67	1.00
Days mean	0.67	1.58	
Mean	S1-1.47 S2-1.23 S3-0.67 Z_1- 1.08 Z_0-1.171		
CD (0.05)	D-0.67 S-NS Z-NS S X Z-NS D X S X Z-NS		

1. Shelf life

Cowpea pods stored under PZECC had 2.48 days shelf life and those stored under ambient condition had 1.60 days. (Table 59.). Seasons had no significant effect on shelf life of cowpea.

There was no significant interaction effect of seasons and storage conditions on shelf life of cowpea pods.

2. Physiological loss in weight

Cowpea pods kept under PZECC had less physiological loss in weight (12.33%) than those kept under ambient storage condition (24.49%) (Table 60.). Cowpea pods stored during S_3, March-May had least physiological loss in weight (16.76%) which was on par with cowpea stored during S_1 (June- September). Cowpea stored during S_2 (October-February) had highest physiological loss in weight (21.32%).

Cowpea pods stored under PZECC during S_1, June-September had least (10.79%) physiological loss in weight which was on par with cowpea stored under same condition during S_2, October-February (12.81%). Cowpea stored under ambient condition during S_2 (October-February) had highest (29.83%) physiological loss in weight.

Cowpea pods stored under PZECC during S_2 (October-February) had least (18.29%) physiological loss in weight which was on par with those stored under same condition during S_1, June-September (19.71%). Cowpea stored under PZECC during S_3, March-May had highest physiological loss in weight (23.22%) on 2nd day after storage.

Table 59. Effect of season and storage condition on shelf life of stored cowpea.

Treatments	Shelf life(days)		
S_1Z_0	2.44		
S_1Z_1	1.56		
S_2Z_0	2.58		
S_2Z_1	1.67		
S_3Z_0	2.42		
S_3Z_1	1.58		
Mean	S1-2.00 Z_0- 2.48	S2-2.13 Z_1-1.60	S3-2.00
CD (0.05)	S- NS	Z- 0.36	S X Z- NS

Table 60. Effect of season and storage condition on physiological loss in weight of stored cowpea.

Physiological loss in weight (%)		
Treatments	1 day after storage	2 day after storage
S_1Z_0	10.79	19.71
S_1Z_1	23.50	-
S_2Z_0	12.81	18.29
S_2Z_1	29.83	-
S_3Z_0	13.39	23.22
S_3Z_1	20.12	-
Mean	S_1- 17.15 S_2-21.32 S_3-16.76 Z_0 -12.33 Z_1-24.49	
CD (0.05)	S-1.62 Z - 1.32 S X Z- 2.29	CD -2.93

3. Marketability

Cowpea stored under PZECC had better marketability (81.48%) compared to those stored under ambient storage conditions (64.81%) (Table 61.). Seasons had no significant influence on marketability of stored cowpea pods. Marketability decreased from 100% on the day of storage to 46.30% on first day after storage.

There was no significant interaction effect of seasons and storage conditions on marketability of cowpea.

There is no significant effect of treatments on marketability of cowpea on 2^{nd} day after storage.

4.6.2. Physical quality parameters

Physical quality parameters like colour and texture of cowpea pods stored under PZECC and at ambient condition in three different seasons were recorded and described below.

1. Colour

Cowpea pods stored under PZECC had better colour (8.07) when compared to those stored under ambient storage condition (6.73) (Table 62.). Cowpea stored during S_1, June-September had higher colour score (7.85) which was on par with those stored during S_2, October-February (7.50). Cowpea stored during S_3 (March-May) had least colour score (6.85). Colour score of cowpea pods decreased from 8.63 on the day of storage to 6.17 on the first day.

There was no significant interaction effect of seasons and storage conditions on colour of cowpea pods.

There was no significant effect of treatments on colour of cowpea pods on 2^{nd} day after storage.

Table 61. Effect of season and storage condition on marketability of stored cowpea.

Treatments	Marketability (%)			
	Days after storage		Treatment mean	2nd day after storage
	0th day	1st day		
S_1Z_0	100.00	66.67	83.33	22.22
S_1Z_1	100.00	22.22	61.11	-
S_2Z_0	100.00	66.67	83.33	22.22
S_2Z_1	100.00	44.44	72.22	-
S_3Z_0	100.00	55.56	77.78	33.33
S_3Z_1	100.00	22.22	61.11	-
Days mean	100.00	46.30		
Mean	S_1- 72.22 S_2- 77.78 S_3-69.45 Z_0 -81.48 Z_1- 64.81			
CD (0.05)	D-13.79 S- NS Z - 13.79 S X Z- NS D X S X Z- NS			CD - NS

Table 62. Effect of season and storage condition on colour of stored cowpea.

Treatments	Colour score			
	Days after storage		Treatment mean	2nd day after storage
	0th day	1st day		
S_1Z_0	8.80	8.40	8.60	6.00
S_1Z_1	8.80	5.40	7.10	-
S_2Z_0	8.60	7.60	8.10	5.20
S_2Z_1	8.40	5.40	6.90	-
S_3Z_0	8.60	6.40	7.50	4.40
S_3Z_1	8.60	3.80	6.20	-
Days mean	8.63	6.17		
Mean	S_1-7.85 S_2-7.50 S_3-6.85 Z_0 -8.07 Z_1- 6.73			
CD (0.05)	D-0.39 S-0.47 Z -0.39 S X Z- NS D X S X Z- NS			CD - NS

2. Texture

a. Bio-yield point

Cowpea pods stored under PZECC high bio-yield point (222.27 N) compared to those stored under ambient storage conditions (189.63 N) (Table 63.). Seasons had no significant effect on bio-yield point of cowpea. Bio-yield point decreased with storage; it was 264.45 N on the day of storage and 147.44 N on first day after storage.

There was no significant interaction effect of seasons and storage conditions on bio-yield point of cowpea.

Cowpea pods stored under PZECC during S_1, June-September and S_3, March-May had high (123.17 N) bio-yield point and those stored under same condition during S_2, October-February had least (107.36 N) bio-yield point on second day after storage.

b. Flesh firmness

Cowpea pods stored under PZECC had high flesh firmness (111.03 N) compared to those stored under ambient storage conditions (87.03 N) (Table 64.). Seasons had no significant effect on flesh firmness of cowpea. Flesh firmness decreased from 128.21 N on the day of storage to 69.85 N on first day after storage.

There was no significant interaction effect of seasons and storage conditions on flesh firmness of cowpea pods.

There was no significant effect of treatments on flesh firmness of cowpea on 2^{nd} day after storage.

Table 63. Effect of season and storage condition on bio-yield point of stored cowpea.

Treatments	Bio-yield point (N)			
	Days after storage		Treatment mean	2nd day after storage
	0th day	1st day		
S_1Z_0	245.91	197.23	221.57	123.17
S_1Z_1	281.42	102.36	191.89	
S_2Z_0	265.89	181.42	223.65	107.36
S_2Z_1	266.16	104.02	185.09	
S_3Z_0	245.91	197.23	221.57	123.17
S_3Z_1	281.42	102.36	191.89	
Days mean	264.45	147.44		
Mean	S_1-206.73 Z_0 -222.27	S_2-204.37 Z_1-189.63	S_3-206.73	
CD (0.05)	D-19.08 SX Z- NS	S- NS	Z -19.08 D X S X Z- NS	CD -12.08

Table 64. Effect of season and storage condition on flesh firmness of stored cowpea.

Treatments	Flesh firmness (N)			
	Days after storage		Treatment mean	2nd day after storage
	0th day	1st day		
S_1Z_0	114.80	107.59	111.19	62.64
S_1Z_1	137.73	39.67	88.70	
S_2Z_0	133.90	87.51	110.71	51.81
S_2Z_1	130.30	37.08	83.69	
S_3Z_0	114.80	107.59	111.19	62.64
S_3Z_1	137.73	39.67	88.70	
Days mean	128.21	69.85		
Mean	S_1- 99.95 Z_0-111.03	S_2-97.20 Z_1- 87.03	S_3-99.95	
CD (0.05)	D-9.73 S X Z- NS	S- NS	Z - 9.73 D X S X Z- NS	CD - NS

4.6.3. Chemical quality parameters

1. Total carotene

Storage conditions had no significant effect on total carotene content of stored cowpea pods (Table 65.). Cowpea pods stored during S_3, March-May had highest total carotene content (0.62 mg/100g). Least (0.57 mg/100g) total carotene content was observed during S_1, June-September. Total carotene content of cowpea increased with the storage; it ranged from 0.56 mg/100g on the day of storage to 0.62 mg/100g at first day after storage.

There was no significant interaction effect of seasons and storage conditions on total carotene content of cowpea.

There was no significant effect of seasons and storage conditions on total carotene content of cowpea on second day after storage.

2. Vitamin C

Storage condition had significant effect on vitamin C content of stored cowpea pods (Table 66.). Cowpea pods stored during S_2 (October-February) had higher (0.34 mg/100g) vitamin C content which was on par with those stored during S_1, June-September (0.28 mg/100g). Least (0.24 mg/100g) vitamin C content was observed during S_3, March-May. Vitamin C content of cowpea decreased with storage; it was 0.25 mg/100g on the day of storage and 0.32 mg/100g at first day after storage.

