STORAGE EFFICIENCY OF ZERO ENERGY COOL CHAMBER UNDER LOCAL CONDITIONS

by

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1998

DECLARATION

I hereby declare that the thesis entitled "**STORAGE EFFICIENCY OF ZERO ENERGY COOL CHAMBER UNDER LOCAL CONDITIONS**" is a bonafide record of research and that the thesis has not previously found the basis for the award of any degree, diploma, associateship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "**STORAGE EFFICIENCY OF ZERO ENERGY COOL CHAMBER UNDER LOCAL CONDITIONS**" is a record of research work done independently by **Ms. ANJANA. V.**, 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.

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DEDICATED TO MY

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INTRODUCTION

INTRODUCTION

Modern living has brought about little change in the food preferences of our people, but there has been a significant change in the availability of various foods including vegetables. Vegetables play an important role in human nutrition. Today, people consume more vegetables than ever before waranting for their preservation for longer period.

According to FAO production estimates India is second largest producer of vegetables after China with an estimated annual production of 50 million tonnes. But there is diversified demand for vegetables due to the increase in the population of our country. However the agroclimatic conditions and soil types of India are suitable for growing all types of vegetables. But they pose unique set of problems compared to other perishable or semiperishable commodities. Vegetables remain active in their post-harvest phase and carry out all the vital physiological and metabolic processes. Significant losses occur during post-harvest handling due to improper storage and marketing methods followed in developing countries. The net post-harvest loss for vegetables is estimated to be around 20 to 40 per cent in our country.

It has been established that post-harvest loss reduction is cheaper than an equivalent increase in food production. Unfortunately in India post-harvest management of fruits and vegetables is being inadequately dealt with. As a result a huge amount of the highly nutritious fruits and vegetables produced are being wasted. These losses result in a national loss of Rs.5000 crores per annum. It also accounts to poor return to growers and high cost of materials affecting the consumers. Therefore it is necessary to lay great emphasis on an integrated approach to post-harvest management of vegetables. Nayital (1993) opined that proper storage of what has already been produced is of prime importance and assumes considerable economic and social importance for a country like India.

Under common storage methods, vegetables lose their appearance and market value due to ageing and loss in weight and moisture. Khurdiya (1985) reports that the shelf life of vegetables depend upon type of storage, temperature and humidity. Lowering temperature of storage atmosphere is known to extend shelf life of fruits and vegetables.

One of the common methods to prevent storage losses of vegetables is refrigeration. Here temperature ranges from 0-13°C (quality control in fruit and vegetable processing 1988). But cold storage facilities are costly and not get commonly available in our country.

According to Sethi and Maini (1989) a fair portion of fruit and vegetable at present going waste can be easily salvaged to up grade our nutritional standard and ensure more remunerative returns to growers and reasonable price to consumers by adopting some of the simple low-cost energy techniques for management of fresh fruit and vegetable marketing in India.

In hot and dry weather prevailing over much of India for a significant period of the year, the use of low cost evaporative coolers are found to be useful in short term storage of fruits and vegetables. Evaporative cooling method is considered as one of the best and cheapest method of storage. It doesn't involve any conventional energy sources or power. Habibunsia (1995) had the opinion that the evaporative cool storage is a better alternative to refrigerated storage which doesn't involve heavy capital investment.

Zero Energy Cool Chamber standardised at IARI, New Delhi is a storage device based on the principle of evaporative cooling. It is reported to enhance shelf life of fruits and vegetables by lowering down the temperature and maintaining high humidity inside the chamber. It can be installed any where even by an unskilled person as it does not require any specialised skill. However no work has been done on the efficiency of this simple and cheap storage structure, under the high temperature and humidity conditions of Kerala. Details regarding the feasibility of this device in our situation for enhancing storability and maintaining post harvest quality of vegetables is required in order to popularise this simple and low cost technology for short term storage of fruits and vegetables. Thus to fill this gap a study was undertaken to generate data pertaining to the efficiency of zero energy cool chamber under local atmospheric conditions and to make suitable recommendations. The storability of vegetables in zero energy cool chamber based on physiological, chemical and organoleptic changes in comparison with traditional as well as innovative method have been attempted in this investigation. Transmission of the technology among vegetable growers was also aimed at this study.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Fresh vegetables are highly perishable commodities. The post-harvest life of harvested vegetable extent from few hours to few days. Within this short span of time 20-40 per cent of the produce is spoiled due to inadequate post harvest operations. This loss can be minimised by proper storage, packaging and transportation methods. A review of literature on the related works done in different places is presented under the following titles.

2.1 Nutritional and commercial significance of vegetables

2.2 Importance of proper storage of vegetables

2.3 Shelf life of fresh vegetables

2.4 Methods adopted for storing vegetables

2.5 Pre treatments for storage of fresh vegetables

2.6 Effect of different storage methods on the quality of vegetables

2.1 Nutritional and commercial significance of vegetables

The nutritional and commercial significance of vegetables in our country for improving health and wealth of the community have been reported by many workers.

2.1.1 Nutritional significance of vegetables

Tindall (1980) detected high ascorbic acid and iron content in bittergourd. Stancu *et al*. (1980) claimed that egg-plants compare well with other vegetables for most of the nutrients except vitamin C. Kumar *et al*. (1983) judged carrot as a rich source of vitamins and minerals. Nath *et al*. (1987) observed vegetables as a good source of proteins, carbohydrates, minerals, vitamins and roughage which constitute the essentials of a balanced diet.

Sesadri (1989) considered vegetables as a rich source of crude fibre which not only helps in bowel movement but also beneficial in reducing absorption of antinutritious factors and reducing incidence of ulcer, cancer and cardio vascular diseases. Shanmughavelu (1989) defines vegetables as "protective supplementary foods" since they contain large quantities of minerals, vitamins and essential amino acids which are required for normal functioning of human metabolic process.

Percapita availability of fruits and vegetables came up to 150 g/day although percapita requirement of 230 g/day is recommended by ICMR expert group. Sethi (1987) emphasized that at least two fold increase in percapita availability is essential to balance our diet.

Beegum (1991) ascertained the vegetables as a good source of water and minerals which enables the body to maintain acid-base balance. Swaminathan (1993) detected green leafy vegetables as a rich source of carotene, ascorbic acid and calcium. He also pointed out beans and peas as good source of proteins.

2.1.2 Commercial significance of vegetables

Shanmughavelu (1989) considered vegetabes as an asset providing a good source of income to growers. The author also emphasize its role in Indian economy by earning Rs.2 to 4 crores as foreign exchange by export of raw as well as processed products. According to FAO estimates (1985) the world production of vegetable was 402 million metric tonnes.

Wills *et al*. (1981) emphasize the fact that vegetables are vital for increasing the income of farmers and generating employment in rural areas. Habibunsia (1995) estimated 90 million tonnes of fruits and vegetable production in India. With an annual production of around 100 million tonnes, fruits and vegetables earn 20 to 30 times more foreign exchange as claimed by Kanchana (1995). India is the second largest producer of fruits and vegetables with 8.6 per cent and 11.5 per cent of global out put as estimated by Mohandas (1995). Studies conducted by Rao (1995) revealed that our country produces about 48 million tonnes of vegetables.

An estimate by Rajkumar (1995) reveals that during the closing year of last decade, India exported 42,000 tonnes of fresh vegetables. He also pointed out that inspite of high level of production the lack of post-harvest technology and linkages result in a national loss of Rs.5000 crore per year. Thyagi (1995) has opined that horticulture crops cover about 6.8 per cent of the area and contributed 18 per cent of India's gross agricultural output. Horticultural crops are high value crops with potential for both export and value addition through food processing as revealed by Vineetha and Latha (1995). Sethi (1996) proclaimed that India is the second largest producer of vegetables in the world after China with an estimated annual production of 66.58 million metric tonnes.

2.2 Importance of proper storage

Woodroof (1975) opined that seasonal restriction on fixed plant capacities have necessitated controls on raw product delivery during peak seasons and properly storing them for off seasons. Maini (1983) emphasise the need for proper storage of vegetables when there is a surplus quantity and low price in the market.

Bourne (1986) classifies the causes of post-harvest losses of perishable crops in developing countries as primary causes due to pre-harvest and harvesting factors and secondary losses due to poor and inadequate storage and transportation facilities. Hardenburg (1986) believed that appropriate storage can minimise wilting, regrowth, ripening, senscence and decay. Benwart (1987) pointed out that fruits and vegetables are perishable commodities and need special storage treatment to prevent lossess. Sethi (1987) had the opinion that being perishable and living commodities there is 20 to 40 per cent losses in horticultural commodities due to improper handling, transportation and storage methods. Sethi (1989) recommended some of simple and low cost storage techniques by which a fair portion of vegetable and fruits at present going waste can be easily salvaged to upgrade our nutritional standard and ensure remunerative returns to growers.

Jeffries and Jeger (1990) found that in developing countries, due to lack of sophisticated storage facilities there occur a loss of 10 to 50 per cent during the post-harvest period. Williams *et al.* (1991) indicated that vegetable quality is an unstable character which can be maintained over a period of time. He also says that such maintenance will benefit everyone in the production - consumption chain. Madan and His co-workers (1993) had the opinion that the practices carrently in use in post harvest handling and facilities used for storage, packaging and transport are out dated and contribute directly to post-harvest loss.

Roy (1993) proclaimed that one of the reasons for the post-harvest losses of fruits and vegetables is lack of proper storage facilities. Sethi (1996) reports that the post-harvest losses of vegetables can be reduced to some extent by using appropriate storage techniques.

2.3 Shelf life of fresh vegetables

According to Choudhary (1968) the harvested brinjal can be kept for 7 to 10 days in good condition at 10°F to 13°F and 85 to 90 per cent relative humidity. Studies conducted by Erheart (1971) revealed that broccoli held at 35°F had a shelf life of 2 to 4 days. Exposure of mature green tomatoes to ethylene absorbaents at 20°C has been reported to extend the storage life up to a maximum of 20 days (Ogura *et al*. 1975). Stewart (1979) found that musk melon can be stored up to 14 days in 20 per cent CO_2 and 21 per cent O_2 at 5°F and 3 days in air at 20°F. Bhatnagar and Singh (1982) also conducted storage studies on musk melon at room temperature and found to be keeping well up to 8 days. According to Reyall and Lipton (1979) broccali held at 2.5°C was in good condition after 3 weeks of storage.

Extensive trials conducted by Philippon *et al*. (1986) on green beans frozen (-8°C to -3°C) without blanching and then stored at 25°C retained acceptable sensory qualities for 6 months.

Singh *et al.* (1980) and Kalra *et al.* (1988) found that okra has a shelf life of 2 to 3 days in ambient conditions. It can be extended up to 7 to 8 days at room temperature by pre-packing in unventilated 100 guage polyethylene bag and extend up to 16 to 18 days by storing in low temperature (50 to 52°F and 85-90 per cent RH). Thangaraj and Irulappa (1988) suggested a highest storage period of 95 days when waxing, hot water treatment and cool chamber storage was done in combination for storage of mango. Pantastico (1990) studied the optimum temperature and relative humidity for different vegetables in attaining maximum shelf life. The results were as follows

	Temperature	Relative humidity (%)	Shelf life
Bittergourd	0.6 - 1.7°C	85-90	4 weeks
Lettuce	0.6 - 1.7°C	95	3-6 days
Okra	8.9°C	90	2 weeks

Studies conducted by Pathmanabhan and Nagarjun (1992) revealed that mature sapota fruits stored in polyethylene bag placed perferated plastic vial containing 10g $CaCl_2$ per kg of fruits had a storage life up to 12 days while it was 3 to 4 day at ambient conditions. The brine treated and irradiated carrot could be preserved up to 60 days at optimum salt and irradiation levels as advocated by Hasan (1993).

2.4 Methods adopted for storing vegetables

Ramana *et al.* (1981) classifies storage methods currently used as

i) Storage under ambient conditions
ii) Evaporative cool storage
iii) Low temperature storage
iv) Controlled or modified atmosphere storage
v) Hypobaric or low pressure storage
vi) Storage after irradiation

2.4.1 Storage under ambient condition

Dalal *et al.* (1971) suggested the application of vegetable wax emulsions viz. Waxol-W and Waxol-O on fresh fruits and vegetables for storage at ambient conditions extended their shelf life by at least 50 per cent to 100 per cent without affecting their quality. Ryall and Pentzer (1974) opined that in developing countries where refrigeration facilities are absent or restricted, fungicidal wax treatments have a great importance in extending the storage life of fruits and vegetables. Another method recommended by Salunkhe and Desai (1984) for extending storage life is by coating with a material containing a mixture of sucrose esters of fatty acids and polysaccharide. According to Waks (1985) waxing is very useful in reducing mold rots.

2.4.2 Evaporative cool storage

Theoretically the lowest temperature that can be reached within a chamber, by the evaporation of water is the wet bulb temperature as detected by Hall (1975). Maini (1983) found that the storage life of fresh vegetable is considerably increased by keeping them in evaporative cool chamber immediately after harvest. Evaporative cool storage is widely used for storage of fruits and vegetables (Roy 1985).

Sethi (1987) found that evaporative cool storage is very usefull in the storage of vegetables during the hot and dry weather prevailing over much of India for a significant part of the year. Thangaraj and Irulappa (1988) ascertained that low cost storage structure such as zero energy cool chamber is very useful for the storage of fruits and vegetables. Saibaba (1990) also recommend zero energy cool chamber from readily available materials for short term storage of vegetables. Sethi (1996) recommend the use of low cost low energy and simple viable technologies such as evaporative cool storage for shoot term storage of fruits and vegetables after harvest. Kaul (1987) obtained satisfactory results using an evaporatively cooled structure which maintains the temperature at 2 to 4°C and relative humidity of 95 per cent when potato tubers were stored for 12 weeks with less physiological losses.

Studies conducted by Thangaraj and Irulappa (1988) recorded a highest storage period of 95 days when waxing hot water treatment and zero energy cool chamber storage was done in combination for the storage of mango.

Studies conducted by Habibunsia (1995) on Alphanso and Totapuri mangoes showed a shelf life of 17 days in evaporative cool chamber with 4.2 per cent PLW and 82 per cent marketability against ten days with 9 per cent PLW and 82 per cent marketability of fruits at room temperature. Sathish *et al.* (1993) conducted storage studies on tomatoes revealed that the control tomatoes at 27°C and relative humidity 65 per cent spoiled after 15 days. The tomatoes which were kept in low cost self cooling storage based on evaporative cooling was in good condition upto 35 days. Baviskar (1995) reports that shelf life of ber fruits could be extended upto 10 days in zero energy cool chamber whereas shelf life was 6 days at room temperature.

2.4.3 Low-temperature storage

Woolrich (1965) recommends refrigeration as the most widely used method of short term preservation for a variety of foods. Pantastico *et al.* (1975) found that most of tropical fruits and vegetables develop chilling injury due to their sensitivity to low temperature. Ryall and Lipton (1979) suggest refrigeration as the primery means of maintaining broccoli quality and reducing the rate of senscence. Studies conducted by Belin Roth (1986) on different vegetables found that packaging in polythene bag and kept under refrigerated storage enhanced the storage life. Bhobe and Pai (1986) reported that the quality of frozen vegetables can be remained constant for a long period of time. Quality control agency for fruits and vegetable processing (1988) recommends refrigeration as the common method to reduce temperature of vegetable tissue and the temperature ranges from 0 to 13°C depending on variety, perishability, relative humidity and climate. Vaccum cooling of fresh fruits and vegetables is outlined by Galan (1993) as a new technology for refrigeration.

Reports published by International Fruit World (1993) reveals that after harvesting, respiration and other metabolic activities increase which can be governed by decreasing the temperature and thus the storage life increases. Om praksh (1995) has the opinion that refrigeration inhibits chemical changes thus preserving its natural characteristics and also reducing microbial spoilage.

2.4.4 Controlled or Modified Atmospheric (CA) storage

CA storage is a system for holding produce in an atmosphere that differs substantially from normal air in respect to the proportion of N_2, O_2 or CO_2 (Lipton, 1968).

Ryall and Lipton (1979) suggest CA storage as a system for holding fresh fruits and vegetables in an atmosphere that differs substantially from normal air.

Studies conducted by Aharony *et al*. (1983) revealed that the fruits stored in CA storage + ethylene absorbent were firm and exhibited less decay than fruits in CA storage only. Works done at CFTRI has shown that exposure of banana bunches (Ramana *et al*. 1983), carrot (Aida, 1983) and green chillies (Selvaraj, 1987) to MA storage extended their shelf life significantly.

Alvarez and Gareia (1990) revealed that fresh fruits and vegetables can be stored using reactive absorbants to oxidise CO_2 and ethylene generated by the produce. Studies conducted by Bowmik and Pan (1992) found that green tomatoes stored under CA storage had a storage life of 8 weeks. The result of storage study on shredded cabbage conducted by Kaj and Ueno (1993) showed that it could be kept in good condition at high O_2 (5 to 10 per cent) and high CO_2 (5 to 15 per cent) atmosphere. CA storage can be used to overcome the shelf life problem of tropical fruits and vegetables as elicited by Omprakash (1995).

2.4.5 Hypobaric or low pressure storage

Lougheed *et al*. (1983) observed that a produce at a pressure of less than 1/10th of normal atmosphere pressure, increases the shelf life. Salunkhe and Wu (1985) found 20 to 90 per cent increase in shelf life of fruits and vegetables stored in hypobaric storage. At the same time Sommer (1985) opined that the apparatus is costly and the technique has been applied on a very limited scale.

Irving (1988) has reported that reduction in oxygen concentration can be achieved by reducing the total pressure surrounding the produce. According to Burg (1988) commercial application of low pressure storage is yet to be undertaken.

2.4.6 Irradiation

Key (1973) suggested irradiation treatment on tubers before storage to inhibit sprout growth.

Salunkhe and Desai (1984) opined that irradiation technique is useful to disinfect the commodity and extend storage life but the capital cost is very high and over dose will cause harmful effect on quality. Lu *et al*. (1989) noticed an increase in nutrient content of stored sweet potato as a result of irradiation treatment.

Thomas (1994) recommends certain optimum dosage for improving the keeping quality of different vegetables. Omprakash (1995) pointed out that irradiation is a cold process, which unlike chemical treatment, leave no residue in addition to keeping the environment clean.

2.4.7 Indigenous methods of storage

Devadas (1965) reported covering amaranthus with moist cloth as an effective storage method. She also recommends janatha refrigerator as household method for storing vegetables. According to Thampan (1979) cassava tubers could be kept for four days in moist sawdust filled boxes.

Phandins and Annapoorna (1980) studied the effect of house hold storage methods such as covering with moist cloth, open storage and janatha refrigerator and the results indicated that janatha refrigerator as the best method of storage for green vegetables. Padmaja and Rajamma (1982) found that dry saw dust was unable to prevent dehydration of sweet potato beyond one month of storage.

Mud coating of tubers is one of the most economic method for increasing shelf life (Balagopal and Murthy 1984).

Cohen and Hicks (1985) opined that storing vegetables under shade by misting with fine spray is of great help in maintaining freshness of green vegetables. Dayal *et al*. (1990) reported better results in sweet potato stored under sand compared to those kept is ambient conditions. Moist sand can be used to store both cassava and sweet potato for about 3 to 4 months (Anon., 1991).

2.5 Pre-treatments for storage of vegetables

2.5.1 Pre-cooling:

Verbeck (1986) revealed that pre-cooling of vegetables prior to storage will reduce the weight loss. While

Hackert *et al*. (1987) observed no significant difference among pre-cooling treatment on weight loss in broccoli. Studies conducted by Gareepy *et al*. (1991) observed that pre-cooling the asparagas spears prior to storage reduced the losses by more than 20 per cent. According to Prit chand *et al*. (1992) the spread of cottony soft rot in stored carrots could be controlled most effectively by pre-cooling the produce immediately after harvest.

2.5.2 Packaging

Swami and Iyenkar (1961) conducted studies on prepackaged beans in different gauges of poly ethylene film bags with and without vents and have reported that 1.17 per cent of aeration at 47 to 50°F and 80 to 85 per cent relative humidity increased the storage period of green beans from 8 days to 15 days.

Maaker (1986) studied the effect of perforations in polymeric films on weight loss and observed that it had a direct influence on weight loss. Wills *et al*. (1989) reviewed that packaging not only provides convenient units for marketing and distribution but also protects the fruits and vegetables from damage.

Risse (1989) observed that film wrapping of vegetables retarded weight loss, colour development, chilling injury and maintained the firmness and internal quality.

Khan *et al*. (1990) has the opinion that poly ethylene bags could be advantageously used for convenient handling, storage and in retaining the produce in good condition for a considerable long period. Usefulness of polypropylene films in packaging of fresh produce was revealed by Chowdhary (1990).

Rao (1993) opined that the shelf life of vegetables could be greately enhanced if packaging is combined with low temperature storage. Roy and Pal (1993) reviewed that use at plastics in packaging help in minimising the cost and increasing the shelf life.

2.5.3 Chemical sprays

According to Brown (1972) thiobenzol is being more extensively applied by approximately 70 per cent of the commercial packing houses of Florida. Hermendez (1973) reported that treatment of green plantain with 2000 PPM of thiobendzol suscessfully prolonged the storage life. The produce was stored in sealed polyethylene bag.

Salunkhe *et al*. (1975) has the opinion that sprouting of potato and onion during storage can be prevented by pre-treating them with chemicals such as methyl naphthalene acetic acid and maleic hydroxide. Eckert (1984) reports that chemical treatments have been commercially employed for important fruits like banana, citrus and grapes for controlling their post-harvest losses. Salunkhe and Desai (1984) recommends a wide range of chemicals to control post harvest losses of fruits. These chemicals include chlorine, SO_2, borax, sodium carbonate and captan. Rama and Narasimha (1985) revealed that chemical treatments were effective to prevent storage sprouting of potato upto 60th and 75th day of harvest. Use of gibberellic acid as antisenescent regulator and some fungicides to reduce decay loss and enhance shelf life have been reported by Abdelkader (1965) and Jitender kumar *et al*. (1987).

Pal *et al*. (1991) have investigated that the shelf life of carrot was extended for 5 days at room temperature to 33 days in zero energy cool chamber on application of 1500 ppm. MH as preharvest spray coupled with 100 ppm chlorine as prestorage treatment without much alteration in chemical composition. The least physiological loss in weight, maximum freshness and firmness of carrot were observed in MH treated carrot coupled with 100 ppm chlorine as prestorage treatment and when stored in the zero energy cool chamber after 33 days of storage.

Studies conducted by Nath *et al*. (1992) on fruits dipped in calcium nitrate (1 per cent), GA_3 (50 ppm), CCC (500 ppm) and Borax (4 per cent) packed in perforated polythene bags and stored at ambient temperature showed calcium nitrate (1 per cent) as the best treatment to minimize the weight loss of fruits.

5.4 Wax coating

Bose and Basu (1954) have investigated the possibility of extending the storage life of fresh mangoes by paraffin coating by dipping the fruits at 80°C to 10 seconds in 50 per cent concentration of wax. The wax coating restricted the respiration and resulted in preserving the fruits for 45 days as against 14 days with the untreated mangoes. The optimum conditions specified by the authors for storage of mangoes were 12 to 18°C and 90 per cent relative humidity.

Morales and Zomelin (1974) have investigated the possibility of extending preservative life of fresh orange, lemons, grape fruits, tangerines and mangoes by wax coating. The experimental wax coating extended the shelf life of lemon by a period extending ten weeks and oranges by eight weeks when stored at 10°C and 75 to 80 per cent relative humidity.

Studies conducted on ber fruits kept in perforated polythene bags as such and also after treatment with two types of wax emulsion. Both the wax treatments were found to be effective in reducing PLW and spoilage (Jawenda *et al*. 1980). Dalal *et al*. (1970) reported better organoleptic retention of waxed fruits.

Garg and Ram (1972) reported that the wax coating helped to check the transpiration and respiration rates in fruits resulting in the reduction of losses in fruit weight during storage. According to Bal *et al*. (1978) wax treatment did not affect the retention of ascorbic acid. Studies on kinnow fruits have also showed similar results (Mann and Randhawa, 1978).

2.6 Effect of different storage methods on the quality of vegetables

Studies conducted by Tressler and Evers (1957) revealed that the quality factors have been protected if proper storage conditions were maintained. The effect of storage on different quality parameters of vegetable have been studied by many workers.

2.6.1 Chemical qualities

Ingalls *et al*. (1950) found that riboflavin in vegetables is relatively stable during the entire storage period. Studies conducted by Srivastava *et al*. (1962) in tomatoes revealed that pre-cooling followed by refrigerated storage helps in better retention of moisture and ascorbic acid and more uniform development of colour.

Pushpamma and Joshi (1970) observed a maximum loss of ascorbic acid during open storage and minimum in freezing.

Devadas (1965) studied ascorbic acid retention during different storage methods. The average losses under home conditions reported was a) Refrigeration - 8 per cent b) Janata

Refrigerator - 16.1 per cent c) Moist cloth 22.9 per cent and d) Polythene basket - 40 per cent. Studies conducted by Smith (1967) revealed that the ascorbic acid content of tubers decreases during storage.

Erheart (1971) revealed that vegetables held at 35°F for 2 to 4 days showed reduction in ascorbic acid than that not stored and the chlorophyl was little effected by storage. Hameed *et al*. (1980) observed that low temperature storage brings about decrease in starch and increase in sugar content of cassava. Sundaresan *et al*. (1990) recorded a starch reduction from 59.4 to 49 per cent and 10 per cent moisture loss by 120 days storage of yams.

Chikkasubbana *et al*. (1991) proclaimed that packaging of lettuce head in perforated polyethylene bags will reduce assorbic acid content. Peory and Kelin (1992) observed that ascorbic acid in beans decreases during refrigerated storage. The author also found that B-carotene of beans and broccoli observed no change during frozen storage from that of fresh. Study conducted by Joshi and Khandekar (1993) revealed that in cool chamber storage the moisture content, TSS and acidity retention was more than that of ambient temperature storage at both ripe and full ripe stages of tomato. While storage of fruits, Rangavalli *et al*. (1993) observed a gradual rise in its sugar content due to the starch hydrolysis by ripening.

2.6.2 Physical characteristics

Lipton and Stewart (1961) observed a slight reduction in weight loss in contaloupes subjected to hydrocooling.

Uncini *et al*. (1977) found that weight loss and shrivelling could be greately reduced in pepper packed in polyethylene bags and stored at 8 to 9°C.

Zerbini *et al*. (1978) pointed out that hydrocooling combined with low temperature storage immediately after harvest reduced the weight loss. Ben Yoshua *et al*. (1979) studied the effect of seal packaging on toamto LDPE film. The results showed that shrinkage was practically nil and weight loss was reduced by five fold.

Saimbi (1983) estimated a loss of 31 per cent to 37 per cent fresh weight after 4 days in carrots left unwrapped whereas packaging in polyethylene bags resulted only 5 to 11 per cent loss of fresh weight after 20 days of storage. Salinus *et al*. (1987) revealed that asparagus spear sealed in polyethylene bags reduced the percentage weight loss. Rissi (1989) observed that film wrapping of vegetable retarded the weight loss. Chikkasubhana *et al*. (1991) found that prepacking of lettuce before storage reduced physiological loss in weight.

Significant reduction in weight loss was observed by Santi *et al*. (1992) in tomatoes stored under C.A. storage at

98 per cent relative humidity. The effects of water misting on lettuce, broccoli and carrot under retail trade storage conditions studied by Dickmann *et al*. (1993) revealed lower weight loss compared with these vegetables stored without misting.

2.6.3 Organoleptic qualities

The effect of storage conditions on sensory quality of green beans were studied by Philippon (1986). The results showed that when stored at -8°C to -30°C they retained acceptable sensory quality and chlorophyll concentration was less susceptable than colour.

Rissi (1989) observed that film wrapping of vegetable will enhance decay and development of off flavour. Hackert *et al*. (1991) studied a diversing range of flavours in different varieties of sweet potato. Verma (1990) proved that the organoleptic qualities of chemically treated and stored potatoes were satisfactory. Sensory and physical changes of bread fruits under different storage treatments were evaluated by Sankat (1993) and waxing appeared to be the best choice which showed lowest physical and sensory changes during storage. Kaj and Ueno (1993) stored shredded cabbage under controlled and modified atmosphere and found that browning was suppressed at increased CO_2 concentration and the development of off flavour was delayed with increase in O_2 concentration.

Studies conducted by Mohammed and Wickram (1993) revealed the film wrapped bittergourds stored at 4°C were still marketable upto 20 days with lowest fresh weight loss. Garande *et al.* (1995) conducted storage study on packed jamun fruit under open storage, cool chamber and cold storage methods. It was found that the maximum physiological loss in weight was noticed in open storage and minimum in cold storage conditions.

2.6.4 Microbial incidence

Uncini *et al.* (1977) found that disease incidence in hot peppers could be greatly reduced by keeping packed peppers at 8 to 9°C. Pre-cooling asparagus before storage reduced the rate of deterioration during storage period (Lill 1980).

Seymour *et al.* (1980) found that pre-cooling before storage increased rotting in vegetables.

Pritchand *et al.* (1992) reported the spread of cottony soft rot in stored carrots could be controlled by pre-cooling the produce. Tan *et al.* (1992) observed high incidence of microbial rotting on broccole stored in sealed polyethylene bag.

Studies conducted by Barth *et al.* (1993) observed that broccole stored for 96 hr at 20°C had no microbial growth. Dickman *et al* (1993) pointed out that there was no marked increase in microbial count between water misted and non-misted vegetables. Garg *et al*. (1972) studied the microflora of commerically packed and stored vegetables at 3.3°C and 15°C. The results showed a significant proportion of microflora at both the temperature. Garande *et al*. (1995) observed no incidence of spoilage in jamun fruits kept in cold storage.

MATERIALS AND METHODS

MATERIALS AND METHODS

The materials used and methods adopted in the investigation to assess the "Storage Efficiency of Zero Energy Cool Chamber under Local conditions" are detailed under the following headings.