Interaction effect of seasons and storage conditions was non-significant on vitamin C content of cowpea.

There was no significant effect of treatments on vitamin C of cowpea on 2^{nd} day after storage.

Table 65. Effect of season and storage condition on total carotene content of stored cowpea.

Treatments	Total carotene ($mg.100g^{-1}$)			
	Days after storage		Treatment mean	2^{nd} day after storage
	0^{th} day	1^{st} day		
S_1Z_0	0.55	0.59	0.57	0.58
S_1Z_1	0.51	0.63	0.57	-
S_2Z_0	0.54	0.61	0.58	0.60
S_2Z_1	0.56	0.65	0.60	-
S_3Z_0	0.59	0.63	0.61	0.63
S_3Z_1	0.61	0.63	0.62	-
Days mean	0.56	0.62		
Mean	S_1-0.57 Z_0 -0.59	S_2-0.59 Z_1-0.60	S_3-0.62	
CD (0.05)	D-0.02 S X Z- NS	S- 0.03	Z - NS D X S X Z- NS	CD - NS

Table 66. Effect of season and storage condition on vitamin C of stored cowpea.

Treatments	Vitamin C ($mg.100g^{-1}$)			
	Days after storage		Treatment mean	2^{nd} day after storage
	0^{th} day	1^{st} day		
S_1Z_0	0.19	0.24	0.22	0.38
S_1Z_1	0.24	0.43	0.34	-
S_2Z_0	0.29	0.34	0.31	0.43
S_2Z_1	0.34	0.38	0.36	-
S_3Z_0	0.24	0.24	0.24	0.38
S_3Z_1	0.19	0.29	0.24	-
Days mean	0.25	0.32		
Mean	S_1-0.28 Z_0 -0.26	S_2-0.34 Z_1- 0.31	S_3-0.24	
CD (0.05)	D-0.05 S X Z- NS	S- 0.06	Z –NS D X S X Z- NS	CD - NS

4.6.4. Organoleptic quality parameters

Effect of seasons and storage conditions on organoleptic quality parameters of stored cowpea pods are shown in Table 67.

1. Appearance

Appearance of cowpea pods was significantly affected by the treatments on first day of storage. Mean score was highest for cowpea pods stored under PZECC during S_1, June-September (5.7).

2. Colour

Colour score obtained by hedonic rating were significantly affected by the treatments on first day after storage. Mean scores obtained for colour was highest (5.3) for cowpea stored under PZECC during S_3, March-May.

3. Texture

Scores obtained for texture of cowpea by hedonic rating were significantly affected by treatments on first day after storage. The score was highest (5.2) for those stored under PZECC during S_1, June-September.

4. Taste

Taste was significantly affected by the treatments on first day after storage. The mean score was highest (5.8) for those stored under PZECC during S_1, June-September.

5. Flavour

Seasons and storage conditions had significant effect on flavour of stored cowpea pods. Cowpea stored under PZECC during S_1, June-September had maximum mean score (8.10).

Table 67. Effect of season and storage condition on organoleptic quality parameters of stored cowpea.

Treatments	Appearance (mean score)		Colour (mean score)	
	0^{th} day	1st day	0^{th} day	1st day
S_1Z_0	7.8	5.7	6.7	4.3
S_1Z_1	7.5	3.3	7.3	2.9
S_2Z_0	7.6	5.1	7.2	4.4
S_2Z_1	7.4	3.0	8.0	3.1
S_3Z_0	7.7	4.8	7.9	5.3
S_3Z_1	7.3	2.9	7.4	3.3
k value	1.25	31.67	8.01	22.99
Treatments	Texture (mean score)		Taste (mean score)	
	0^{th} day	1st day	0^{th} day	1st day
S_1Z_0	7.9	5.2	8.2	5.8
S_1Z_1	7.3	2.8	7.8	3.3
S_2Z_0	7.4	3.8	8.0	4.9
S_2Z_1	6.8	3.0	7.6	3.0
S_3Z_0	7.5	4.4	8.1	5.2
S_3Z_1	7.2	2.5	7.7	2.8
k value	4.85	27.56	3.31	33.8
Treatments	Flavour (mean score)		overall (mean score)	
	0^{th} day	1st day	0^{th} day	1st day
S_1Z_0	8.1	5.8	8.1	5.4
S_1Z_1	7.7	3.1	7.3	3.3
S_2Z_0	7.9	5.1	7.5	4.4
S_2Z_1	7.3	2.5	7.2	2.5
S_3Z_0	8.0	5.2	7.6	4.9
S_3Z_1	7.5	2.7	7.3	2.9
k value	5.49	34.94	3.18	34.3
$\chi 2$	11.07			

6. Overall acceptability

Seasons and storage conditions had significant effect on overall acceptability of stored cowpea pods on first day after storage. Cowpea pods stored under PZECC during S_1, June-September had maximum mean score (5.4) for overall acceptability.

4.6.5. Microbial load

1. Bacterial load

Storage conditions, seasons and their interaction had no significant effect on bacterial load of stored cowpea pods (Table 68.). There was no significant difference between bacterial load during storage.

2. Fungal load

Storage conditions, seasons and their interaction had no significant effect on fungal load of stored cowpea (Table 69.). Fungal load of 0.61 log cfu/cm^2 on the day of storage increased to 1.70 log cfu/cm^2 on first day after storage.

TEMPERATURE AND RELATIVE HUMIDITY DURING THE STUDY

Temperature and relative humidity inside the PZECC and under ambient condition is shown in table 70. During the storage period, the ambient temperature varied between 28.01°C during S_1, June-September and 31.04°C during S_3, March-May. Whereas the temperature inside the evaporative cooler varied between 17.20°C during S_1, June-September and 23.77°C during S_3, March-May.

The relative humidity ranged between 70.59% during S_3, March-May and 83.51% during S_1, June-September under the ambient conditions. Relative humidity was between 90.70% in PZECC during S_3, March-May and 98.23% during S_1, June-September.

Table 68. Effect of season and storage condition on bacterial load of stored cowpea.

Treatments	Bacterial load(Log colony forming units/cm^2)		
	Days after storage		Treatment mean
	0^{th} day	1st day	
S_1Z_0	4.48	4.57	4.527
S_1Z_1	4.42	4.49	4.475
S_2Z_0	4.50	4.36	4.458
S_2Z_1	4.42	4.53	4.425
S_3Z_0	4.39	4.46	4.432
S_3Z_1	4.58	4.38	4.480
Days mean	4.47	4.46	
Mean	S1-4.50 Z_0-4.47	S2-4.44 Z_1-4.46	S3-4.46
CD (0.05)	D-NS S X Z-NS	S-NS	Z-NS D X S X Z-NS

Table 69. Effect of season and storage condition on fungal load of stored cowpea.

Treatments	Fungal load (Log colony forming units/cm^2)		
	Days after storage		Treatment mean
	0^{th} day	1^{st} day	
S_1Z_0	0.77	2.84	1.80
S_1Z_1	0.67	0.77	1.18
S_2Z_0	0.77	1.43	0.72
S_2Z_1	0.00	2.36	0.72
S_3Z_0	0.00	1.43	1.10
S_3Z_1	1.43	1.33	1.38
Days mean	0.61	1.70	
Mean	S1- 1.49 Z_0-1.21	S2- 0.72 Z_1-1.09	S3-1.24
CD (0.05)	D-0.71 S X Z-NS	S-NS	Z-NS D X S X Z-NS

Table 70. Temperature and relative humidity inside the PZECC and ambient condition

Season	PZECC		Ambient	
	Temperature (^0C)	RH (%)	Temperature(^0C)	RH (%)
S_1 (June-September)	17.20	98.23	28.01	83.51
S_2(October- February)	20.51	90.57	27.00	77.28
S_3 (March-May)	23.77	90.70	31.04	70.59

WEATHER DATA RECORDED DURING THE STUDY

Weather data during the study is shown in Appendix II.

Discussion

5. DISCUSSION

Post harvest loss and quality deterioration of horticultural commodities take place due to lack of several management practices including refrigerated storage. Setting up of cold storages will be ideal to reduce post harvest loss and manage price fluctuation considerably, but is not easily acceptable to small and marginal farmers of Kerala, as refrigeration is energy intensive, expensive, difficult to install and run in farmers' fields and not always environment friendly, hence has not gained pace in our state. In the absence of cold storages and related cold chain facilities, the farmers are being forced to sell their produce immediately after harvest which results in glut situations and low price realization.

Considering acute energy crisis, a low cost storage facility accessible to them will go a long way in removing the risk of distress sale to ensure better returns. Unless there are systematic solutions to manage the surplus in horticulture perishables, time and money spent on cultivation will be a mere waste. Pusa Zero Energy Cool Chamber (PZECC) is a simple, low cost, effective and accepted storage structure developed for short term storage of fruits and vegetables at farm level in Rural North India especially in summer, where high temperature and low humidity prevails (Roy and Khurdiya, 1986). It is a double walled storage structure made of bricks, developed at IARI, New Delhi, which operates on the principle of evaporative cooling and maintains an inside temperature 10-15^{0}C lower than the outside temperature. If this structure is suited to humid tropics of Southern Kerala, it would be a satisfactory option for short term maintenance of horticultural perishables during glut period, reducing the wastage of perishable commodities and thus providing remunerative prices to the growers. Hence the study entitled "Feasibility of Pusa Zero Energy Cool Chamber as low cost on-farm storage structure under Kerala condition" was undertaken with the objective to evaluate the feasibility of Pusa Zero Energy

Cool Chamber as a low cost on-farm storage structure for horticultural perishables during different seasons under humid tropical climate of Kerala.