3.1 Vegetables selected for the study

3.2 Collection of vegetables

3.3 Selection of storage systems

3.4 Construction of Zero Energy cool chamber (Z.E.C.C)

3.5 Working principle of Z.E.C.C.

3.6 Operation of Z.E.C.C.

3.7 Storage of vegetables under different storage media

3.8 Assessment of shelf life with reference to Z.E.C.C.

3.9 Popularisation of Z.E.C.C. among vegetable growers

3.10 Statistical analysis of the data

3.1 Vegetables selected for the study

Vegetables are perishable commodity and they need special storage treatment to prevent losses (Benwart, 1987). Vegetable quality is an unstable character which has to be maintained over a period of time. According to Williams *et al.* (1991) maintenance of vegetable quality will benefit every one in the production consumption chain.

Large varieties of vegetables are grown in Kerala favoured by wide range of agro-climatic conditions. The nearby panchayat Kalliyoor has been identified for vegetable cultivation by KHDP. The vegetables that are mainly produced here include bittergourd, snakegourd, amaranthus, cowpea, ladies finger and brinjal. In the present storage trial, preference was given to the vegetables that are locally cultivated in abundance. Hence five locally available vegetables as listed below are selected for the study.

1) Amaranthus
2) Bhindi
3) Bittergourd
4) Brinjal
5) Snake gourd

3.1.1 Amaranthus

Amaranthus was selected, among leafy vegetables since it is commonly available and widely used in our country. This vegetable suffer the maximum post-harvest losses of 52 per cent as reported by Waheed (1986). Amaranthus is the most common leafy vegetable grown during summer and rainy seasons in India.

3.1.2 Bhindi

Bhindi, popularly known as ladies finger is an important vegetable crop grown throughout India. Being the summer crop the vegetables have a poor shelf life (Madan *et al*. 1993). More over the fruits become fibrous fast if not rightly taken care of. There is a need to develop reasonable handling technology so as to extend the market span of bhindi. Hence this widely used vegetable was preferred for studying its shelf life qualities.

3.1.3 Bittergourd

Bittergourd has a relatively high nutritional value compared to other cucurbitaceae, mainly iron and ascorbic acid content (Tindall, 1980). It is a vegetable grown in almost every vegetable garden in and around Vellayani in Trivandrum district. Hence this crop was included in the storage study of vegetables using different storage methods with particular reference to Zero Energy Cool Chamber.

3.1.4 Brinjal

One of the most common and principle vegetable crops grown all through the year is brinjal. It is highly productive and usually finds its place as the poor man's crop (Choudhary, 1976). Though it is not cultivated by local farmers in large scale they are grown commonly in the kitchen gardens in this locality. Hence this was selected for the study.

3.1.5 Snake gourd

Snake gourd occupies a pride of place among vegetables particularly in South India, where it is being most commonly grown. This vegetable was selected because it is very common in this locality producing a high yield.

3.2 Collection of vegetables

The selected five vegetables viz. amaranthus, bhindi, bittergourd, brinjal and snake gourd collected from two different sources were used for the study. Freshly harvested vegetables from the Instructional Farm, Vellayani (Research Station) and vegetables cultivated by vegetable growers (local farm) in Kalliyoor Panchayat, an area identified for vegetable cultivation by KHDP*, Vellayani were used in the investigation. Vegetables from two different sources were selected in this study particularly because the pre-harvest factors such as cultivars, cultural practices - density of planting, shading, tillage, irrigation, mulching and manurial practices affect the incidence of post-harvest disorders as reported by Walker (1987). Vegetables from Instructional Farm and local farmers differ in cultural practices, use of fertilizers, insecticides and fungicides which may affect shelf life as mentioned earlier. Attention was given to harvest the vegetables without damage before 8 am in the day of storage. According to Williams and his co-worker's (1991) care during harvesting will affect the susceptibility of the produce to loss of quality. Wills and Lee (1981) had the opinion that harvesting should be carried out in the early morning to avoid higher level of field heat.

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*KHDP - Kerala Horticulture Development Programme was started by the Government of Kerala in 1994 with financial assistance from EEC for the comprehensive development of vegetable cultivation in the State.

3.3 Selection of storage systems

Vegetables are one of the most important and perishable horticultural crops. The post-harvest losses can be reduced significantly by proper storage method to improve shelf life as reported by Gordan Half Care (1980). Sethi and Maini (1993) recommended some of the simple and low cost method for proper post-harvest management of fruits and vegetables in order to upgrade our nutritional standards and ensure more remumerative returns to growers and reasonable price to consumers.

The shelf life of vegetables depends upon the type of storage, temperature and humidity (Kurdiya, 1985). In this study, preference was given to low cost and effective methods for storing vegetables which can be easily adopted by the local farmers. Information regarding the uses of such simple and cheap storage structures for enhancing the storability and maintaining the post harvest quality of vegetables under local conditions is not available.

The already practised local storage methods were compared with the zero energy cool chamber method which also require no energy for its operation and compared with the energy oriented walk in cooler for its performance in short term storage of vegetables. Thus the methods identified include

1. Walk-in-cooler
2. Zero Energy Cool Chamber
3. Sprinkling water
4. Covering with leaves
5. Open storage

3.3.1 Walk-in-cooler

Refrigeration is the most effective and widely used method for short term storage of vegetable (Woolrich 1965). Walk-in-cooler is a refrigerated room in which temperature and humidity can be controlled. It is a very effective method to store large quantities of vegetables. But, huge capital investment and technical expertise is required for this type of storage system. According to Sethi *et al*. (1987) use of refrigeration would save great quantities of precious food stuffs from loss or deterioration. But rising cost of building and refrigeration equipment is working as damper for quick addition of new cool storage capacity. However this facility was available in the Instructional Farm, Vellayani which was utilised for the purpose of seed storage. Hence this method was included in the experiment to draw a comparative effect of the performance of Z.E.C.C. against the energy oriented and highly technical and costly storage method.

3.2.2 Zero Energy Cool Chamber (Z.E.C.C.)

Z.E.C.C. is a simple and energy saving post-harvest technology to enhance shelf life of fruits and vegetables which has been developed at IARI, New Delhi. It doesn't need any specialised skill for construction or operation. The raw materials required for construction of the chamber are locally available. Irulappa and Thangaraj (1988) suggests Z.E.C.C. as a low cost and effective method for the short term storage of fruits and vegetables. According to Sethi (1996) wastage of hort-crops at post-harvest stage can be prevented by developing and using low cost, low energy and simple viable technologies like Z.E.C.C. As reported by Saibaba (1990) low cost Z.E.C.C. based on evaporative cooling for short term storage of fruits and vegetables is effective. This method is reported to be adoptable for small scale farmers. Thus its effectiveness in Kerala conditions is aimed at the selection of this method for storage in this study.

3.3.3 Sprinkling water

According to Cohen and Hicks (1985) misting with spray of water provide a benefit of evaporative cooling and is of great help in maintaining freshness for short period. Hence its feasibility as a cheap storage practice against evaporative cooling method was attempted.

3.3.4 Covering with leaves

Another storage method included in the present investigation was covering with banana leaf. This is a readily available material for the farmers of Kerala and is being used as a common practice by vegetable producers in the storage for immediate transportation of vegetables to the sales counter and hence banana leaf covering was thought of considering in this study. The leaves are more or less a waste after the harvest of the fruit and is available in abundance even in the home-steads.

3.3.5 Open storage

The practice of storing fruits and vegetables in open basket has been found very common and therefore taken as the control method under ambient conditions of storage especially in the tropical climate, the fruits shrivel rapidly due to wide variations in the temperature and relative humidity leading to heavy losses as reported by Proctor (1981). Open basket storage is widely used in the house holds as well as by farmers for storage just before vegetables are delivered to the main market. Therefore its effectiveness was compared with the efficiency of zero energy cool chamber.

3.4 Construction of Z.E.C.C.

In hot and dry weather prevailing over much of India for a significant part of the year, the use of evaporative coolers can considerably reduce dry bulb temperature and raise the humidity inside the chamber and successfully aid the storage of fresh fruits and vegetables after harvest (Sethi *et al.* 1987). Z.E.C.C is such a device and the details on its construction is given below.

3.4.1 Site of construction

The storage device was constructed beneath the shade of a tree at College campus, Vellayani. An elevated area was chosen in order to prevent water logging. A water tap was available near the chamber which facilitated easy access to water.

3.4.2 Materials used for the construction of the chamber

The chamber was constructed with low cost, locally available materials. The raw materials used for the construction of Z.E.C.C. were bricks, sand, bamboo sticks, grass and gunny bags.

Bricks - Precautions were taken to select 400 clean, unbroken and uniform bricks.
Sand - Clean, river bed sand free from organic matter, clay and other particles was used.
Bamboo sticks: Clean bamboo sticks were cut into required size and used to make the frame of the lid.
Gunny cloth: Lid of the chamber was made using gunny cloth taken from used gunny bags which were free from holes or tare.

Grass: Long leafy fodder grass collected from the campus was also spread over the gunny cloth.

3.4.3 Design and construction

a. Chamber: The chamber constructed was a double walled rectangular structure with dimensions 160 cm x 100 cm for the outer wall. A gap of 3" was left between the walls. A single layer of bricks was laid initially at the rectangular base of the chamber. The bricks for the double walls were held in place using mud paste. The cracks and crevices on the inside wall was also filled with mud paste so that an even surface was obtained without providing room for cockroaches. The space between the two walls were then filled with the river bed sand.
b) Top cover: A top cover for chamber was constructed with two layers of gunny cloth in a bamboo frame. This particular material was selected due to its ability to hold water. A layer of grass was spread over the gunny cloth to safeguard from damage by rodents. The size of the lid was in proportion with the outer dimension of the chamber.

c) Shed: It is important that the cool chamber should not receive any direct sunlight and at the same time it should be exposed to a lot of aeration. To facilitate this requirement an open shed was constructed over the chamber.

Zero energy cool chamber : outside view

Zero energy cool chamber : Inside view

3.5 Working principle of Z.E.C.C.

The basic principle of the working of Z.E.C.C. is evaporative cooling. Evaporation of water produces considerable cooling effect and the faster the evaporation greater will be the cooling (Roy 1985). When continuous air that is not saturated with water is blown across, the evaporation of water from the wet surface or sand, bricks and the lid occurs. When evaporation takes place, the heat inside the chamber is absorbed and temperature is lowered. During the evaporation of water into vapour, a quantity of heat equal to latent heat of evaporation is consumed and inside the chamber the quantity of heat is removed from within, resulting in the lowering of inside temperature (Kaul and Sukumaran, 1984).

3.6 Operation of Z.E.C.C.

After construction of the chamber it was made clean and free from rotten materials. The chamber was disinfected by sprinkling chlorine water. Pre-cooling of the chamber was effected before storing vegetables. It is done by sprinkling water over bricks of the wall, the floor, sand and the top cover until complete saturation point is attained. A Maximum Minimum thermometer and a Wet-Dry thermometer were kept inside the chamber to record the temperature and relative humidity. Initialization of temperature and relative humidity was attained by repeated sprinkling of water. Daily sprinkling of water once in the morning and once in the evening were carried out to maintain temperature and humidity through out the storage period of vegetables in the chamber.

3.7. Storage of vegetables under selected storage media

Five kg each of two sets representing the two sources of vegetables were stored (in duplicate). This pattern was followed uniformly for all the five treatments. For this 25 kg (5 kg x5) of each vegetable were collected from two sources viz. Instructional Farm and local farmers. Vegetables of approximately uniform size and free from pest and diseases were selected. These vegetables were collected immediately after harvest. Damaged and bruised vegetables were discarded since this will limit the storage life as reported by Zomorodi (1990). According to Williams *et al*. (1991) if vegetables are infested with pest and diseases, it may deteriorate more quickly.

The storage experiment was carried out on the same day of harvest of each vegetables. Harvesting was carried out on the cooler part of the day ie. in the early morning for reducing the field heat as suggested by Gour and Bajpai (1982) Atmospheric temperature and relative humidity during the days of storage were recorded.

Details of the procedures on storage of vegetables under storage systems selected in this study are furnished below.

Five sets of each fresh vegetables in duplicate were weighed out at 5 kg lots. The same vegetables collected from two sources viz. Instructional Farm and Local farmers were subjected to experiment simultaneously. Study was undertaken at two seasons from September and October months were chosen for the first season likewise February and March was considered for the second season to put up the experiment. Vegetables as per the lay out plan were stored in five media as detailed below.

1) Weighed vegetables were placed in a polyethylene bag and stored in the walk-in-cooler installed at the Instructional Farm, Vellayani. The temperature of walk in cooler was maintained at $\pm 4°C$.

2) Weighed vegetables were placed in plastic crates and kept inside the disinfected and pre-cooled zero energy cool chamber. The sand between the walls of chamber and the top-cover was wet three times daily during storage of vegetables in zero energy cool chamber. Temperature and RH of the chamber was initialised and recorded before storage of vegetables in it.

3) Vegetable of required quantity were weighed and kept in a basket. This set was sprinkled with water thrice daily. Basket containing vegetables under the treatment was kept in a room near to the chamber. The basket was left without covering.

4) Clean and fresh plantain leaves were collected and wrapped over the weighed vegetable lots. This was placed in a basket and was kept in the above mentioned room.

5) Required quantity of vegetables were placed in a plastic basket. Vegetable baskets were kept in the room adjacent to the chamber. The vegetables were exposed to ambient temperature and relative humidity during storage on the open state.

3.8 Assessment of shelf life of stored vegetables

The National Food Processor Association (1981) defined that a product is within its shelf life when the product quality is generally accepted for its purporated use by its consumers.

The freshness and quality retention of the vegetables stored in different media along with the nature and extent of damage and deterioration during storage was evaluated by specific observations and thereby the shelf life was studied. Williams *et al*. (1991) reported that the quality of vegetables depend upon several factors which when combined determine acceptability of the produce to the buyer. These fall into two distinct categories. 1) easily perceived characters such as appearence, texture and colour 2) less easily perceived characters of nutritive value.

Thus the following parameters were judged for assessing the shelf life of vegetables stored

1) Physical changes
2) Physiological Loss in Weight (PLW)
3) Chemical changes
4) Microbial changes

3.8.1 Physical changes

The physical characters of vegetables decide their acceptability by consumers and were recorded daily during storage. Shelf life days were assessed by testing the vegetables daily for physical changes occurred during storage physical parameters tested include colour, texture and appearance. According to Salunkhe and Desai (1984) vegetables are notorious for losing water after harvest leading to wilting and shrivelling which turn the vegetable tissue tough or mush affecting texture and appearance of vegetables. Such physical changes that display the total freshness of vegetables were assessed by the use of a suitably structured score card (Appendix I) at a five point scale. Scoring was conducted daily with a panel of ten selected judges. External appearance viz. shrivelling wilting, yellowing and drying observed visually and were considered while scoring vegetable for physical quality. This external assessment was continued till the vegetable under each storage medium were found to lose their physical qualities upto a level that affects the profit margin of the producers as suggested by Shanmughavelu (1989). This also helps to safeguard the interests of consumers.

3.8.2 Physiological Loss of Weight (PLW)

The percentage loss in weight during storage is an important factor associated with post harvest handling of vegetables. Therefore the PLW was assessed daily to compute the cumulative weight loss. The PLW during storage of vegetables was calculated on the basis of initial weight against the weight on consecutive storage days of each sample and expressed in terms of percentage loss Salunkhe and Desai (1984) suggested that around 10 per cent Physiological Loss of Weight will cause loss of freshness in vegetables. Thus the tolerable level of reduction for successful storage was fixed at a maximum level of 10 per cent. The pathological loss was also included for computing the general weight loss.

3.8.3 Assessment of chemical changes

According to Tressler and Evers (1957) when vegetables were stored at optimum conditions the nutrients as well as other quality factors have been protected. Fresh and stored vegetables were analysed for studying the extent of chemical quality protection during storage in this investigation. Stored vegetables were analysed on the last successful storage day of every sample. Chemical composition of vegetable samples were estimated at the commencement of storage in order to find out the loss in nutrient constituents due to storage. Major nutritional qualities analysed were moisture, total mineral, fibre and ascorbic acid. The chemical analysis was done in triplicate for each parameters after harvest (initial) and at the end of shelf life (final) under each storage condition. The procedures followed for the analysis of nutrient composition of vegetables are as detailed below:

i) Fresh vegetables and stored samples were analysed for its progressive changes in moisture content following the method reported by Ramulu *et al*. (1983).

ii) Total ash content of fresh and stored vegetables were analysed by the method suggested by Ranganna (1978).

iii) Crude fibre was estimated by acid alkali digestion method suggested by Chopra and Kanwar (1978).

iv) Vitamin C retention have been considered as an indication of all nutrient retention (Tessler and Evers, 1975). The ascorbic acid content of vegetables were determined according to the method of A.O.A.C. (1955) using dichlorophenol indophenol dye.

3.8.4 Microbial changes

The external appearance of stored vegetables were recorded for pathological damage. The damaged vegetable samples were evaluated for presence of microbial invasion at the laboratory by using standard plate method (SPC). Nutrient agar, potato dextrose agar and maltose extract agar media were used for detecting the presence of bacteria, fungi and yeast respectively.

3.9 Popularisation of Z.E.C.C. among vegetable growers

Inspite of our countries achievements, the fruits of research and new technologies remained beyond the reach of vast majority of farmers (Hali, 1995). In the present study the researcher has made simultaneous effort to transfer the information on the use of this simple and cheap storage device and its feasibility in maintaining the quality of harvested vegetables as revealed through this work to the local farmers of nearby area. Hence with this aim of popularisation of this technology among vegetable growers a lecture cum demonstration programme was conducted. The procedures on the technology transfer attempt is detailed below.

3.9.1 Selection of field level adopters

Beneficiaries are to be chosen based on the objective of the knowledge discremination. Hence vegetable growers who have taken up this as the main source of income were selected from Kalliyoor panchayat of Trivandrum rural area. This location is a vegetable growing area nearest to the university campus. 25 vegetable cultivators who expressed their interest to get familiarised with the operation of zero energy cool chamber were identified through an informal talk with them at their group cultivation centres.

The knowledge of selected farmers on storage methods of vegetables and storage practices followed by them including the economics of vegetable cultivation was studied. A partially objective questionnaire was constructed for this purpose following the procedure adopted by Rajamma (1982) with slight modifications. The questionnaire is presented in Appendix-II. Questionnaire was administered by interview method. Question as well as answer choices were read out by the investigator and the answers were noted in order to enable easy answering.

3.9.2. Conduct of one day education programme

A one day education programme was planned and conducted with the main objective of transferring the information on zero energy cool chamber to the grass root level and to stimulate interest on this storage device among the farmers.

A convenient day and time was fixed in consultation with the selected growers. Candidates were asked to come over to the site at the university campus, where the experimental study on storage of vegetables in zero energy cool chamber was carried out by the investigator.

The educational programme comprised of lecture and demonstration class, with special reference to low cost storage technology and use of zero energy cool chamber for this purpose.

The theory class was arranged during the morning session. The lecture class highlighted various aspects of vegetable storage, low cost storage methods emphasising zero energy cool chamber and the working principles and construction of cool chamber. The farmers were well explained on the details of cool chamber, raw materials required, construction procedures, pre-cooling and disinfecting the chamber and every details regarding storage of vegetables. The steps were repeated several time and farmers were persuaded to ask questions to clear their doubts.

Demonstration on storage of vegetables in zero energy cool chamber was conducted at the afternoon session. Demonstration was supplemented with active discussion. The farmers were asked to sprinkle water and wet the chamber at the right way. The operation procedures were demonstrated step by step. Involvement of all the participants were ensured during the demonstration.

3.9.3 Pre and post evaluation

The impact of an education and popularisation programme administered to the farmers can be evaluated on the basis of the knowledge gain. Accordingly the knowledge and awareness gained through the education programme was evaluated. An education schedule was formulated for the purpose and is appended in Appendix III.

By using their previous knowledge as well as the impact of demonstration and information imparted through the lecture class were assessed.

This assessment of gain in knowledge on zero energy cool chamber formed the dependent variable of the data pooled by evaluation. The difference in the knowledge score of the respondents between pre-class and post-class indicated a measure of gain in knowledge. An attempt was also made to gather the views of the participants regarding the use of this low cost storage technology.

3.10 Statistical analysis of the results

The data was subjected to statistical analysis using the design factorial CRD. Assessment of gain in knowledge of farmers was assessed based on the difference in percentage of rightly answered questions in the pre and post test schedules.

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

Physical and chemical characteristics of vegetables continuously change during post-harvest storage depending on the storage condition and environment. The study entitled "storage efficiency of zero energy cool chamber under local conditions" was undertaken to find out the feasibility of zero energy cool chamber for short term storage of fruits and vegetables under the high temperature and humid conditions of Kerala. Five vegetables viz. Amaranthus, Bhindi, Bittergourd, Brinjal and snakegourd collected from two sources - Instructional Farm, Vellayani and local farmers were stored in five storage systems. The storage treatments tried were, keeping in walk-in-cooler, Zero Energy Cool Chamber (Z.E.C.C.). Sprinkling water, covering with leaves and open storage. Experiment was conducted in two seasons. Gain in knowledge of the local farmers on the use of simple storage structure through one day training imparted to them was also measured. The results obtained through this investigation are detailed under the following headings.

4.1 Influence of storage on physical qualities of vegetables

4.2 Influence of storage on Physiological Loss in Weight (PLW) of vegetables.

4.3 Influence of storage on chemical qualities of vegetables.

4.4 Influence of storage on microbiological aspects of vegetables

4.5 Shelf life of vegetables under different storage media.

4.6 Range of weather parameters in zero energy cool chamber and ambient conditions during experiment.

4.7 Popularisation of zero energy cool chamber among vegetable growers and assessment of gain in knowledge.

4.1 Influence of storage on physical qualities of vegetables

Vegetables are highly perishable material and during their storage, the physical qualities are affected. The physical characteristics of vegetables decide their acceptability by the consumers and indicate storage stability. As reported by Williams *et al*. (1991) the quality of vegetables depend upon easily perceived characters such as appearance, colour and texture. Quality is the composite of characteristics which have significance in determining the market span of vegetables. Influence of different storage treatments on physical characteristics of five vegetables were measured through sensory evaluation tests to determine their freshness level. The organoleptic evaluation was done using a panel of ten judges as per the procedure of Watts *et al*. (1989) for the fresh samples. Appearance, colour and texture of vegetables were rated on a five point scale, the maximum score given was '5' and the minium "1".

4.1.1 Influence of storage on the appearance of vegetables

Appearance is a visual property including colour, texture, conformation, size and shape of vegetables. It helps in determining the freshness of vegetables. The general appearance of vegetables stored under various storage methods was assessed and the mean score are depicted in Tables 1 to 5.

Amaranthus

Results presented in Table-1 showed significant variation of storage media on the appearance of stored amaranthus. The observations were recorded on the second day of storage.

Table 1 Influence of storage on appearance of amaranthus

Storage systems	Season I			Season II		
	Research station	Local farm	Mean	Research station	Local farm	Mean
Walk-in-cooler	5.0	5.0	5.0	5.0	5.0	5.0
Z.E.C.C.	4.8	4.7	4.8	5.0	4.9	4.9
Sprinkling water	3.8	2.7	3.3	2.6	2.7	2.7
Covering with leaves	3.8	2.6	3.2	2.4	2.4	2.4
Open storage	3.0	2.3	3.2	2.4	2.4	2.4
Mean	4.3	3.5		3.5	3.5	
		SE	CD		SE	CD
A		6.24	-		5.77	-
B		9.86	0.28		9.13	0.26
AB		0.14	-		0.13	-

A - Sources B - Storage systems

Amaranthus stored under different methods


ZERO ENERGY
COOL CHAMBER
WALK-IN
COOLER
SPRINKLING
WATER
COVERING
WITH LEAVES

The appearance of amaranthus showed the cent per cent score of 5 for samples in walk-in-cooler during both seasons. The appearance score of this vegetable stored in zero energy cool chamber was on par with walk-in-cooler, having a mean score value of 4.8 in the first season and 4.9 in the second season. For amaranthus under all the other three storage media of ambient conditions, scores were much lower. The lowest score of 3.2 was obtained for both covering with leaves and open storage during first season and the same was remained at 2.4 for the second season. Sprinkling water method was on par with the above traditional sotrage methods during the first and second season acquiring a score of 3.3 and 2.7. There was no significant difference observed between two sources with regard to the appearance of stored amaranthus during the two seasons.

The appearance of amaranthus stored in walk-in-cooler on the second day was superior and the cool chamber results were almost comparable to this. The appearance of amaranthus in the other storage systems on the same day were inferior. This is because of the wrinkling of the leaves and wilted appearance when stored. Appearance of amaranthus was better on the first season compared to second. But the seasonal difference was not noticeable in the case of cooler and cool chamber storage.

Bhindi

The effect of storage on general appearance of bhindi collected from two different sources at two seasons were studied and the data on this is given in Table 2.

Table 2 Influence of storage on appearance of bhindi

Storage systems	Season I			Season II		
	Research station	Local farm	Mean	Research station	Local farm	Mean
Walk-in-cooler	4.8	5.0	4.9	5.0	5.0	5.0
Z.E.C.C.	3.8	4.9	4.4	5.0	5.0	5.0
Sprinkling water	2.3	2.5	2.4	2.8	2.9	2.9
Covering with leaves	2.5	2.5	2.5	3.1	3.2	3.2
Open storage	2.9	2.4	2.4	2.8	2.9	2.9
Mean	3.2	3.5		3.7	3.8	
		SE	CD		SE	CD
A		6.44	-		6.24	-
B		0.10	0.29		9.90	0.28
AB		0.14	-		0.14	-

A - Sources B - Storage systems

Analysis of results on the 4th day during first season and third day during second season revealed that appearance of bhindi maintained the same initial status when stored in walk-in-cooler (4.9 and 5.0) and zero energy cool

Bhindi stored under different methods


OPEN
STORAGE
5th DAY
COVERING
WITH LEAVES
5th DAY
ZERO ENERGY
COOL CHAMBER
5th DAY
WALK-IN
COOLER
5th DAY
SPRINKLING
WATER
5th DAY

chamber (4.4 and 5.0) in both the seasons with the exception that those stored in zero energy cool chamber lost its appearance in season I. In both the seasons other three methods resulted in poor appearance. Both open storage and sprinkling water recorded lower score (2.4 and 2.9) at season first and season second respectively. Bhindi wrapped in leaves maintained a score level of 3.2 which was significantly different from other storage systems during second season while it was on par at first season. There was no significant difference between two sources in both the seasons.

The best result on the physical quality of bhindi was obtained from walk-in-cooler followed by zero energy cool chamber on the fourth day during first season while on the third day during second season both the systems exhibited uniform performance with maximum value on appearance. The three indigeneous methods experimented gave inferior appearance quality for bhindi at both seasons due to its faded look. There was no variation between sources.

Bittergourd

The data on general appearance of bittergourd stored under different storage media are depicted in Table 3.

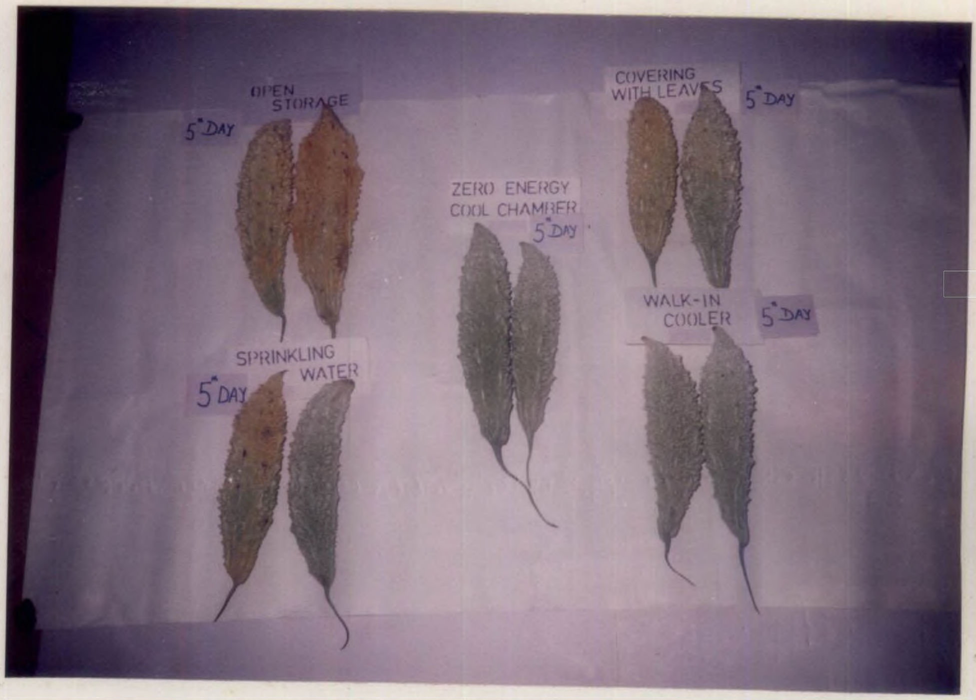
Table 3 Influence of storage on appearance of bittergourd

Storage systems	Season I			Season II		
	Research station	Local farm	Mean	Research station	Local farm	Mean
Walk-in-cooler	5.0	5.0	5.0	5.0	5.0	5.0
Z.E.C.C.	4.6	5.0	4.8	5.0	5.0	5.0
Sprinkling water	2.5	3.4	3.0	2.5	2.5	2.5
Covering with leaves	2.4	3.4	2.9	2.4	2.5	2.5
Open storage	2.2	3.2	2.7	2.5	2.4	2.5
Mean	3.3	4.0		3.5	3.5	
		SE	CD		SE	CD
A		5.80	-		5.70	-
B		9.20	0.26		9.20	0.26
AB		0.13	-		0.13	-

A - Sources   B - Storage systems

Results on the fifth day and third day observations related to the appearance of stored bittergourd in the first and second season showed that vegetable stored in walk-in-cooler (5.0 in both seasons) and zero energy cool chamber (4.8 and 5.0 in first and second season) maintained the fresh appearance. During both the seasons other three methods were found to be inferior attaining a score of 3.0 for samples stored by sprinkling water method, 2.9 for leaf covered sample and 2.7 for open storage as against a uniform score of 2.5 in second season.