Six different fruits and vegetables, viz., papaya, snake gourd, cucumber, bitter gourd, amaranth and cowpea were stored in perforated plastic crates under Pusa zero energy cool chambers (PZECC) each of 165cm length, 115 cm breadth and 75 cm height during three seasons viz., June – September (S_1), October - February (S_2) and March – May (S_3) by maintaining 85-95% relative humidity inside the chamber (Z_0) with same set of commodities kept under ambient storage conditions as control(Z_1). The study was conducted as six separate experiments for different commodities and possibility of storage of each commodity during different seasons was assessed based on physical, physiological, chemical and sensory quality parameters.

Shelf life, physiological loss in weight and marketability are the three physiological parameters deciding quality of a perishable commodity. Papaya, snake gourd and bitter gourd stored in PZECC during March- May and October- February had high shelf life, marketability and colour, whereas cucumber had high shelf life and marketability when stored in PZECC only during March – May. Though the treatment combinations had no significant effect, amaranth and cowpea kept inside the PZECC had high shelf life, marketability and colour with low physiological loss in weight. Shelf life and marketability of commodities as influenced by season and storage condition are depicted in Fig.1 and Fig .2 respectively. But the enhanced shelf lives were 1.55 and 1.66 days for papaya, 0.89 and 0.66 days for bitter gourd and 0.78 and 1.55 days for cucumber when kept in ZECC during S_2 (Oct- Feb) and S3 (March- May) respectively compared to their corresponding ambient storage. Amaranth had two days additional shelf life when kept under ZECC. Leafy amaranth stored in zero energy brick cooler (ZEBC) and evaporative charcoal cooler (ECC) maintained a near farm-fresh state for an additional 2 days and a salable state for up to 5 days more than those stored at ambient room conditions (Ambuko *et al.*, 2017). Islam and Morimoto (2012) reported that tomato and eggplant had a shelf life of 7 and 4 days at

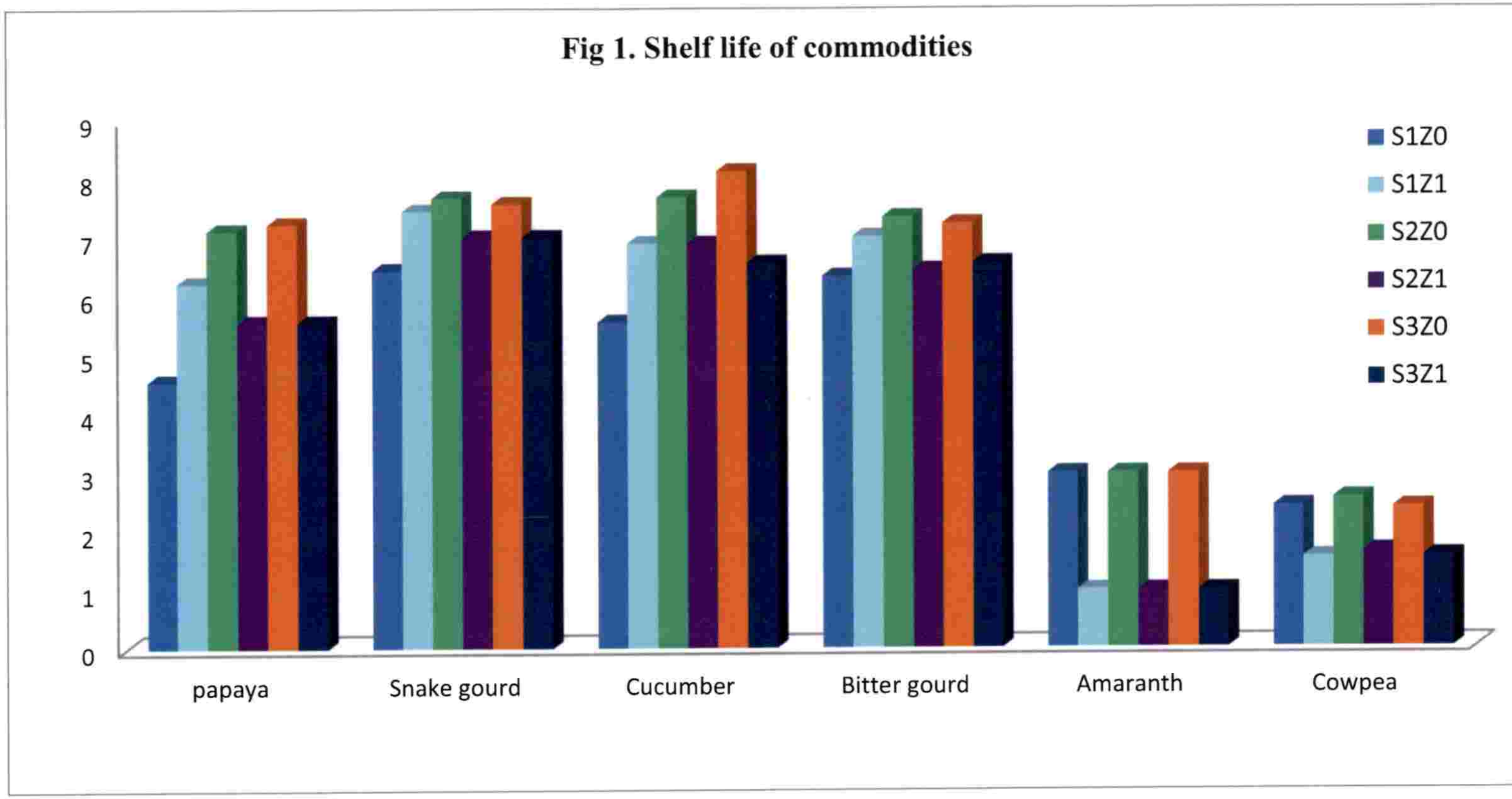


Fig 1. Shelf life of commodities as influenced by season and storage condition.

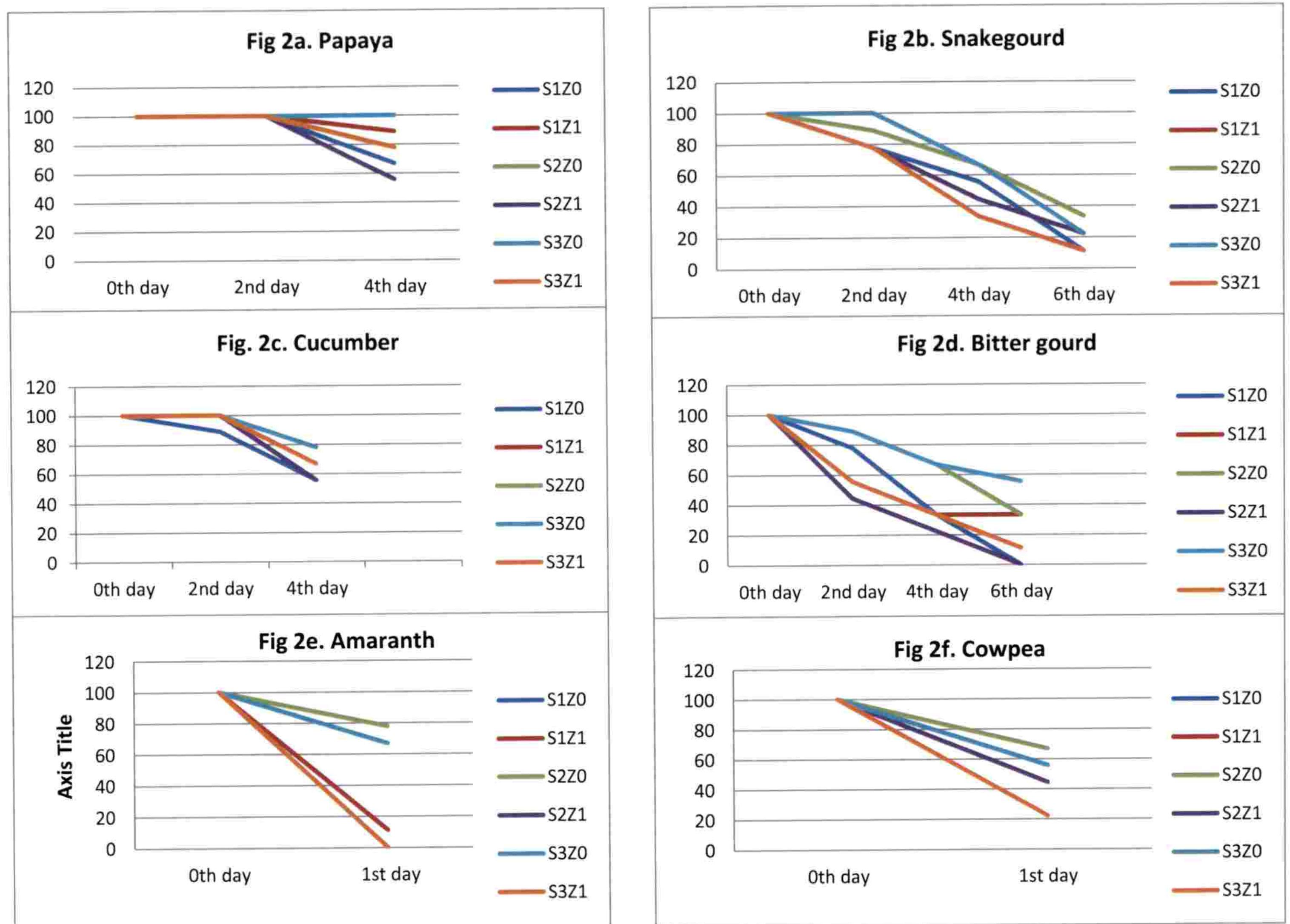


Fig 2. Marketability of commodities as influenced by season and storage condition