Bittergourd stored under different methods


OPEN STORAGE
5th DAY
COVERING WITH LEAVES
5th DAY
ZERO ENERGY COOL CHAMBER
5th DAY
WALK-IN COOLER
5th DAY
SPRINKLING WATER
5th DAY

It was evident from the results of appearance of stored bittergourd that the performance of both walk in cooler and cool chamber systems remained superior with almost similar values at both seasons. Storage by sprinkling water, covering with leaves and open method indicated poor appearance and thereby less freshness in the Bittergourd from both research station and local farmer. The shining of its skin was lost in these methods. Seasonal variation was observed indicating better results during the first season.

Brinjal

The effect of storage on appearance of brinjal collected from two sources during the two seasons of the year is presented in Table 4.

Table 4 Influence of storage on appearance of brinjal

Storage systems	Season I			Season II		
	Research station	Local farm	Mean	Research station	Local farm	Mean
Walk-in-cooler	5.0	5.0	5.0	5.0	5.0	5.0
Z.E.C.C.	5.0	5.0	5.0	4.6	4.7	4.7
Sprinkling water	2.6	3.1	2.9	2.5	3.1	2.8
Covering with leaves	2.5	3.3	2.9	2.7	2.8	2.8
Open storage	2.5	3.3	2.9	2.3	2.8	2.6
Mean	3.5	3.9		3.4	3.7	
		SE	CD		SE	CD
A		5.30	-		7.2	-
B		8.30	0.23		0.11	0.32
AB		0.12	-		0.16	-

A - Sources B - Storage systems

Brinjal stored under different methods


5th DAY
COVERING
WITH LEAVES
SPRINKLING
WATER
OPEN
STORAGE


8th DAY
WALK-IN
COOLER
ZERO ENERGY
COOL CHAMBER

From Table 4 it is evident that the various storage treatments had significant influence on the general apperance of vegetables. Similar to the trend found in the case of other vegetables, walk in cooler and cool chamber registered significantly highest score of 5.00 each during first season and 5.00 and 4.7 during second season. Whereas open storage recorded the lowest value of 2.9 and 2.6 at both seasons. Almost similar score level was attained by brinjal stored by sprinkling water and covering with leaves in its appearance. Observation for appearance of brinjal for the first season was taken on the 5th day and for second season on the fourth day. There was no significant difference observed between the two sources at both the seasons.

Storage of brinjal under different systems emphasised that its appearance in cooler stored and cool chamber stored samples were highly appreciable, which was similar during first season and almost equal at second season. In the other three systems appearance of brinjal revealed to be much inferior at both seasons and of both sources. Appearance of brinjal under these storage methods were in the same tune. The glossy appearance of skin had changed which resulted in poor grading.

Snakegourd

Relevant data on influence of storage on appearance of snakegourd are presented in Table 5. Data was statistically analysed to draw interaction between them.

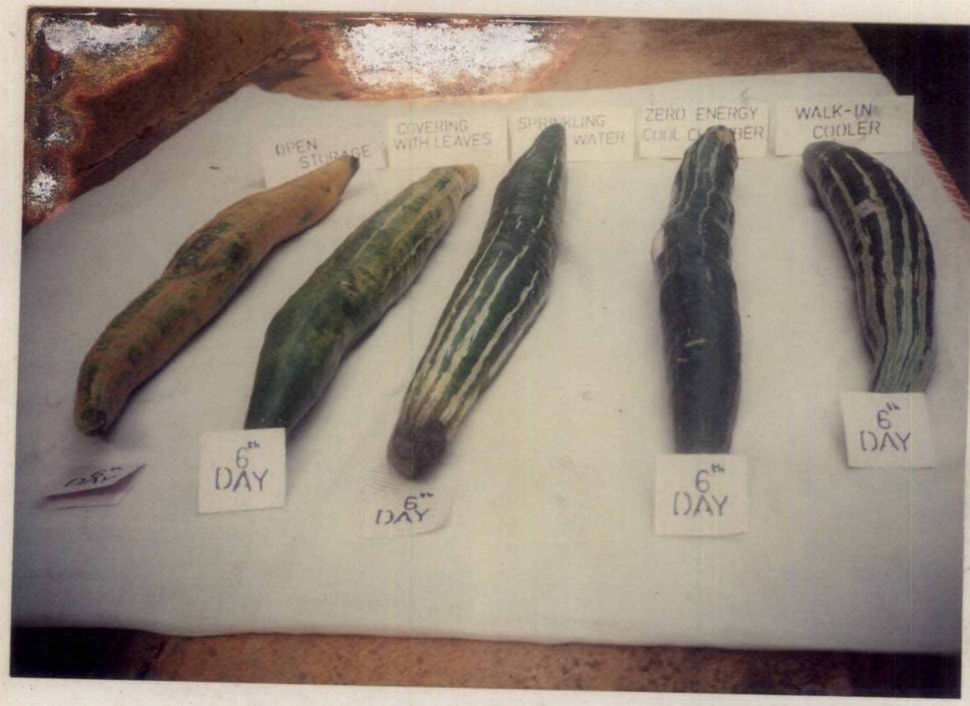
Table 5 Influence of storage on appearance of snakegourd

Storage systems	Season I			Season II		
	Research station	Local farm	Mean	Research station	Local farm	Mean
Walk-in-cooler	5.0	5.0	5.0	5.0	5.0	5.0
Z.E.C.C.	4.8	5.0	4.9	4.0	4.3	4.2
Sprinkling water	2.5	4.2	3.4	2.9	2.6	2.8
Covering with leaves	2.5	3.9	3.2	2.7	2.7	2.7
Open storage	2.5	4.2	3.4	2.6	2.6	2.6
Mean	3.5	4.5		3.4	3.4	
		SE	CD		SE	CD
A		5.80	-		7.70	-
B		9.20	0.26		0.12	0.34
AB		0.13	-		0.17	-

A - Sources B - Storage systems

From the Table it was evident that there existed a significant difference between the storage systems during both seasons. The appearance score of snakegourd was cent per cent on the seventh day and fifth day with respect to walk in cooler at the two seasons. Score level of snakegourd in cool chamber stood at 4.9 and 4.2 that was on par with walk-in-cooler during first season but it was significantly low (4.2) in second season. There was no significant difference noted between snakegourd stored by sprinkling water, covered with

Snakegourd stored under different methods


OPEN STORAGE
COVERING WITH LEAVES
WATER
ZERO ENERGY
WALK-IN COOLER
6th DAY
6th DAY
6th DAY
6th DAY

leaves and open method and found to be much inferior to samples stored in the first two methods. No significant difference was found between two sources.

Appearance of stored snakegourd was best with refrigerated cool store immediately followed by cool chamber storage with an equally good result at the first season. Cool chamber stored snakegourd appeared to be better than the traditionally followed methods. The two different sources of collection exhibited no variation.

The physical appearance of vegetables is directly related to its freshness. It was clearly evident that walk in cooler, the mechanically operated system was most efficient to retain fresh appearance. This is due to its capability of maintaining constantly low temperature conditions. Om Prakash (1995) reported that low temperature is the most effective mehtod for retaining the freshness of vegetables.

Freshness as revealed by the appearance of vegetables studied in this experiment was adequately and well preserved during the study period when zero energy cool chamber was used for the storage of vegetables viz. amaranthus, bhindi, bittergourd, brinjal and snakegourd. Storage studies conducted by several workers also revealed the same fact. Roy and Pal (1988) found that marketability, freshness and firmness was retained up to 18 days when stored is cool chamber where as in control, carrots became unmarketable within 5 days when stored at room temperature.

Another study by Waskar and Roy (1993) indicated that the cool chamber stored fruits looked fresh and firm than the room temperature stored fruits. Bhatnagar *et al*. (1990) also found that cool chamber is effective in maintaining fruit acceptability for longer period. This non energy oriented low cost device maintain low temperature and higher humidity than atmospheric conditions which in turn helps to maintain the fresh appearance of vegetables.

A seasonal variation noticed in the study with regard to maintenance of freshness may be attributed to the atmospheric weather conditions as evident by better freshness when storage was carried out in the first season (September and October). This results could be supported by the report of John (1961) who stated that respiration and transpiration of vegetables were high when the humidity is low which will affect the appearance of vegetables.

4.1.2 Influence of storage on colour of vegetables

Colour is powerfully associated with the freshness of vegetable and is commonly an index of spoilage, which is also one of the criteria that helps to determine the market span. The effect of storage under five different storage systems on the colour of vegetables were studied in two seasons. Higher score of colour indicates delay in deterioration which means lesser physiological disorders. William and Tucker (1991) reports that vegetables have the best colour and appearance at harvest. The majority of vegetables however are not suited to long term storage and many vegetable lose the colour, crispness and appearance soon after harvest.

Amaranthus

Results on retention of colour in stored amaranthus collected from two sources and stored under five different storage media are presented in Table 6.

Table 6 Influence of storage on colour of amaranthus

Storage systems	Season I			Season II		
	Research station	Local farm	Mean	Research station	Local farm	Mean
Walk-in-cooler	5.0	5.0	5.0	5.0	5.0	5.0
Z.E.C.C.	4.8	4.7	4.8	5.0	5.0	5.0
Sprinkling water	3.8	2.7	3.3	2.5	2.5	2.5
Covering with leaves	3.8	2.6	3.2	2.4	2.3	2.3
Open storage	4.0	2.3	3.2	2.4	2.4	2.4
Mean	4.3	3.5		3.5	3.5	
		SE	CD		SE	CD
A		5.90	0.18		8.90	-
B		9.30	0.27		8.90	0.25
AB		0.13			0.13	

A - Sources B - Storage systems

Table 6 elucidates that storage have not negatively influenced the colour of amaranthus under the systems, walk-in-cooler and cool chamber. On the second days observation during both the seasons walk-in-cooler (5 each) and cool chamber (4.8 and 5) proved highly efficient in colour retention scoring the maximum values and stood statistically on par. Colour appeal was comparatively less in remaining three room temperature storage of amaranthus. Their scores were 3.3, 3.2 and 3.2 in first season and 2.5, 2.3 and 2.4 at second season in sprinkling water, covering with leaves and open storage methods respectively and was found on par.

Amaranthus collected from local farmer recorded better score with a mean of 4.3 and was significantly different to Research Station sample (3.5). But during the second season the colour change was more or less similar in sample selected form both the sources.

From the results, it is evident that zero energy cool chamber storage is as good as the advanced technology oriented method walk-in-cooler in maintaining colour similar to fresh amaranthus. Whereas storage by the common methods followed in this study degraded the colour of amaranthus to a considerable extent on the second day due to loss of natural red colour by wilting and appearence of greenish patches especially in sprinkling water method. Colour retention pattern of different storage systems marked almost the same pattern in both seasons in the case of amaranthus, a vegetable whose maturity and harvesting pattern is highly valued in its quality.

Bhindi

Colour scores obtained for bhindi stored under five different storage media were analysed and presented in Table 7.

Table 7 Influence of storage on colour of bhindi

Storage systems	Season I			Season II		
	Research station	Local farm	Mean	Research station	Local farm	Mean
Walk-in-cooler	5.0	5.0	5.0	5.0	5.0	5.0
Z.E.C.C.	5.0	5.0	5.0	5.0	5.0	5.0
Sprinkling water	2.8	2.8	2.8	2.9	2.9	2.9
Covering with leaves	2.6	2.7	2.6	2.9	2.8	2.9
Open storage	2.7	2.7	2.7	2.7	2.7	2.7
Mean	3.6	3.6		3.7	3.7	
		SE	CD		SE	CD
A		7.33	-		0.08	-
B		0.12	0.33		0.12	0.34
AB		0.16			0.17	

A - Sources B - Storage systems

From the above Table values, it is evident that storage of bhindi in walk-in-cooler as well as cool chamber recorded maximum score of 5 during both seasons. Colour appeal was comparatively less in other three storage methods such as sprinkling water, leaf covering and open storage having a score of 2.8, 2.6, 2.7 respectively on the 4th day of storage in the first season and 2.9, 2.9, 2.7 on the third day of storage in second season. These three methods were statistically on par with each other. Bhindi collected from local sources and Research Station recorded same score (3.6) for first season and 3.7 for second season.

Results reveal that cool chamber and cooler stored bhindi showed same colour retention. The highly advanced method of storage ie walk-in-cooler and non-energy oriented low cost zero energy cool chamber method obtained a colour profile upto the level of fresh bhindi.

The remaining three local methods of sotrage degraded the colour of bhindi to a considerable extent on the fourth day during first season and 3rd day during second season. The fresh greenish colour was lost and a dull look was noticed in all the three storage systems. The colour of samples collected from local farmers as well as that of research station exhibited same colour in the case of bhindi.

Bittergourd

The influence of storage on colour of bittergourd is shown in Table 8.

Table 8 Influence of storage on colour of bittergourd

Storage systems	Season I			Season II		
	Research station	Local farm	Mean	Research station	Local farm	Mean
Walk-in-cooler	5.0	5.0	5.0	5.0	5.0	5.0
Z.E.C.C.	5.0	5.0	5.0	5.0	5.0	5.0
Sprinkling water	2.5	3.5	3.0	2.3	2.7	2.5
Covering with leaves	2.3	3.2	2.8	2.3	2.7	2.5
Open storage	2.4	3.4	2.9	2.3	2.7	2.5
Mean	3.4	4.0		3.4	3.6	
		SE	CD		SE	CD
A		5.50	-		5.40	-
B		8.70	0.24		8.50	0.24
AB		0.12			0.12	

A - Sources B - Storage systems

The data given in the Table 8 shows maximum colour score of 5.0 for bittergourd stored in walk-in-cooler as well as cool chamber, on the fifth day in first season and 3rd day during second season. Bittergourd stored by sprinkling water, covering with leaves and open storage gave a colour score of 3.0, 2.8 and 2.9 respectively which was statistically on par during first season. During second season the above mentioned three methods recorded a score of 2.5, 2.5 and 2.4 and were also statistically on par. During both seasons the values on the two sources were on par.

The results obtained revealed that the skin colour of bittergourd was most effectively preserved in walk in cooler as well as zero energy cool chamber during both seasons. The other three indigeneous storage methods performed poor colour retention during storage. The fresh green colour was changed to slight yellowish colour resulting in early ripening of bittergourd stored under these methods. Colour change in bittergourd collected from local sources was almost similar to the research station sample. Storage season had negative effect in colour criteria of stored vegetable.

Brinjal

Colour performance of brinjal stored under five different storage systems in the present study is shown in Table 9.

Table 9 Influence of storage on colour of brinjal

Storage systems	Season I			Season II		
	Research station	Local farm	Mean	Research station	Local farm	Mean
Walk-in-cooler	5.0	5.0	5.0	5.0	5.0	5.0
Z.E.C.C.	5.0	5.0	5.0	5.0	5.0	5.0
Sprinkling water	2.7	3.6	3.2	2.5	2.6	2.6
Covering with leaves	2.4	3.3	2.9	2.4	2.5	2.5
Open storage	2.3	3.4	2.9	2.5	2.5	2.5
Mean	3.5	4.1		3.5	3.5	
		SE	CD		SE	CD
A		5.5	0.15		5.7	-
B		8.7	0.24		9.1	0.26
AB		0.12			0.13	

A - Sources B - Storage systems

Brinjal stored in walk-in-cooler as well as cool chamber recorded a maximal score of five on the fifth day during first season and the same was observed on the 4th day during second season. Open storage and covering with leaves recorded minimum values at both seasons the scores being 2.9 and 2.5 each respectively for two seasons. The colour of vegetables from different sources revealed a significant difference at storage during first season and was on par at the second season.

It can be concluded that cool chamber as well as cooler stored brinjal could retain best colour in brinjal similar to the fresh sample during both seasons. However the remaining three traditional methods of storage registered very poor colour appeal. In these three methods the fresh glossy greenish colour had disappeared giving a pale yellow colouration to the skin.

Snakegourd

Data on the storage behaviour related to colour of snakegourd under the present experiment is shown in Table 10.

Table 10 Influence of storage on colour of snakegourd

Storage systems	Season I			Season II		
	Research station	Local farm	Mean	Research station	Local farm	Mean
Walk-in-cooler	5.0	5.0	5.0	5.0	5.0	5.0
Z.E.C.C.	5.0	5.0	5.0	3.8	4.4	4.1
Sprinkling water	2.5	4.5	3.5	3.3	3.4	3.4
Covering with leaves	2.3	4.5	3.4	3.0	2.8	2.9
Open storage	2.4	4.3	3.4	2.5	2.5	2.5
Mean	3.4	4.7		3.5	3.6	
		SE	CD		SE	CD
A		5.90	-		7.50	-
B		0.09	0.27		0.12	0.33
AB		0.13			0.17	

A - Sources B - Storage systems

The data revealed that two methods viz. cooler and zero energy cool chamber were found to be highly efficient and do not impair colour of snakegourd with maximum score level (5) during first season on the seventh day of storage. Colour criteria was judged to be lower for the rest of the systems with values 3.5, 3.4 and 3.4 and remained on par statistically.

Colour aspects of stored snakegourd collected from local source and from research station were found to be on par with each other at both seasons.

During second season storage, study was made up to fifth day. In this season walk-in-cooler recorded maximal colour score (5) followed by cool chamber with a score of 4.1. The minimal score was registered for snakegourd stored under open storage (2.5) and leaf covered (2.9) which were statisticaly on par.

To conclude, colour retention was observed to be good in both walk-in-cooler and zero energy cool chamber. The remaining three methods were able to retain a satisfactory colour to the stored snakegourd. This was accounted mainly due to the appearance of light yellow colour especially at the tips of this vegetable during the initial period that was spreading gradually as the storage period extended. The trend during the different season and behaviour of snakegourd from two sources were remained in the same pattern.

The foregoing discussion on the colour changes of different vegetables due to storage, indicate that all vegetables maintained their fresh colour in zero energy cool chamber almost as good as walk-in-cooler since colour of vegetables were less affected by storage under zero energy cool chamber. It indicated the efficiency of the storage device to keep up the freshness of vegetables. As it is a well-known fact that highest efficiency to maintain fresh colour after storage was achieved for walk-in-cooler, this method is costly and it need energy to maintain low temperature whereas in the case of cool chamber the temperature is lowered by natural evaporation of water and retention of higher humidity inside the chamber helps in keeping vegetables fresh. All the other three methods were proved to be less effective in maintaining fresh colour of vegetables when compared to cool chamber. This data is adequately supported by other workers. In a study conducted by Wasker and Roy (1993) it was reported that cool chamber stored banana fruits looked fresh and firm after 26 days as compared to 14 days at room temperature.

The local sources recorded better colour profile during first season compared to research station sample. The harvesting treatment of the farmer and the time of harvest may be the beneficial facts while in the second season, the two sources showed almost similar colour characteristics. Produce harvested during the coolest part of the day and handled carefully cause less injuries.

Between the five storage systems, almost same pattern of colour retention was observed during both seasons. Among the three common methods, colour retention of vegetable was found to be slightly better in sprinkling water method as noted in few observations.

4.1.3 Influence of storage on texture of vegetables

Texture constitute physical property of vegetables apprehended both by the eyes and the skin. This property was assessed by touching the vegetables and examining by feel with hand. The texture property is very important in determining the freshness and fibre content of vegetables.

Williams *et al*. (1991) suggests texture as one of the quality parameter of vegetables in determining the acceptability of produce. Vegetables collected from Research Station as well as local sources were stored under five storage systems during two seasons. These were analysed for changes occurred in texture upon storage in the different methods under study. The mean scores obtained for texture of different vegetables are studied in order to find out the efficiency of storage systems.

Amaranthus

Influence of five different storage methods on texture of amaranthus were detailed in Table 11.

Table 11 Influence of storage on texture of amaranthus

Storage systems	Season I			Season II		
	Research station	Local farm	Mean	Research station	Local farm	Mean
Walk-in-cooler	5.0	4.8	4.9	5.0	5.0	5.0
Z.E.C.C.	5.0	4.8	4.9	5.0	4.8	4.9
Sprinkling water	3.7	2.6	3.2	2.7	2.6	2.7
Covering with leaves	3.8	2.5	3.2	2.4	2.6	2.5
Open storage	3.5	2.3	2.9	2.5	2.3	2.4
Mean	4.2	3.4		3.5	3.9	
		SE	CD		SE	CD
A		5.39	0.17		5.25	-
B		0.101	0.28		8.3	0.23
AB		0.14	-		0.12	-

A - Sources B - Storage systems

As presented in the Table during both seasons walk-in-cooler and cool chamber appeared to be the treatment of choice because it retained firm texture in amaranthus up to two days giving a score of 4.9 with a point higher for cooler stored sample in the second season. Texture values decreased steeply in the other methods. During the first season, sprinkling water method and covering with leaves showed the same mean value (3.6) on texture of amaranthus where as poorest texture was exhibited by openly stored amaranthus with a score of 2.9 and was significantly different from the above two methods. These three treatments on the second season remained on par in the performance of texture with scores 2.7, 2.5 and 2.4 respectively.

There was significant difference observed between texture of amaranthus collected from research station and local sources with a better score for local source (4.2) and 3.4 for research station in first season and stood on par during second season.

From the above analysis, it is clear that texture quality of amaranthus could be maintained to the extent of cooler treatment when zero energy cool chamber was used for storage. But the texture was noticably poor when amaranthus was stored by sprinkling water, covering with leaves and in open basket. Under these methods, the amaranthus became soft and pliable irrespective of seasonal variations. However a better firmness was noticed during first season when water was sprinkled and covered with leaf.

Bhindi

The effect of storage on texture attributes of bhindi shown by the scores are detailed in Table 12.

Table 12 Influence of storage on texture of bhindi

Storage systems	Season I			Season II		
	Research station	Local farm	Mean	Research station	Local farm	Mean
Walk-in-cooler	5.0	5.0	5.0	5.0	5.0	5.0
Z.E.C.C.	4.6	5.0	4.8	5.0	5.0	5.0
Sprinkling water	2.6	2.6	2.6	2.5	2.4	2.5
Covering with leaves	2.6	2.6	2.6	2.5	2.5	2.5
Open storage	2.5	2.5	2.5	2.3	2.4	2.4
Mean	3.5	3.5		3.4	3.4	
		SE	CD		SE	CD
A		6.10	-		5.56	-
B		9.70	0.27		8.80	0.25
AB		0.14	-		0.12	-

A - Sources B - Storage systems

The data collected on the fourth day of storage at first season and third day at second season observed that the mean value for cool chamber (4.8 and 5.0) was observed close to walk-in-cooler (5.0 each). However these were significantly on par. Texture rating of bhindi was much lower on the common storage methods with 2.5 and 2.4 in the open storage and 2.6 and 2.5 in rest two methods at both the seasons. The three method remained statistically on par. Vegetables from two sources did not vary in their texture performance in the two seasons.

The results summarise that cool chamber was as effective as walk-in-cooler in retaining the soft texture of bhindi irrespective of seasonal variation. The remaining three methods were very poor to retain the firmness of bhindi when stored. Bhindi stored by sprinkling water leaf covering and open storage turned to be hard due to dryness. Thus its softness was lost. Source variation and season variation could not contribute any difference in changing the texture of bhindi.

Bittergourd

Mean scores obtained for storage of bittergourd under five storage systems are summarised in Table 13.

Table 13 Influence of storage on texture of bittergourd

Storage systems	Season I			Season II		
	Research station	Local farm	Mean	Research station	Local farm	Mean
Walk-in-cooler	5.0	5.0	5.0	5.0	5.0	5.0
Z.E.C.C.	5.0	5.0	5.0	5.0	5.0	5.0
Sprinkling water	2.5	3.4	3.0	2.6	2.7	2.7
Covering with leaves	2.5	3.3	2.9	2.6	2.7	2.7
Open storage	2.3	3.3	2.8	2.5	2.5	2.5
Mean	3.5	4.0		3.5	3.6	
		SE	CD		SE	CD
A		5.5	-		5.6	-
B		8.7	0.25		8.8	0.25
AB		0.12	-		0.12	-

A - Sources B - Storage systems

Data on the fifth day and third day of storage recorded an excellent score in texture of bittergourd stored in walk-in-cooler and zero energy cool chamber having the cent per cent scores during the two storage seasons. The other three storage systems recorded less preferable mean scores for texture of bittergourd. First season scored 3.0 for sprinkling water 2.9 for leaf covered sample and 2.8 to open stored bittergourd which was on par. In second season the scores were 2.7 for sprinkling water and leaf covering followed by 2.5 for open basket storage and that is also statistically non-significant. No marked difference between two sources were observed in two seasons.

The effectiveness of cool chamber was well comparable to walk-in-cooler to keep up the firm texture of bittergourd when stored upto five days which is enlightened from the research data. It was also revealed from the results that the other three storage systems viz. sprinkling water, covering with leaves and open storage, were not proved to be much advantageous in maintaining good texture in bittergourd when stored compared to cool chamber storage.

Brinjal

Table 14 summarisis the textural changes occured in brinjal during storage.

Table 14 Influence of storage on texture of brinjal

Storage systems	Season I			Season II		
	Research station	Local farm	Mean	Research station	Local farm	Mean
Walk-in-cooler	5.0	5.0	5.0	5.0	5.0	5.0
Z.E.C.C.	5.0	5.0	5.0	5.0	5.0	5.0
Sprinkling water	2.7	3.5	3.1	3.4	3.4	3.4
Covering with leaves	2.5	3.3	2.9	3.4	3.3	3.4
Open storage	2.6	3.7	3.1	3.3	3.4	3.4
Mean	3.6	4.1		4.0	4.0	
		SE	CD		SE	CD
A		5.5	-		5.5	-
B		8.7	0.25		8.8	0.25
AB		0.12	-		0.12	-

A - Sources B - Storage systems

As depicted in the Table, the highest maximum score of five was recorded for texture of brinjal stored in walk in cooler and zero energy cool chamber during both seasons. Meanwhile the other three storage systems viz. sprinkling water, covering with leaves and open storage registered lower textural properties for brinjal which was on par with each other obtaining scores of 3.1, 2.9 and 3.1 respectively. During second season also the above storage methods obtained a same score (3.4) in texture of stored brinjal.

Data were recorded in the fifth day and fourth day in the first and second seasons respectively. There was no noticable variation in texture attribute of brinjal between sources at both seasons.

The storage results emphasized the highest efficiency of walk in cooler as well as zero energy cool chamber in maintaining the original texture of brinjal during storage. However the three storage methods locally used were found to be very poor in retaining the fresh texture of brinjal. In general no marked deviation was observed between sources or seasons regarding textural change of brinjal at storage.

Snakegourd

Data regarding influence of storage on texture of snakegourd are presented in Table 15.

It can be noticed from the results on 7th day during first season for snakegourd stored in walk-in-cooler and cool chamber recorded high value for texture scoring 5 and 4.9 respectively. These two treatments statistically remained on par. The lowest score for the texture was found in open stored snake gourd (2.2) followed by covering leaves (2.9) and sprinkling water (3.4).

Table 15 Influence of storage on texture of snakegourd

Storage systems	Season I			Season II		
	Research station	Local farm	Mean	Research station	Local farm	Mean
Walk-in-cooler	5.0	5.0	5.0	5.0	5.0	5.0
Z.E.C.C.	4.9	5.0	4.9	3.8	4.4	4.1
Sprinkling water	2.4	4.6	3.4	2.4	2.5	2.5
Covering with leaves	2.3	4.6	2.9	2.4	2.4	2.4
Open storage	2.4	3.8	2.5	2.2	2.2	2.2
Mean	3.4	4.5		3.2	3.3	
		SE	CD		SE	CD
A		0.06	-		6.5	-
B		9.60	0.27		0.10	0.29
AB		0.14	-		0.14	-

A - Sources B - Storage systems

Results of the second season experiment on the fifth day observed maximum texture value in walk in cooler (5) stored brinjal followed by that of cool chamber (4.1) and these remained significantly different.

The texture score of the other three treatments were significantly lower and were found on par. There was no noticeable difference observed between samples collected from local sources and research station during both the seasons.

From the above results it can be seen that the produce stored in walk-in-cooler retained the best texture during both seasons while cool chamber stored snakegourd was comparable during first and second season. Snakegourd stored by sprinkling water, covering with leaves and open storage were observed to be much inferior in texture retention for both experiments.

Between the two sources as well as seasons, the texture had no variation. Thus it may be concluded that the efficiency of cool chamber was closer to that of walk-in-cooler and at the same time remained highly efficient than other three traditional methods in retaining texture of snakegourd on storage.

It was concluded that cooler stored vegetables were proved to be better in retaining the texture followed by zero energy cool chamber. The texture is one of the important index in determining the freshness of stored samples and thereby the efficiency of the particular storage system. Second to walk-in-cooler, highest efficiency was noted with zero energy cool chamber. The comparatively low temperature and higher humidity than atmospheric conditions that could be maintained inside the chamber, is the primary reason for the success of cool chamber storage than the other three methods to maintain good texture on storage.

Pal and Roy (1988) found that marketability, freshness and firmness of carrot retained up to 18 days when stored in zero energy cool chamber while in the control carrot become unmarketable within five day when stored at room temperature. According to Wasker and Roy (1993) cool chamber stored fruit looked fresh and firm than the room temperature stored chemically treated fruit.

The three storage methods viz. sprinkling water, covering with leaves and open storage contributed poor texture profile during storage. It may be due to the higher transpiration and respiration rates of vegetables under these methods and thereby higher water loss which resulted in shrinkage, dryness or softness.

During first season, local sources retained good texture compared to research station which might be due to the maturity variation in harvesting. While this was not revealed in the second season. For leafy vegetables, bhindi etc. delayed harvest-will result in lower quality.

All the physical qualities were protected by zero energy cool chamber stored vegetables almost closer to the refrigerated storage viz. walk in cooler. Compared with the three room-temperature storage methods zero energy cool chamber is thus a feasible method for short term storage to preserve

the physical qualities of vegetables. Chowdhary and Bhatnagar (1954) reported that increased rate of physical changes are due to increased rate of photosynthesis. In cool chamber storage the rate of photosynthesis is controlled as the vegetables are kept in a closed structure. While this is not so in the other storage methods studied.

4.2 Influence of storage on physiological loss in weight of vegetables

Post harvest vegetables are still alive, if not stored properly deterioration will be caused (Williams *et al.* 1991). The Physiological Loss in Weight (PLW) is an important observation that help to determine the effectiveness of any storage system.