room temperature, respectively, as compared to 16 and 9 days when stored in the ZECC in Japan. Kanak and Sanjay (2013) revealed that Jamun cv Goma Priyanka fruits packed in perforated polythene bag and stored in zero energy cool chamber had four days economic shelf-life and 82.50% marketable fruits while control (under ambient condition) had one day economic shelf-life and zero per cent marketability only. Singh and Satapathy (2006) observed an enhanced shelf life of 5 days for bitter gourd, capsicum, and cauliflower whereas; shelf life of tomato and pineapple was increased for about 6 and 9 days respectively, inside the cool chamber constructed at Meghalaya as compared to room temperature storage. Devi and Singh, 2018 reported that shelf life of vegetable and fruit crops like cabbage, broccoli, tomato, pineapple, passion fruit and banana could be enhanced through ZECC and physiological loss in weight (PLW) in ZECC was comparatively less as compared to the room condition in Churachandpur district of Manipur. Azene *et al.*, 2014 reported that the evaporative cold storage improved the shelf life of papaya fruits by more than two fold in Ethiopia. The average relative humidity at the time of experimentation in Ethiopia was 43.0% under the ambient conditions and 78.8% in evaporative cooler. Maintenance of a high relative humidity inside the chamber while outside RH is low, helped to retain turgidity in stored commodities by lowering the water loss, there by resulting in enhanced shelf life. The physiological loss in weight of all commodities was low when stored in ZECC, compared to those stored in ambient condition (Fig 3.). Hence the commodities under PZECC were fresh and turgid compared to those which are stored under ambient condition (Plate 5.). The highest weight loss was recorded by Azene *et al.* (2014) for non packaged papaya fruits and Samira *et al.*, 2013 for bell peppers stored under ambient conditions. Samira *et al.*, 2013 also reported 16 days shelf life for pepper fruits stored at ambient condition while those stored in evaporative cooler were kept up to 28 days. Evaporative cooling helps in reducing temperature and increasing the relative humidity of an enclosure, and has been extensively tried for enhancing the shelf life of horticultural produce (Jha and

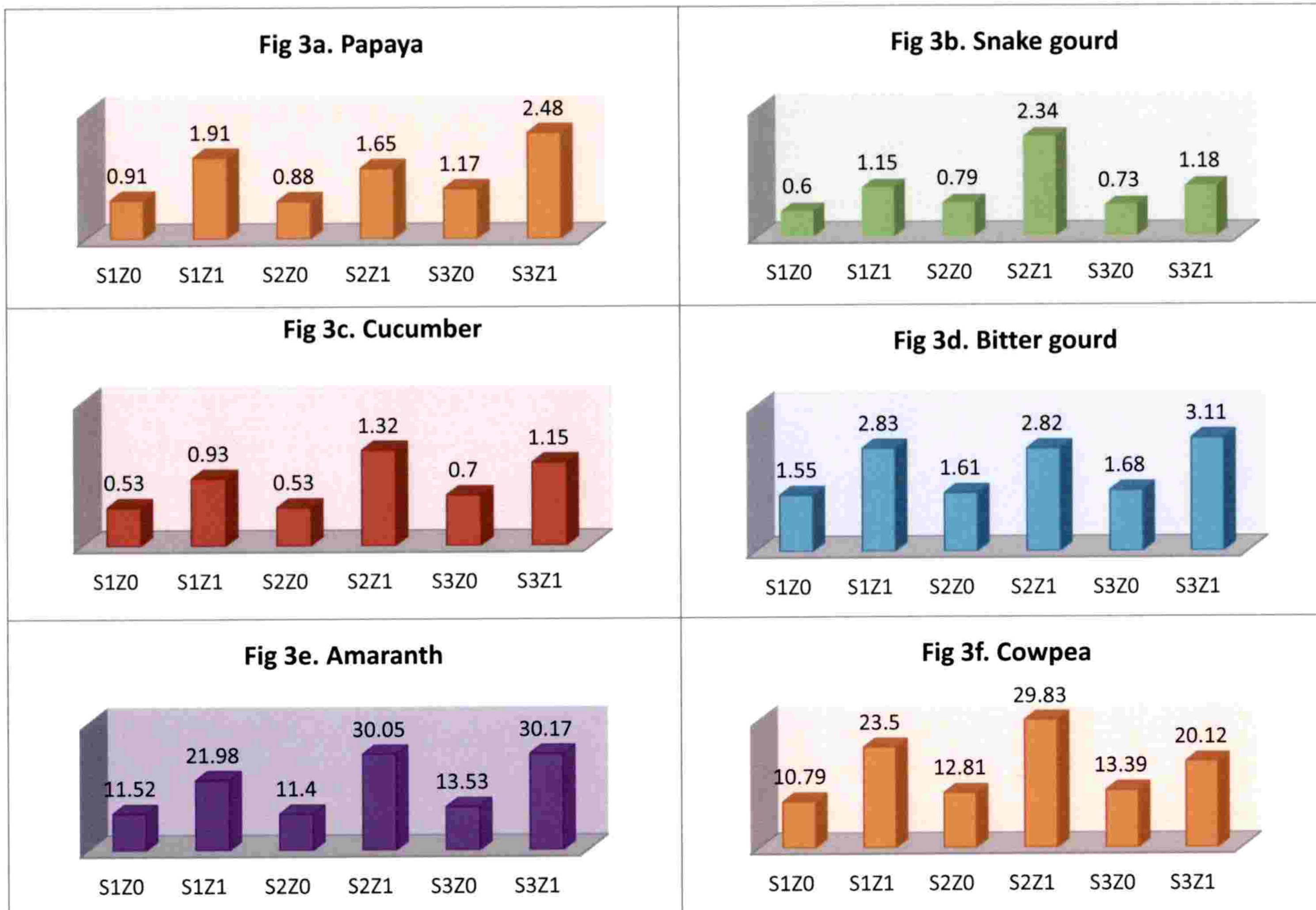


Fig 3. Physiological loss in weight as influenced by season and storage condition.

Chopra, 2006), (Odesola and Onyebuchi, 2009) and is helpful in maintaining the freshness of the commodities (Dadhich *et al*., 2008). The evaporative cooled storage structure has proved to be efficient and economical means for short term, on-farm storage of fruits and vegetables in hot and dry regions. But under our tropical humid climatic condition, only marginal increase in shelf life could be received in the present study, that too only during March- May and October- February period.

Papaya, bitter gourd, cucumber & snake gourd had least shelf life when stored in PZECC during June- September (Fig 1.). Storage under the chamber during June – September had resulted in poor colour development in bitter gourd and snake gourd, poor texture in snake gourd and lowest marketability in cucumber. Quality of commodities was better under ambient storage conditions during rainy season. Storing the commodities under PZECC during rainy season resulted in high water content and hence further rotting of commodities. Loss of weight and development of symptoms resulting from water loss, i.e., loss of glossy appearance, softness, shriveling, and dryness of the peel, in papaya fruits are greatly influenced by the relative humidity and temperature of the storage area (Nunes *et al*., 2006) which is in agreement with the present results. During rainy season, relative humidity could not be maintained in the prescribed range of 85-95% and was in the high range of 98.2 to 98.3% ; high RH together with the very low temperature inside the PZECC resulted in rotting and rapid spoilage of the commodity compared to ambient storage. Increased physiological loss in weight (PLW) and spoilage percentage with advancement of storage period was general phenomena in all commodities when stored under PZECC during rainy season. Evaporative cooling is a physical phenomenon in which evaporation of a liquid, typically into surrounding air, cools an object in contact with it. Evaporative cooling occurs when air, that is not too humid, passes over a wet surface; the faster the rate of evaporation the greater the cooling. The efficiency of an evaporative cooler depends on the humidity of the surrounding air. Very dry air can absorb a lot of moisture so greater cooling occurs. In the extreme case of air that is totally saturated with water, no evaporation can take place and no cooling occurs (Basediya *et al.*, 2013).

The chemical constituents which are present in each commodity were analyzed during the storage period. Papaya, the only fruit used in the experiment had lower Total Soluble Solids (13.06^0 B) when stored in PZECC. Dhaka *et al.*, 2001 reported a slower increase in TSS of the mango fruit at cool chamber conditions than ambient temperature storage. The low TSS could be attributed to the lower temperature and higher humidity resulting in slower rate of respiration rate and ripening. Azene *et al.* (2014) reported that packaging and cooling maintained the chemical quality of papaya fruits better than the control sample fruits towards the end of storage periods. Kanak and Sanjay (2013) reveled that jamun cv Goma Priyanka packed in perforated polythene bag and stored in zero energy cool chamber had high retention of total soluble solids, total sugar and reduction in titratable acidity with advancement of storage period. Increase in TSS under ambient storage might be due to physiological loss in weight that increased the concentration of juice.

But majority of the nutritional parameters of vegetables, which are used under the present experiment were unaffected by the storage conditions. Carotene content in snake gourd and cowpea, vitamin C of bitter gourd, cucumber and cowpea and oxalate content in amaranth were not influenced by the treatments under our study. Several other research findings have revealed that chemical quality parameters are influenced by the storage conditions. Samira *et al.* (2013) reported higher ascorbic acid content in bell peppers stored in evaporative cooler. Arun *et al.* (2006) could observe a high retention of ascorbic acid in chlorine water treated lemon fruits stored in zero energy cool chamber. The improper and inefficient working of ZECC under tropical humid climate might be the reason for not influencing the chemical quality parameters of the commodities under the present experiment.

The season had significantly influenced majority of the quality parameters of commodities under study. Maximum Total soluble solids (13.93^{0}B), total sugar (32.54 mg/100g), total carotene content and least titrable acidity (0.15%) in papaya fruits, least oxalate content (3.16 mg/100g) in amaranth and highest total carotene content (0.62mg/100g) in cowpea were reported when stored during S_3, March-May. Agronomic factors such as growing season, harvesting practices, plant maturity, plant species, plant variety and plant parts can also have a large effect on oxalate accumulation in forage plants (Rahman and Kawamura, 2011). Fallovo *et al.*, 2009 reported high total chlorophyll and nitrate contents in lettuce crop grown in summer season compared with the spring season. The higher nitrate concentration in the summer season could be associated with a higher range of temperatures.

Total carotene content of snake gourd and bitter gourd or vitamin C content of cucumbers and bitter gourd were not influenced by season. In a study by Fallovo *et al.*, 2009, no significant difference among treatments was observed for carotenoid content in lettuce.

Papaya, Amaranth and cowpea had highest vitamin C content (58.81, 24.23 and 0.34 mg/100g respectively) when stored during S_2, October-February. Amaranth stored during S_2 had higher (10.23 mg/100g) total carotene content. This is in agreement with the findings of Fallovo *et al.*, (2009) who had reported that leafy lettuce grown in a floating system in the spring season exhibited higher leaf quality with higher contents of glucose, sucrose and total carbohydrates and lower nitrate content than those grown in the summer season.

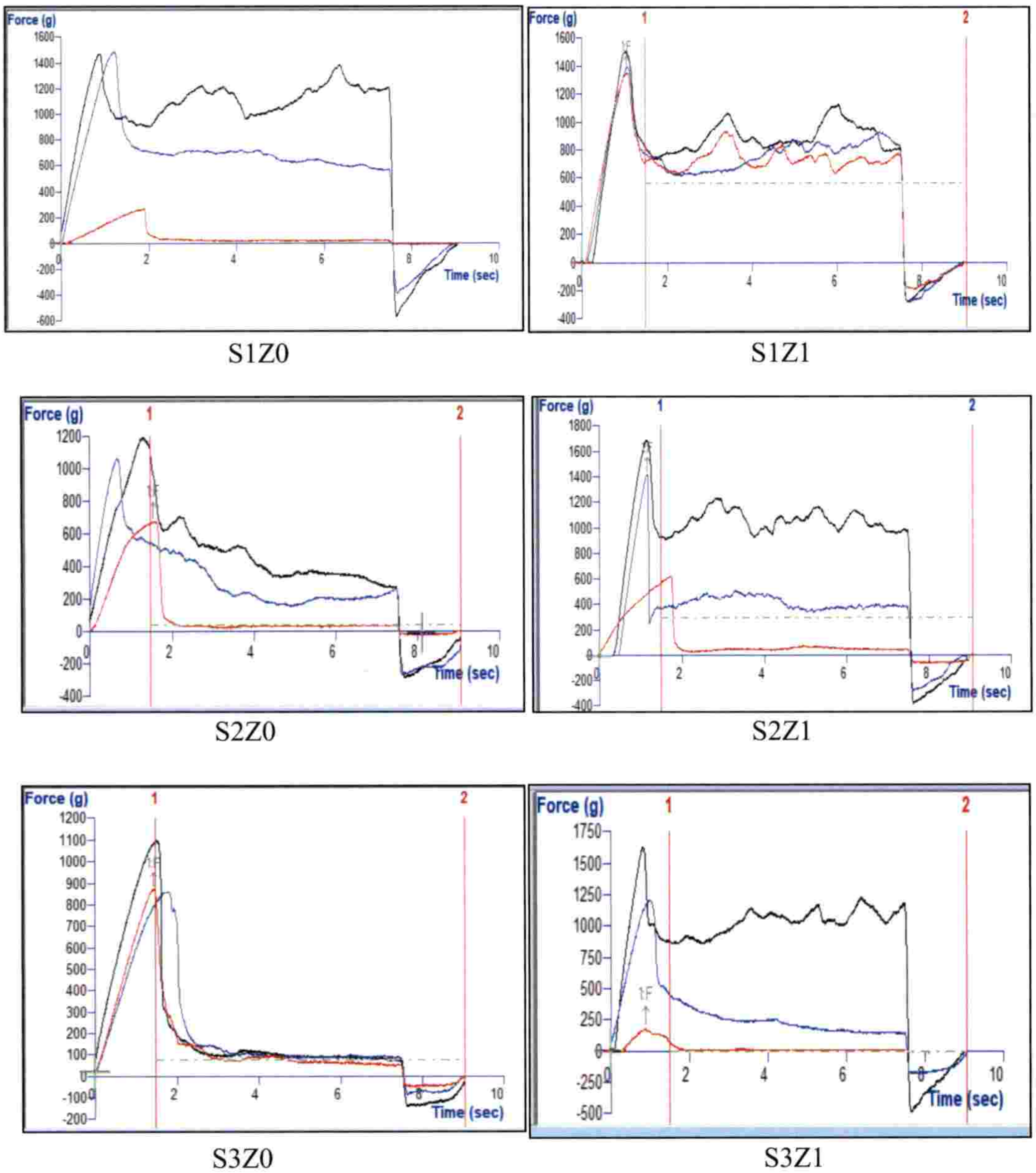
Texture is a major quality parameter influencing marketability and acceptability of any horticultural produce. Texture was measured in terms of bio-yield point and flesh firmness. The point at which, the appropriate probe of a texture analyser punctures through the fruit skin and begins to penetrate into the fruit flesh, is represented by the sudden change in slope of graph, called "bio-yield point" and it causes an irreversible damage. As the fruits become firmer the force required to puncture through the skin is more hence resulted higher bio-yield point.

Different commodities responded differently when texture during storage under two different conditions was analyzed. Textural parameters measured in terms of flesh firmness and bio-yield point were good for papaya kept in PZECC during S_3 (March- May). Papaya fruits, Bitter gourd and cowpea stored under PZECC had better texture as indicated by higher bio yield point and flesh firmness. Snake gourd and cucumbers stored under the ambient condition had better flesh firmness. This is in accordance with the findings of Ramakrishnan and Godara, 1993 who had reported decreased fruit firmness in ber fruits stored under ZECC. But storage conditions individually had no significant effect on textural parameters of amaranth

Papaya and cucumbers stored under PZECC during S_3, March-May had highest bio-yield point and flesh firmness, whereas snake gourd stored under PZECC during S_2, October-February had highest textural quality parameters. Cucumbers and amaranth stored under ambient condition during S_1, June-September had better textural parameters. Firmness of fruits and vegetables influences all the textural parameters associated with the commodity. There was no significant interaction effect of seasons and storage conditions on flesh firmness of cowpea pods and bitter gourd. According to Kader *et al.*, 1978, the textural quality of tomatoes was influenced by flesh firmness and skin toughness.

Texture (Firmness and bio-yield point) of all commodities gradually deteriorated or reduced during storage. But the rate of reduction in firmness and bio-yield point was less in commodities stored in PZECC compared to those stored in ambient condition (Fig 4.).

Quality-related attributes are to be measured to investigate and control quality. Quality of produce encompasses sensory attributes, nutritive values, chemical constituents, mechanical properties, functional properties and defects. With reference



------- 0th day

------- 2nd day

------- 4th day

Fig 4. Texture of papaya as influenced by season and storage condition.

to fruits and vegetables, the characteristics that impart distinctive quality may be described by four different attributes viz., color and appearance, flavor (taste and aroma, Texture and nutritional value. These four attributes typically affect consumers in the order specified above. The visual appearance and color are evaluated first, followed by the taste, aroma, and texture (Abbott, 1999). Sensory quality has a key influence on how consumers perceive the quality of a product and on consumers' preferences. Sensory analysis constitutes an indispensable tool to obtain information on those aspects of food quality to which no other analytical technique can be applied and it plays an important role in the quality control of foods. Sensory quality attributes were analyzed for the stored commodities by hedonic scoring.