Since the loss occuring in storage in most of the vegetables is mainly due to PLW the lowest PLW gives highest efficiency of a particular storage method. According to Data and Eronica (1987) loss of fresh weight is a common observation during storage whatever be the treatment applied for storage.

Hence the influence of the five storage treatments on Physiological Loss in Weight (PLW) of selected vegetables were studied. For determination of PLW the cumulative loss in weight was calculated on the basis of initial weight and recorded daily. The microbiological loss was also considered. The reduction in weight was expressed as percentage loss.

Amaranthus

Table 16 depicts the Physiological Loss in Weight of stored amaranthus recorded during two seasons.

Table 16 Physiological loss in weight (PLW %) of stored Amaranthus

Storage systems	Season I			Season II		
	Local	Research station	Mean (%)	Local	Research station	Mean (%)
Walk-in-cooler	0.25	0.30	0.28	0.25	0.25	0.25
Z.E.C.C.	1.60	1.55	1.58	1.60	1.55	1.58
Sprinkling water	8.50	9.00	8.75	8.50	9.00	8.75
Covering with leaves	8.50	9.50	9.60	9.00	8.50	8.75
Open storage	10.50	10.50	10.50	10.50	9.50	10.00
Mean	5.87	6.17		5.97	5.76	
		SE	CD		SE	CD
A		0.34	1.06		0.32	1.00
B		0.21	-		0.26	-
AB		0.48	-		0.45	-

A - Storage systems B - Sources

From Table 16 it can be seen that the physiological loss in weight (PLW) of amaranthus in different storage system was significantly varying on the second day during both seasons.

Minimum loss in weight of amaranthus was found in walk in cooler (0.28%) followed by zero energy cool chamber (1.58%). Higher percentage loss was found in the other three storage systems viz. sprinkling water covering with leaves and open storage which recorded 8.75%, 9.00% and 10.50% respectively. These treatments also showed marked difference with highest loss in open stored sample. The trend shown by these three systems in the second season (February-March) was also similar. At the same time unlike first season, water sprinkling method and leaf covering method recorded the same loss (8.75%) and remained on par. These systems recorded significantly higher PLW compared with cool chamber and cooler stored samples.

During both the seasons, no marked difference was observed between PLW of amaranthus collected from local sources and research station sample.

On perusal of the data, it can be clearly stated that among the low cost methods zero energy cool chamber was found highly effective in reducing PLW of amaranthus on short term storage. The results in both walk-in-cooler and cool chamber were outstanding while in other three methods, the loss was rapid. Pathological loss was also noted in the case of sprinkling water method due to water logging in the leaves. Weight loss pattern at two sources as well as seasons were same.

Bhindi

The effect of storage on Physiological Loss in Weight (PLW) of bhindi is given in Table 17.

Table 17 Physiological Loss in Weight (PLW %) of stored bhindi

Storage systems	Season I			Seasons II		
	Local	Research station	Mean (%)	Local	Research station	Mean (%)
Walk-in-cooler	3.00	2.70	2.85	0.80	0.30	0.55
Z.E.C.C.	4.00	5.00	4.50	0.80	4.00	2.40
Sprinkling water	7.60	8.00	7.80	8.00	8.40	8.20
Covering with leaves	9.00	10.00	9.50	8.40	8.40	8.40
Open storage	9.00	10.00	9.50	10.00	10.00	10.00
Mean	6.520	7.140		5.60	6.22	
		SE	CD		SE	CD
A		0.64	2.0		1.22	3.8
B		0.40	-		0.77	-
AB		0.90	-		1.72	-

A - Storage systems B - Sources

Table 17 revealed that different storage treatments had significant effect on Physiological Loss in Weight (PLW) of bhindi stored during both seasons. Significantly low PLW was recorded in walk in cooler (2.85%) which was on par with zero energy cool chamber (4.5%) on the fourth day during first season. Markedly higher loss was observed in open storage as well as in leaf covered sample (9.5% each) that remained on par with sprinkling water (7.80%).

During second season, bhindi stored under open basket and leaf covered sample showed difference on the 3rd day recording 10.00% and 8.40% loss respectively which was on par with each other. All other systems followed the same pattern as in the first season. No significant difference was observed between two sources during first and second season.

The data highlights that the PLW percentage was rather minimum during storage in walk-in-cooler followed by zero energy cool chamber as against the fall in weight found in other three systems. Both sources recorded almost same rate of weight loss during the two seasons.

Bittergourd

Storage behaviour of bittergourd on the Physiological Loss in Weight with different media is detailed in Table 18.

Table 18 Physiological Loss in Weight (PLW %) of stored bittergourd

Storage systems	Season I			Season II		
	Local	Research station	Mean (%)	Local	Research station	Mean (%)
Walk-in-cooler	3.0	3.0	3.0	0.2	0.2	0.2
Z.E.C.C.	3.0	5.0	4.0	2.0	4.6	3.0
Sprinkling water	9.0	10.0	9.5	8.0	9.6	8.5
Covering with leaves	10.0	11.0	10.5	10.0	10.0	10.0
Open storage	10.0	11.0	10.5	11.0	11.0	11.0
Mean	7.0	8.0		6.2	6.8	
		SE	CD		SE	CD
A		1.10	3.20		1.12	3.80
B		0.64	-		0.76	-
AB		1.42	-		1.70	-

A - Storage systems B - Sources

The statistical analysis of the data revealed that bittergourd in walk-in-cooler and zero energy cool chamber remained significantly different from other three storage methods in weight loss during both seasons. The lowest wieght loss was recorded in walk-in-cooler the loss being 3.0% and zero energy cool chamber (4.0%). Weight loss was maximum in both covering with leaves and open stored samples of bittergourd with a mean per cent loss of 10.5% and stood on par with bittergourd stored by sprinkling water (9.5%). The data was analysed on fifth day during first season. In the case of second season open stored bittergourd recorded 11% loss and leaf covered sample 10% which was on par. Bittergourd stored under all the other storage methods recorded same pattern as first season on the 3rd day of storage.

However no marked difference was noted between two sources at the two seasons.

While discussing the data it can concluded that walk-in-cooler and zero energy cool chamber showed highest efficiency with low physiological loss in weight. The weight loss was higher in bittergourd stored at atmospheric temperature and humidity.

For both the seasons similar loss was obtained for bittergourd collected from local farm and Instructional Farm.

Brinjal

Brinjal being a hardy vegetable, the physiological losses and market appeal in this crop are often associated with its post harvest marketing problems. The physiological loss in weight of brinjal stored under different system, recorded is presented in Table 19.

Table 19 Physiological Loss in Weight (PLW %) of stored brinjal

Storage systems	Season I			Season II		
	Local	Research station	Mean (%)	Local	Research station	Mean (%)
Walk-in-cooler	0.40	2.00	1.20	0.40	1.20	0.80
Z.E.C.C.	2.00	2.00	2.00	1.60	2.40	2.00
Sprinkling water	8.00	5.50	6.75	7.00	8.00	7.50
Covering with leaves	7.60	5.50	6.55	8.60	10.00	9.60
Open storage	7.00	10.00	8.50	10.00	10.00	10.00
Mean	5.00	5.00		5.40	6.32	
		SE	CD		SE	CD
A		0.69	2.20		0.71	2.20
B		0.43	-		0.45	-
AB		0.97	-		1.00	-

A - Storage systems B - Sources

From the above Table it was noted that all the storage systems were significantly different during both seasons. The lowest value of 1.2% was recorded in walk-in-cooler. An encouraging result with only 2% loss in brinjal was recorded in zero energy cool chamber on the fifth day of storage and stood on par with brinjal stored under walk-in-cooler. The loss in weight was high in all the remaining three stage systems loss in leaf covered sample (6.55%) followed by 6.75% for brinjal stored by sprinkling water and 8.5% for the sample kept in open basket and stood on par. The same pattern of loss in weight was observed during fourth day at second season of storage. The two sources recorded same mean value for loss in weight during first and second seasons.

It can be seen that physiological loss in weight was maximum with the ordinary methods of storage at all durations. PLW was much less and remained more or less same in both in walk in cooler and zero energy cool chamber stored brinjal. For the two seasons almost same loss in weight was recorded for both sources.

Snakegourd

The physiological loss in weight of snakegourd stored in different storage systems recorded on the seventh day during first season and fifth day during second season are presented in Table 20.

Table 20 Physiological Loss in Weight (PLW %) of stored snakegourd

Storage systems	Season I			Season II		
	Local	Research station	Mean (%)	Local	Research station	Mean (%)
Walk-in-cooler	2.70	2.80	2.80	3.20	4.00	3.60
Z.E.C.C.	2.00	5.00	3.50	5.60	6.60	5.80
Sprinkling water	7.00	9.00	8.00	7.00	8.60	7.50
Covering with leaves	8.00	10.00	9.00	9.50	10.60	9.75
Open storage	8.00	10.00	9.00	10.00	10.00	10.60
Mean	5.03	6.88		7.06	7.60	
		SE	CD		SE	CD
A		0.84	2.60		1.19	3.80
B		0.53	1.70		0.75	-
AB		1.18	-		1.69	-

A - Storage systems B - Sources

From the Table it was clearly observed that snakegourd stored in walk-in-cooler recorded the minimum loss in weight (2.75% and 3.60%) and stood on par with zero energy cool chamber (3.50% and 5.80%) during first and second season respectively. The remaining three methods were on par with each other during first season. During second season sprinkling water (7.50%) recorded more or less same PLW compared zero energy cool chamber (5.80%). However there was no significant difference observed in sprinkling water. leaf covered (9.75%) and open stored (10.00%) snakegourd samples in the second season.

Difference was found between sources during first season having highest loss of 6.88% for snakegourd from research station and 5.03% for local samples. However less variation among sources were seen in second season. In tune with the results of weight loss at different systems shown by other vegetables, in the case of snakegourd also the PLW in cool chamber was much lower than other low cost methods studied and more or less same to walk-in-cooler stored samples.

Percentage weight loss on storage in different media emphasised that as the storage temperature was lowered, weight losses were reduced. Next to refrigerated condition (walk-in-cooler) weight loss was significantly reduced in zero energy cool chamber compared to other ambient condition storage. Thus in the present search for a low cost storage method for minimum weight loss of vegetables, zero energy cool chamber is detected as a successful medium to limit weight loss. The higher relative humidity environment (RH > 95%) build up in the chamber has probably helped to attain a promising result lowering the speed of biochemical changes in vegetable tissues. Similarly as the storage temperature were lowered weight loss was also reduced. The cool chamber temperature was maintained between 23°C to 19°C during the experiment.

Studies conducted by Phadins and Annapoorna (1980) on the PLW indicated janatha refrigerator as an efficient method second to refrigerated storage in maintaining low rate of physiological loss in weight.

Compared to rest of the three room temperature storage methods weight loss in cool chamber was upto three times lower which shows the feasibility of the particular system. The results were supported by studies conducted by Sanjeev kumar and Nath (1993) on fruits stored under zero energy cool chamber which revealed less physiological loss in weight than a room temperature storage. The phyiological loss in weight of sapota fruit was minimum when stored in cool chamber (Nikam and Wasker 1995). Bhatnagar *et al*. (1990) found that Cool Chamber is effective in minimising weight loss. Carrots stored in cool chamber showed less weight loss than stored at room temperature. According to Ghorai and Sethi (1996), the lower PLW at low temperature may be due to the low rate of transpiration and other metabolic activities occurring in vegetables during storage as evidenced by cooler and cool chamber. Where as these activities were at a higher rate, thereby an increased weight loss in other methods such as sprinkling water, covering with leaves and open storage.

4.3 Influence of storage on chemical composition of vegetables

Vegetables continue to respire even after harvest. The respiration of vegetables involves many enzymatic reactions. The rate of these physiological reactions increases exponentially with increase in temperature and may be described mathematically by use of temperature quotient D_{10}. Vant Hoff a Dutch chemist showed that the rate of chemical reaction approximately doubles with each 10°C rise in temperature (Wills *et al*. 1981).

Post-harvest handling of vegetables are important in influencing the chemical composition of the commodities. According to Adair (1966) loss of vitamins minerals and other constituents appear to be inseparable with storage. The changes in the chemical composition of amaranthus, bhindi, bittergourd, brinjal and snakegourd stored in cool chamber in comparison with the other storage methods in two seasons were assessed to observe the efficiency of this low cost storage device in the retention of nutrients in vegetables stored in it. The major nutrients analysed were moisture, fibre, total minerals and ascorbic acid. These nutrients in the fresh samples were also assessed.

4.3.1 Influence of storage on moisture content of vegetables

Moisture content of the vegetables is an important parameter which decides the quality of vegetables. The initial moisture level was usually observed to be altered by storage. Most vegetables contain more than 80% moisture.

Amaranthus

Influence of storage on the moisture content of the amaranthus were studied and presented in Table 21.

Table 21 Influence of storage on moisture content (%) of amaranthus

Storage systems	Season I			Season II		
	Local	Research station	Mean (%)	Local	Research station	Mean (%)
Fresh	85.63	85.63	85.63	85.70	85.33	85.52
Walk-in-cooler	81.43	81.13	81.28	81.57	81.27	81.42
Z.E.C.C.	81.17	80.50	80.83	81.27	80.57	80.92
Sprinkling water	78.17	78.30	78.23	78.27	78.33	78.27
Covering with leaves	77.67	77.50	77.58	77.60	77.60	77.60
Open storage	77.40	77.17	77.28	77.50	77.27	77.38
Mean	80.20	80.04		80.31	80.06	
		SE	CD		SE	CD
A		7.192	-		7.292	-
B		0.125	0.37		0.126	0.37
AB		0.176	-		0.179	-

A - Sources B - Storage systems

The various storage treatments imparted a significant influence on moisture content. Amaranthus stored under walk-in-cooler registered the highest moisture content of 81.28 and 81.42 per cent on the fourth day followed by the amaranthus (80.83 and 80.92 per cent) stored in cool chamber on the first season (September-October period) and second season (February-March) respectively. Where as on the second day itself open stored (77.28 and 77.38 per cent) and leaf covered (77.58 and 77.60 per cent) amaranthus registered lower values for moisture during first and second season respectively which was on par with each other Amaranthus stored by sprinkling water was observed to have a moisture content of 78.23 and 78.27 per cent which was significantly different from all other storage systems on the second day at both seasons. However there was no significant difference observed between two sources ie amaranthus collected from research station and local farmers.

The data revealed that the stored samples generally gave lower values for moisture content than fresh. The moisture content of fresh sample was observed as 85.60 per cent which was significantly higher than the moisture content of the samples stored under different methods. It was noticed that around 5% loss in moisture, compared to fresh was occurred in walk-in-cooler and cool chamber on the 4th day. However it was 7 to 8 per cent in amaranthus stored under atmospheric temperature as early as on the second day of storage.

These observations indicate that the rate of moisture retention of amaranthus stored under cool chamber was almost as effective as the sample stored in walk-in-cooler. The other three storage systems viz. sprinkling water covering with leaves and open stored samples showed much lower levels of moisture compared to zero energy cool chamber which indicated its capacity to prevent moisture loss compared to the three ordinary methods of storage.

Seasonal as well as source variations were not prominent in amaranthus stored under different storage methods.

Bhindi

Table 22 gives the data on the moisture retention of bhindi stored under different storage methods.