The sensory attributes of commodities were not superior or inferior throughout the same storage condition or season. It varied from commodity to commodity. All the sensory parameters were affected by the treatments in cucumber, amaranth, and cowpea. Appearance and colour of cucumber were higher when stored under PZECC during S3, March-May and S_1, June-September respectively. Taste and flavor score were higher when stored under ambient condition during S1, June-September (Fig 5.). Appearance and colour scores were highest for amaranth stored under PZECC during S1, June-September whereas texture score was highest when stored under ambient condition. Taste and flavor scores for amaranth for amaranth were highest when stored under PZECC during S_3, March-May. In cowpea, appearance, texture, taste and flavor scores were highest when stored under PZECC during S1, June-September and colour during S3, March-May. Roy and Pal (1991) and Mithra *et al.*, 2003 had reported enhanced acceptability with better appearance, texture, taste and flavor for mango, litchi, guava , banana, sapota and mandarin under ZECC. Ramakrishnan and Godara, 1993 had reported decreased organoleptic scores for ber fruits under ZECC storage.

In other commodities, majority of the sensory parameters were not influenced by season and storage conditions. Mean organoleptic scores for appearance and

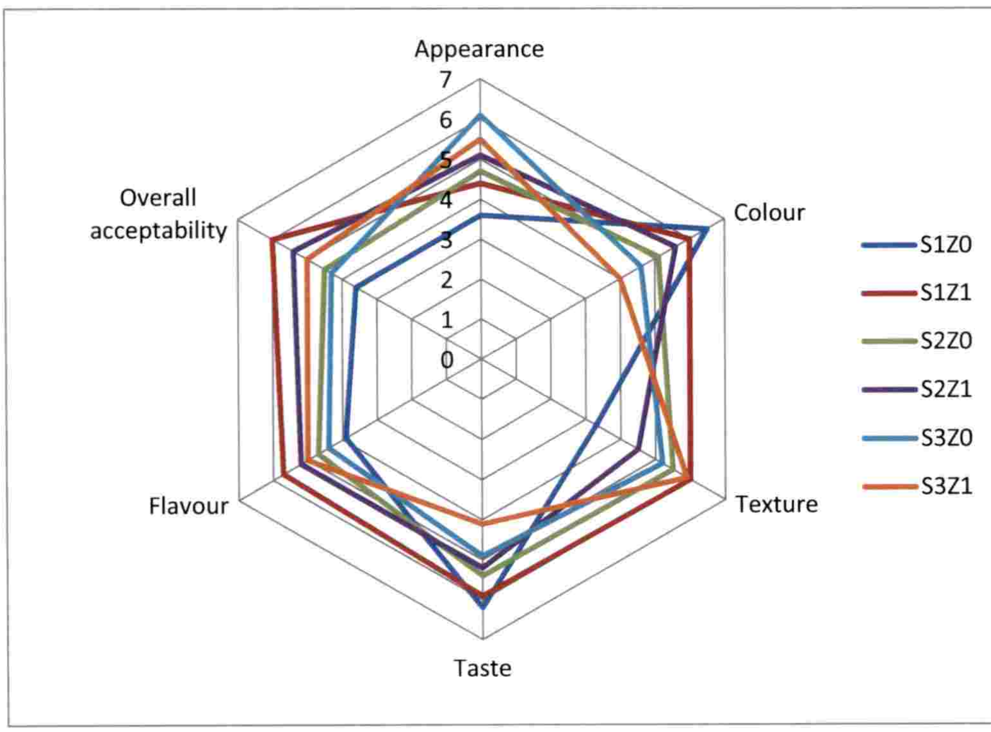


Fig 5. Organoleptic quality parameters of cucumber as influenced by season and storage condition

colour were higher for papaya fruits stored under PZECC during S_2, October-February whereas texture, taste, and flavor of papaya fruits were not affected by the treatments. Colour and flavor scores of snake gourd were highest for snake gourds stored under PZECC during S_3, March-May. But appearance, texture and taste of stored snake gourd were not influenced by the treatments. Mean scores obtained for texture and taste was highest for bitter gourds stored under PZECC during S_2 (October-February). There was no significant effect of seasons and storage conditions on appearance, colour and flavor of stored bitter gourd.

Microbial load of papaya and snake gourd, cowpea, amaranth were not affected by the treatments; But bacterial load in bitter gourd and fungal load incucumber were high when stored under PZECC during June – September. Fungal load was least for cucumbers kept in ambient condition during S_3 (March-May) which was on par with those stored under PZECC during same season and cucumbers stored during S_2 ,October-February irrespective of storage conditions. All the bitter gourd fruits stored under S_2 (October-February) and S_3 (March-May) had least bacterial load irrespective of storage condition. Pareek *et al.*, 2009 reported that PLW, shelf life and microflora of ber fruits could be reduced by storing in PZECC. The maximum per cent browning and decay were observed (Patil *et al.*, 2017) in ZECC storage (9-15°C) of leaf type lettuce cultivars i.e. GKL-1, GKL-2, GKL-3 and Chinese Yellow compared to refrigerated storage (5±1°C).

The study clearly showed that PZECC is a low cost on-farm storage structure which could be constructed at a cost of Rs.5000/- per unit. But the structure helps in marginal enhancement in shelf life of horticultural perishables that too only during March- May and October- February. The commodities were fresh, firm and turgid in acceptable form when stored in PZECC (Plate .5). The structure was not at all suitable during the rainy season (June-September) and the commodities had better physiological parameters and shelf life in rainy season under ambient condition compared to storage under PZECC. Efficiency of the storage structure depends on

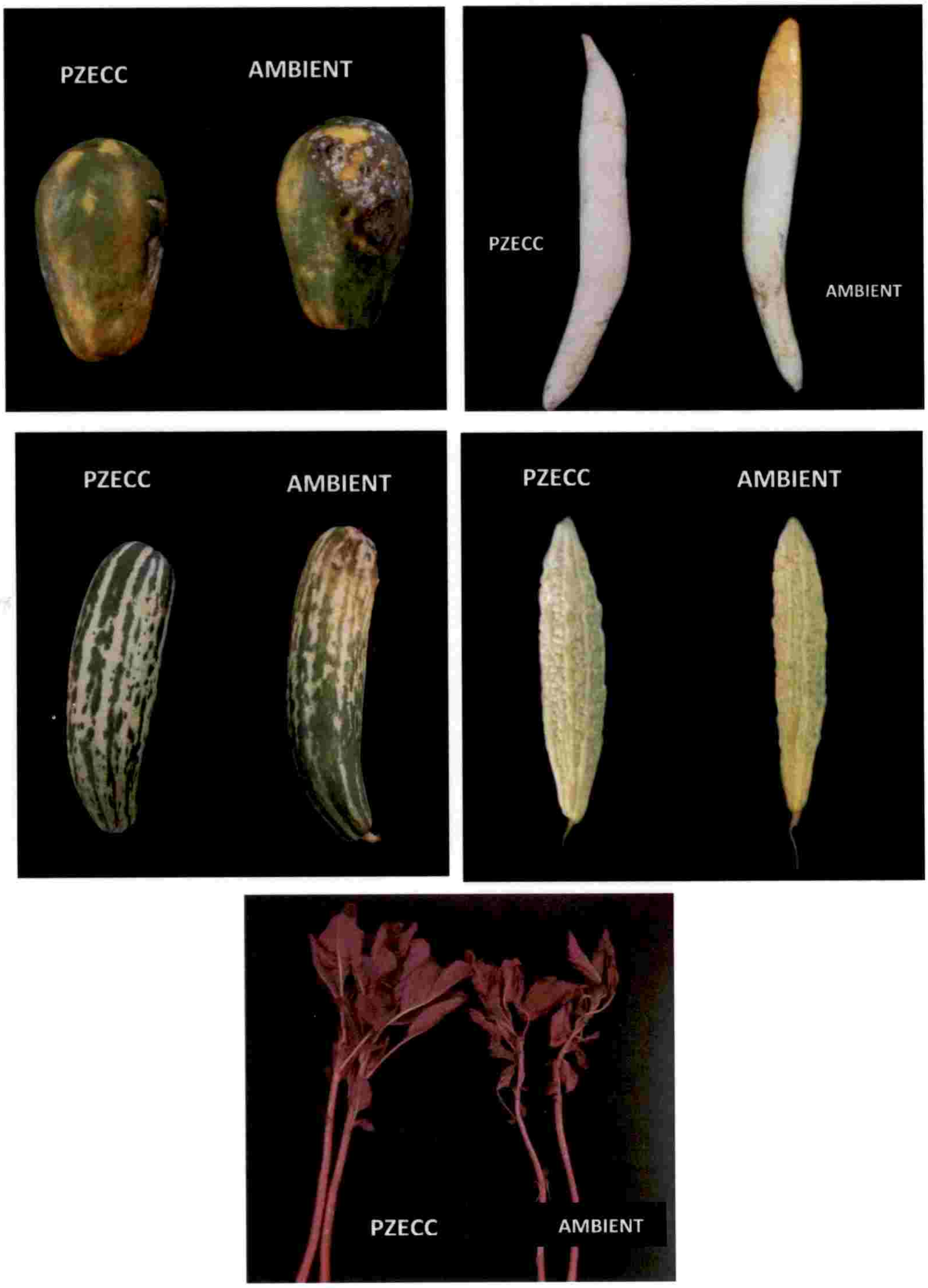


Plate 5. Effect of storage condition on quality of different commodities.

humidity of the surrounding air. Very dry, low humid air can absorb a lot of moisture, resulting in considerable cooling. The materials primarily used in constructing the chamber i.e. bricks and sand both have great capacity to absorb and/or retain water which evaporates slowly and steadily depending on the atmospheric temperature and humidity resulting in cooling. ZECC not only reduces the storage temperature but also increases the relative humidity of the storage which is essential for maintaining the freshness of the commodities. When commodities are exposed to excessive hot temperatures during handling it would result in accelerated ripening, contributing to the depletion of organic acids and sugars due to an increased respiration rate, consequently damage of the produce which is normally observed in fruit stored above the optimum temperature (Lam 1989). A 10-15°C temperature difference between the inside and outside of an evaporative cool chamber was reported and the RH inside will be 30–40% higher than the outside (Dadhich *et al.*, 2008). Under these conditions, wilting and loss of freshness were significantly slowed thereby keeping the fruits and vegetables fresh for up to 3–5 days more inside the chamber than outside. The evaporative cooler is an effective device under such areas in minimizing the extremes of temperature and RH. When the air temperature outside the chamber is at the highest point, while the relative humidity was the lowest point, it results in a higher cooling capacity. But in a tropical humid climate of Kerala, the enhanced humidity will only help to damage the commodities. When the air is totally saturated with water, no evaporation can take place and no cooling occurs. The design used in the present study was the one developed at Pusa, New Delhi which was specifically designed for places of high temperature and low humidity. There are many different styles of evaporative coolers and the design depends on the materials available and the users requirements (Basediya *et al.*, 2013). The result of the present study shows the necessity to modify the design of PZECC for increasing the efficiency of the chamber suited for tropical humid climates.

Jain (2007) developed a modified two stage evaporative cooler (TSEC) to improve the efficiency of evaporative cooling for high humidity and low temperature air conditioning. Several types of materials, namely metals, fibres, ceramics, zeolite and carbon, has potential to be used as heat and mass transfer medium in the indirect evaporative cooling systems (Zhao *et al.*, 2008). Taha *et al.* (1994) designed and tested a special type of evaporative cooler for its performance under different conditions and concluded that the ambient temperature was reduced by 10–13 °C. Islam and Morimoto (2014) recommended a new ZECC with two cooling systems, a solar-driven adsorption refrigerator and an evaporative cooling system as low-cost, energy-saving and useful for storing fruit and vegetables in areas where electricity is unavailable. Ambuko *et al.*, (2017) evaluated the effectiveness of two evaporative cooling technologies, namely, zero energy brick cooler (ZEBC) and evaporative charcoal cooler (ECC), in preserving the postharvest quality of leafy amaranth vegetables.

Shelf life of a commodity is governed by several factors viz., variety, stage of maturity, rate of cooling, storage temperature, relative humidity, packaging system, etc. It is important to keep in mind that they usually interact with each other to influence the overall rate of evaporation, and therefore, the rate and event of cooling. In the present study, the commodities were placed in plastic crates and stored directly under the PZECC. Zero energy cool chamber along with perforated polythene bag was found economically viable for on farm storage of jamun fruits (Lata and Singh, 2013). Singh *et al.* (2017) reported that Pear fruits individually packed in PE 0.05 or 0.01mm and stored at ZECC effectively maintained quality parameters up to 10th day of storage. Hence adoption of proper packaging along with storage in ZECC would have been helpful in enhancing shelf life of stored commodities. Azene *et al.* (2014) reported that the evaporative cold storage combined with packaging improved the shelf life of papaya fruits by more than two fold in Ethiopia.

Postharvest losses refer to measurable quantity and quality loss at harvest, storage, transportation, processing, marketing and preparation before consumption (Buzby *et al.*, 2014). It occurs throughout the value chain, as a result of technical and managerial setbacks during all these steps. Several postharvest technologies have been developed to improve quality, shelf life and reduce postharvest losses on fruits and vegetable. Adoption of postharvest technologies viz., Precooling immediately after harvest, sanitization, surface treatments, proper packaging etc are important steps to reduce fruits and vegetable losses. Hence instead of storing the commodities to the chamber directly inside the chamber immediately after harvest, the commodities would have to be immediately subjected to proper postharvest management practices before storing inside the chamber to get an additional shelf life. Islam and Morimoto (2012) reported that a combination of lower temperature and higher humidity inside the cool chamber, along with hot water treatment and the use of a silver-coated storage container could prevent the decay of tomato and egg-plant, while increasing the shelf life of tomato and egg-plant. Hot water treatment could be used as a disinfectant for tomatoes prior to storage at ZECC in order to reduce decay and microbial growth. Storage under these conditions could extend the shelf-life and preserve the quality of tomatoes harvested at almost full maturity. Application of CaCl2 1.5% and ZECC is considered as an ideal on-farm storage facility for maintaining the quality of Ber fruits (Singh *et al.*, 2010b) and Indian gooseberry (Singh *et al.*, 2010a) under Semi-arid environment of Western India.

The PZECC, designed for the Rural North India which was utilized for the present study as such without any modification cannot be recommended as an efficient on farm storage structure for Kerala. It has to be suitably modified for tropical humid climate and proper post harvest management practices are to be adopted before storing a commodity in the storage structure, so that it would be a satisfactory option for temporary storage of perishable commodities awaiting marketing and short term maintenance of quality horticultural perishables during glut period, reducing the wastage of perishable commodities and thus providing remunerative prices to growers.

Summary

6. SUMMARY

The present investigation entitled "Feasibility of Pusa Zero Energy Cool Chamber as low cost on-farm storage structure under Kerala condition" was conducted at Department of Post Harvest Technology, Kerala Agricultural University, College of Agriculture, Vellayani, Thiruvananthapuram, during the year 2017-2019 with the objective to evaluate the feasibility of Pusa Zero Energy Cool Chamber as a low cost on-farm storage structure for horticultural perishables during different seasons under humid tropical climate of Kerala. The major findings are summarized as follows.

Six different fruits and vegetables, viz., papaya, snake gourd, cucumber, bitter gourd, amaranth and cowpea were stored in perforated plastic crates immediately after harvest under Pusa zero energy cool chambers (PZECC) during three seasons viz., June – September, October - February and March – May by maintaining 85-95% relative humidity inside the chamber with same set of commodities kept under ambient storage conditions as control. The study was conducted as six separate experiments for different commodities and possibility of storage of each commodity during different seasons was assessed based on physical, physiological, chemical and sensory quality parameters.

Papaya, snake gourd and bitter gourd stored in PZECC during March- May and October- February had high shelf life, marketability and colour, where as cucumber had high shelf life and marketability when stored in PZECC only during March - May. Though the treatment combinations had no significant effect, amaranth and cowpea kept inside the PZECC had high shelf life, marketability and colour with low physiological loss in weight.

The enhanced shelf lives were 1.55 and 1.66 days for papaya, 0.89 and 0.66 days for bitter gourd and 0.78 and 1.55 days for cucumber when kept in ZECC during Oct- Feb and March- May respectively compared to their corresponding ambient storage. Amaranth had two days additional shelf life when kept under ZECC indicating that only marginal increase in shelf life could be received under tropical humid climatic condition, that too only during March- May and October- February period.

Papaya, bitter gourd, cucumber & snake gourd had least shelf life when stored in PZECC during June- September. Storage under the chamber during June – September had resulted in poor colour development in bitter gourd and snake gourd, poor texture in snake gourd and lowest marketability in cucumber. Quality of commodities was better under ambient storage conditions during rainy season. High humidity together with the very low temperature inside the PZECC resulted in rotting and rapid spoilage of the commodity compared to ambient storage.

The chemical constituents which are present in each commodity were analyzed during the storage period. Papaya, the only fruit used in the experiment had lower Total Soluble Solids (13.060 Brix) when stored in PZECC.

But majority of the nutritional parameters of vegetables, which are used under the present experiment were unaffected by the storage conditions. Carotene content in snake gourd and cowpea, vitamin C of bitter gourd, cucumber and cowpea and oxalate content in amaranth were not influenced by the treatments under our study.

The season had significantly influenced majority of the quality parameters of commodities under study. Maximum Total soluble solids, total sugar, total carotene content and least titrable acidity in papaya fruits, least oxalate content in amaranth and highest total carotene content in cowpea were reported when stored during March-May.

Total carotene content of snake gourd and bitter gourd or vitamin C content of cucumbers and bitter gourd were not influenced by season.

Papaya, Amaranth and cowpea had highest vitamin C content when stored during October-February. Amaranth stored during October-February had higher total carotene content.

Texture, a major quality parameter influencing marketability and acceptability of any horticultural produce was measured in terms of bio-yield point and flesh firmness. Different commodities responded differently when texture during storage under two different conditions was analyzed. Papaya, Bitter gourd and cowpea stored under PZECC had better texture as indicated by higher bio yield point and flesh firmness. Snake gourd and cucumbers stored under the ambient condition had better flesh firmness. But storage conditions individually had no significant effect on textural parameters of amaranth.

Papaya and cucumbers stored under PZECC during March-May had highest bio-yield point and flesh firmness, where as snake gourd stored under PZECC during October-February had highest textural quality parameters. Cucumbers and amaranth stored under ambient condition during June-September had better textural parameters.

The sensory attributes of commodities were not superior or inferior throughout the same storage condition or season. It varied from commodity to commodity. All the sensory parameters were affected by the treatments in cucumber, amaranth, and cowpea. Appearance and colour of cucumber were higher when stored under PZECC during March-May and June-September respectively. Taste and flavor score were higher when stored under ambient condition during June-September. Appearance and colour scores were highest for amaranth stored under PZECC during June-September whereas texture score was highest when stored under ambient condition. Taste and flavor scores for amaranth for amaranth were highest when stored under PZECC during March-May. In cowpea, appearance, texture, taste and flavor scores were highest when stored under PZECC during June-September and colour during March-May.

In other commodities, majority of the sensory parameters were not influenced by season and storage conditions. Mean organoleptic scores for appearance and colour were higher for papaya fruits stored under PZECC during October-February whereas texture, taste, and flavor of papaya fruits were not affected by the treatments. Colour and flavor scores of snake gourd were highest for snake gourds stored under PZECC during March-May. But appearance, texture and taste of stored snake gourd were not influenced by the treatments. Mean scores obtained for texture and taste were highest for bitter gourds stored under PZECC during October-February. There was no significant effect of seasons and storage conditions on appearance, colour and flavor of stored bitter gourd.

Microbial load of papaya and snake gourd, cowpea, amaranth were not affected by the treatments; But bacterial load in bitter gourd and fungal load in cucumber were high when stored under PZECC during June – September. Fungal load was least for cucumbers kept in ambient condition during March-May which was on par with those stored under PZECC during same season and cucumbers stored during October-February irrespective of storage conditions. All the bitter gourd fruits stored under October-February and March-May had least bacterial load irrespective of storage condition.

The study clearly showed that PZECC is a low cost on-farm storage structure which could be constructed at a cost of Rs.5000/- per unit. But the structure helps in marginal enhancement in shelf life of horticultural perishables that too only during March- May and October- February. The structure was not at all suitable during the rainy season (June-September) and the commodities had better physiological parameters and shelf life in rainy season under ambient condition compared to storage under PZECC.

The evaporative cooler is an effective device under such areas in minimizing the extremes of temperature and RH. When the air temperature outside the chamber is at the highest point, while the relative humidity was the lowest point, it results in a higher cooling capacity. But in a tropical humid climate of Kerala, the enhanced humidity will only help to damage the commodities. When the air is totally saturated with water, no evaporation can take place and no cooling occurs. The design used in the present study was the one developed at Pusa, New Delhi which was specifically designed for places of high temperature and low humidity. The result of the present study showed the necessity to modify the design of PZECC for increasing the efficiency of the chamber suited for tropical humid climates.

Adoption of postharvest technologies viz., Precooling immediately after harvest, sanitization, surface treatments, proper packaging etc are important steps to reduce fruits and vegetable losses. Hence instead of storing the commodities to the chamber directly inside the chamber immediately after harvest, the commodities are to be immediately subjected to postharvest management practices including proper packaging before storing inside the chamber to get an additional shelf life.

The PZECC, designed for the Rural North India which was utilized for the present study as such without any modification cannot be recommended as an efficient on farm storage structure for Kerala. It has to be suitably modified for tropical humid climate and proper post harvest management practices are to be adopted before storing a commodity in the storage structure, so that it would be a satisfactory option for temporary storage of perishable commodities awaiting marketing and short term maintenance of quality horticultural perishables during glut period, reducing the wastage of perishable commodities and thus providing remunerative prices to the growers.

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Appendices

APPENDIX I

KERALA AGRICULTURAL UNIVERSITY
COLLEGE OF AGRICULTURE, VELLAYANI
Department of Post Harvest Technology

Title: Feasibility of Pusa Zero Energy Cool Chamber as low cost on-farm storage structure under Kerala condition.

Score card for assessing the organoleptic qualities for cucumber

Sample: Cucumber (sambar vellari)

Instructions: You are given 6 sambar vellari samples along with partially cooked samples. Evaluate them and give scores for each criterion. (*NB:Taste must be evaluated on the basis of cooked sample. Colour based on colour chart given below)*

Criteria	Samples					
	1	2	3	4	5	6
Colour						
Flavour						
Texture(Hard/firm/soft)						
Taste						
Overall acceptability						
Any other remarks						

SCORE

Like extremely	- 9
Like very much	- 8
Like moderately	- 7
Like slightly	- 6
Neither like nor dislike	- 5
Dislike slightly	- 4
Dislike moderately	- 3
Dislike very much	- 2
Dislike extremely	- 1

Date:

Name :
Signature:

APPENDIX II

WEATHRERDATA RECORDED DURING THE STUDY

Season	Temperature (^{0}C)		RH (%)		Total rainfall (mm)	Wind vel. (km/h)
	Max	Min	Max	min		
S_1 (June-September)	33.42	24.06	90.57	79.17	993.70	7.87
S_2(October-February)	32.10	23.33	97.38	71.88	572.90	6.29
S_3 (March-May)	33.40	25.33	89.19	75.27	349.10	4.91

Abstract

FEASIBILITY OF PUSA ZERO ENERGY COOL CHAMBER AS LOW COST ON-FARM STORAGE STRUCTURE UNDER KERALA CONDITION

By

LEKSHMI S.G.

(2017-12-015)

ABSTRACT

of the thesis submitted in partial fulfilment of the requirements for the degree of

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Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF POST HARVEST TECHNOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM- 695 522

KERALA, INDIA

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ABSTRACT

The experiment entitled "Feasibility of Pusa Zero Energy Cool Chamber as low cost on-farm storage structure under Kerala condition" was undertaken at Department of Post Harvest Technology from 2017-2019 with the objective to evaluate the feasibility of Pusa Zero Energy Cool Chamber as a low cost on-farm storage structure for horticultural perishables during different seasons under humid tropical climate of Kerala.

Six different fruits and vegetables, viz., papaya, snake gourd, cucumber, bitter gourd, amaranth and cowpea were stored in perforated plastic crates under Pusa zero energy cool chambers (PZECC) each of 165cm length, 115 cm breadth and 75 cm height during three seasons viz., June - September, October - February and March – May by maintaining 85-95% relative humidity inside the chamber with same set of commodities kept under ambient storage conditions as control. The study was conducted as six separate experiments for different commodities and possibility of storage of each commodity during different seasons was assessed based on physical, physiological, chemical and sensory quality parameters.

Papaya, snake gourd and bitter gourd stored in PZECC during March- May and October- February had high shelf life, marketability and colour, where as cucumber had high shelf life and marketability when stored in PZECC only during March - May. Though the treatment combinations had no significant effect, amaranth and cowpea kept inside the PZECC had high shelf life, marketability and colour with low physiological loss in weight. The enhanced shelf life received for papaya fruits kept in ZECC was only 1.55 and 1.66 days during Oct- Feb and March- May respectively compared to their corresponding ambient storage, where as it was 0.89 and 0.66 days for bitter gourd and 0.78 and 1.55 days for cucumber. Amaranth had two days additional shelf life when kept under PZECC.

Papaya, bitter gourd, cucumber and snake gourd had least shelf life when stored in PZECC during June- September. Storage under the chamber during June – September had resulted in poor colour development in bitter gourd and snake gourd, poor texture in snake gourd and lowest marketability in cucumber.

All the sensory parameters were affected by the treatments in cucumber, amaranth, and cowpea. In other commodities, majority of the sensory parameters were not influenced by season and storage conditions

Microbial load of papaya and snake gourd, cowpea, amaranth were not affected by the treatments; But bacterial load in bitter gourd and fungal load in cucumber were high when stored under PZECC during June – September.

Carotene content in snake gourd and cowpea, vitamin C of bitter gourd, cucumber and cowpea and oxalate content in amaranth were not influenced by the treatments indicating that majority of the nutritional parameters were unaffected by storage conditions.

PZECC is a low cost on-farm storage structure which could be constructed at a cost of Rs.5000/- per unit. But the structure helped only in marginal enhancement in shelf life of horticultural perishables that too only during March- May and October-February and was not at all suitable during the rainy season (June-September).

The result of the present study showed that the PZECC, designed for the Rural North India as such cannot be recommended as an efficient on farm storage structure for Kerala. It has to be suitably modified for tropical humid climate and proper post harvest management practices are to be adopted before storing a commodity in the storage structure, so that it would be a better option for temporary storage of commodities awaiting marketing and short term maintenance of quality horticultural perishables, reducing the wastage of perishable commodities.