The data presented elucidates significant effect of storage on the moisture content of bhindi on the seventh day in both experiments for samples stored in walk-in-cooler and cool chamber. Observations were recorded on the fourth day during the first season and on the third day in the second season in the case of remaining three storage systems studied.

Table 22 Influence of storage on moisture content (%) of bhindi

Storage systems	Season I			Season II		
	Local	Research station	Mean (%)	Local	Research station	Mean (%)
Fresh	89.60	89.53	89.57	89.20	89.93	89.07
Walk-in-cooler	85.57	85.31	85.44	85.20	85.40	85.30
Z.E.C.C.	83.81	83.39	83.60	85.83	84.77	84.80
Sprinkling water	81.75	81.63	81.69	81.23	80.80	81.02
Covering with leaves	81.19	81.09	81.14	81.47	80.87	81.38
Open storage	80.36	80.36	80.36	81.30	80.47	80.67
Mean	83.71	83.54		83.80	83.61	
		SE	CD		SE	CD
A		7.19	-		8.38	-
B		0.12	0.36		0.15	0.42
AB		0.18	-		0.21	-

A - Sources B - Storage systems

As presented in Table 22, fresh sample were found to contain 89.57 and 89.07 per cent moisture in the first and second seasons respectively. During first season (September-October) bhindi stored in walk-in-cooler recorded the highest moisture content of 75.44 per cent followed by the samples stored in cool chamber (83.60 per cent). The lowest moisture level of 80.36 per cent was recorded in Bhindi stored by open storage method. There was no significant difference obtained for bhindi stored by sprinkling water and covering with leaves. The difference in the moisture content of the samples collected from research station and local farmers were not significant. The same pattern of decrease in moisture content was observed in the second season also.

From the results it was concluded that there was better retention of moisture in bhindi stored under walk-in-cooler followed by the sample stored in zero energy cool chamber. In the remaining three common methods of storage this vegetable had very poor moisture retention when observed in the fourth day during first season and third day itself in second season when compared with bhindi stored in walk-in-cooler as well as cool chamber on the seventh day of storage.

No significant difference was observed in the moisture loss of bhindi collected from research station and local farmers.

Bittergourd

The moisture content of fresh as well as stored bittergourd were assessed and the mean values obtained for moisture content for different systems of storage are presented in Table 23.

Table 23 Influence of storage on moisture content (%) of bittergourd

Storage systems	Season I			Season II		
	Local	Research station	Mean (%)	Local	Research station	Mean (%)
Fresh	92.13	92.00	92.17	92.20	92.30	92.25
Walk-in-cooler	88.17	87.83	88.00	88.20	87.93	88.07
Z.E.C.C.	87.63	87.43	87.53	87.63	87.53	87.58
Sprinkling water	83.43	82.90	83.17	83.57	83.17	83.37
Covering with leaves	83.30	82.50	82.90	83.37	82.57	82.97
Open storage	83.03	82.50	82.80	83.13	82.53	82.80
Mean	86.28	85.89		86.35	86.06	
		SE	CD		SE	CD
A		7.06	0.21		7.01	-
B		0.72	0.36		0.12	0.35
AB		0.17	-		0.17	-

A - Sources B - Storage systems

Data in Table 23 indicates the decrease in moisture content of the bittergourd stored under different storage methods. In both the seasons, the pattern of decrease in moisture content was found to be similar. The highest moisture retention was observed for the bittergourd samples stored in walk-in-cooler as 88% and 88.07% during first and second seasons respectively on the eight day of storage. Bittergourd stored in cool chamber recorded a score of 87.63% and 87.58% (I and II seasons respectively) on the same day, which had obtained second highest scores whereas the moisture content of fresh sample was observed to be 92.17% and 92.25%. The lowest moisture level of 82.80% was recorded for bittergourd stored under open storage on the fifth day during September-October period and third day in February-March period. The mean values obtained for the samples collected from local farmers showed significantly higher value (86.28%) compared to research station (85.89%) sample during first season where as the moisture values were statistically on par with each other during the second season.

The results revealed more efficient retention of moisture in the bittergourd stored in walk-in-cooler. The bittergourd samples stored in zero energy cool chamber also showed almost equal efficiency in reducing moisture loss. Other three traditional storage methods showed lower efficiency than walk-in-cooler and zero energy cool chamber.

At the point of rejection (eighth day) the moisture had dropped only by around 4 to 5 per cent in walk-in-cooler and 5 to 6% in zero energy cool chamber where as in other three room temperature storage methods a higher level of 9 to 10 per cent was noticed on fifth day at first season and third day at second season. Significant difference was not noted for moisture loss between bittergourd from the two sources.

Brinjal

Table 24 presents storage changes in moisture content of brinjal under different storage systems during the two seasons.

Table 24 Influence of storage on moisture content (%) of brinjal

Storage systems	Season I			Season II		
	Local	Research station	Mean (%)	Local	Research station	Mean (%)
Fresh	92.37	92.70	92.50	92.50	92.60	92.50
Walk-in-cooler	88.20	88.10	88.20	88.10	87.90	88.00
Z.E.C.C.	87.70	87.50	87.60	87.60	87.60	87.60
Sprinkling water	83.70	83.50	83.60	83.80	83.70	83.80
Covering with leaves	83.50	83.50	83.50	83.50	83.40	83.50
Open storage	83.40	83.40	83.40	83.13	83.17	83.20
Mean	86.50	86.50		86.40	86.40	
		SE	CD		SE	CD
A		8.29	-		7.01	-
B		0.14	0.42		0.12	0.35
AB		0.20	-		0.17	-

A - Sources B - Storage systems

There was significant differences observed among different storage methods. The highest moisture level obtained in brinjal stored under walk in cooler was 88.20% followed by 87.60% on brinjal stored in cool chamber, on the 8th day of storage. The lowest level of 83.40 per cent moisture was recorded in brinjal samples stored by open storage which was on par with the brinjal samples stored by both covering with leaves (83.50%) and by sprinkling water (83.60%). For these three systems data was collected on the 5th day during the first season. The fresh sample value was 92.50% which was higher than the values obtained for the stored samples of brinjal.

In the second season also the same trend in decrease of moisture content was observed. For the three local methods of data of storage attempted data was collected on the third day of storage.

There was no significant difference in the moisture level of brinjal collected from local farm and research station during the two seasons.

From these observations it can be concluded that brinjal stored in the cool chamber has minimum moisture loss similar to that of the vegetable stored in walk-in-cooler which is around five per cent on the eighth day of storage. However in other three storage systems higher moisture loss of 8-10 per cent were recorded by a storage period of 5 days during first season and by a still lesser day of 3 during second season.

Snakegourd

Table 25 elucidates influence of storage on moisture content of snakegourd stored under five different storage methods.

Table 25 Influence of storage on moisture content (%) of snakegourd

Storage systems	Season I			Season II		
	Local	Research station	Mean (%)	Local	Research station	Mean (%)
Fresh	94.67	94.53	94.60	94.43	94.57	94.60
Walk-in-cooler	90.77	89.63	90.20	89.97	89.77	89.90
Z.E.C.C.	89.57	89.30	89.40	89.70	89.50	89.60
Sprinkling water	85.83	85.63	85.70	86.87	86.07	86.47
Covering with leaves	85.50	85.53	85.50	85.67	85.70	85.70
Open storage	85.40	85.53	85.50	85.50	85.60	85.60
Mean	88.62	88.36		88.70	88.50	
		SE	CD		SE	CD
A		0.12	-		6.59	-
B		0.21	0.62		0.11	0.33
AB		0.30	-		0.16	-

A - Sources B - Storage systems

The data was collected on the ninth day in both the structure viz. cooler and cool chamber where as it was on the seventh and fifth day in methods such as sprinkling water covering with leaves and open storage during the first and second seasons. The fresh samples recorded a score of 94.60% for both the seasons.

During the first season, the snakegourd stored in zero energy cool chamber recorded a score of 89.40% which was on par with the snakegourd stored in walk-in-cooler (90.20%). There was no significant difference in the moisture level of vegetable samples stored by the remaining three storage systems.

For the second season the values obtained for the snakegourd stored in the cooler (89.90%) and in the cool chamber (89.60%) were on par with each other. The maximum loss of moisture was observed in open stored samples (85.60%).

The difference between two sources viz. Local farm and research station were also negligible. From the results of the moisture retention effect of different storage systems in two seasons, efficiency of walk in cooler and zero energy cool chamber as a storage structure in preserving the moisture content of snakegourd can be emphasised. The loss recorded was limited to 4 to 5% in walk-in-cooler and zero energy cool chamber on the eighth day of storage as against 9 to 10 per cent loss in other three methods on the seventh and fifth day at the two storage spells.

Finding of this experiment showed that moisture loss can be reduced to great extent by storing in refrigerated system walk-in-cooler. Further it was also proved that moisture loss could be minimised to considerable level by making use of the low cost technology viz. zero energy cool chamber while the refrigerated method was not affordable to local farmers.

Salunkhe and Wu (1976) reported that all fruits and vegetables continue to loose water vapour after they are harvested. The results of storage studies conducted by other workers also revealed loss of moisture by storage. Most vegetables in fresh form contain morethan 80% water, loss in water causes many vegetables to appear wilted or shrivelled and eventually unmarketable (Kaul, 1989). Studies conducted by Omprakash (1995) reported that for the moisture loss can be minimised by storing them at low temperature and humidity conditions. The present results are in tune with the above reports.

Findings of the experiment showed that moisture loss can be reduced to great extent by storing in the refrigerated device walk in cooler. It was also proved that the moisture loss could be minimised to a considerable level during storage by making use of the low cost technology viz. zero energy cool chamber as while the refrigerated method was not affordable to local farmers. In this device, by the evaporation of water and transfer of heat a low temperature as well as high humidity is maintained. Hence among the low cost methods studied best moisture retention was achieved in the zero energy cool chamber for all the vegetables experimented on two different seasons compared to the other indigenous methods viz. sprinkling water, covering with leaves and open storage. The moisture loss was at a slower rate when stored in cool chamber. Joshi and Khandekar (1993) revealed that in cool chamber storage the moisture retention of both ripe and full ripe stages of tomato was more than those samples stored at ambient temperature storage.

4.3.2 Influence of storage on the total mineral content of vegetables

Vegetables provide almost all the nutrients including minerals. As reported by Nath (1987) leafy and some other vegetables can supply calcium and Iron at low cost. The mineral retention of vegetables like amaranthus, bhindi, bittergourd, brinjal and snakegourd stored by different storage methods are discussed below.

Amaranthus

Table 26 contains the mineral content of fresh samples of Amaranthus as well as the stored samples.

Table 26 Influence of storage on total mineral content (g) of amaranthus

Storage systems	Season I			Season II		
	Local	Research station	Mean (%)	Local	Research station	Mean (%)
Fresh	2.63	2.40	2.52	2.70	2.30	2.50
Walk-in-cooler	2.30	2.30	2.30	2.43	2.30	2.40
Z.E.C.C.	2.23	2.13	2.20	2.33	1.97	2.20
Sprinkling water	2.10	2.13	2.10	2.00	2.10	2.10
Covering with leaves	1.93	2.00	1.97	2.10	1.90	2.00
Open storage	1.90	1.87	1.90	2.10	1.80	1.97
Mean	2.18	2.14		1.28	2.08	
		SE	CD		SE	CD
A		4.86	-		5.54	-
B		8.42	0.25		9.60	0.28
AB		0.12	-		0.14	-

A - Sources B - Storage systems

The data reveals a significant difference in the mineral content of fresh sample value (2.52) and samples stored. The highest mineral retention (2.30) was observed in samples stored in walk-in-cooler during the 4th day of storage followed by the samples (2.20) stored in zero energy cool chamber in the first season. Significant difference was observed between the samples stored by sprinkling water covering with leaves and also by open storage. Lowest value for minerals (1.90) was noticed in samples stored in open method on second day.

A comparison with the mineral values of vegetable for different sources viz. local farm and research station were statistically on par with one another.

During season II (February-March) the same pattern of decrease in mineral content was observed except for amaranthus which was stored by sprinkling with water and leaf covering. The values obtained were on par with each other. A comparison between the two sources also revealed similar results.

As per the results, the lowest mineral loss was observed in the samples stored in cool chamber second only to samples stored in cooler. However the mineral loss was higher in the samples stored by other three storage systems on the second day it self against four days storage in cooler and cool chamber samples. The difference in mineral loss between amaranthus collected from the two sources as well as stored in seasons I and II were negligible.

Bhindi

Bhindi is a fair source of minerals. Changes in the level of total mineral content of bhindi due to storage under different media are presented in Table 27.

Table 27 Influence of storage on total mineral content (g) of bhindi

Storage systems	Season I			Season II		
	Local	Research station	Mean (%)	Local	Research station	Mean (%)
Fresh	0.70	0.67	0.68	0.71	0.69	0.70
Walk-in-cooler	0.68	0.68	0.68	0.69	0.65	0.67
Z.E.C.C.	0.62	0.64	0.63	0.68	0.64	0.66
Sprinkling water	0.59	0.61	0.60	0.67	0.64	0.66
Covering with leaves	0.59	0.56	0.58	0.64	0.61	0.63
Open storage	0.59	0.57	0.58	0.63	0.61	0.62
Mean	0.63	0.63		0.67	0.64	
		SE	CD		SE	CD
A		8.90	-		8.16	-
B		1.54	4.50		0.01	4.13
AB		2.18	-		1.99	-

A - Sources B - Storage systems

The data were collected on the seventh day from samples stored in cooler as well as in cool chamber during the two seasons. In the remaining three storage system, similar data was collected on fourth and third day of storage during 1st and 2nd season respectively. The fresh bhindi registered a mean value for minerals as 0.68 g and 0.7 g in 1 and 2nd season.

During the season I the highest mineral value of 0.68 g (which was same for fresh sample) was recorded in the bhindi stored in cooler while samples stored in cool chamber recorded a mean value of 0.63 for the total mineral retention of bhindi. This was significantly different from the mineral content of the samples stored in cooler. However bhindi stored by the other three storage systems recorded significantly lower values for mineral content. In the samples stored by open storage method and leaf covering same mineral content was recorded and this was on par with the values obtained for bhindi stored by sprinkling water method. Values obtained for the stored sample procured from two sources were also on par with each other. Bhindi stored in February-March recorded the highest value 0.67 g, in cooler and this was more or less similar to the values obtained for fresh Bhindi. Bhindi stored by sprinkling water method as well as cool chamber storage depicted similar values for mineral retention. However the samples stored in the remaining two storage methods recorded significantly lower mineral content. Samples procured from the two sources recorded no notable difference.

It was concluded that the highest retention for minerals was observed in samples kept in walk-in-cooler. This was followed by the samples stored in zero energy cool chamber on the seventh day. Samples kept in other three storage systems recorded lower in mineral content than the fresh as well as cooler stored bhindi at lesser periods of four and three days of storage during first and second season respectively. The difference for mineral content between the samples procured from the two sources were negligible.

Bittergourd

The difference in mineral content due to storage in bittergourd was studied and results obtained is given Table 28.

Table 28 Effect of storage on total mineral content (g) of Bittergourd

Storage systems	Season I			Season II		
	Local	Research station	Mean (%)	Local	Research station	Mean (%)
Fresh	0.81	0.81	0.81	0.82	0.82	0.82
Walk-in-cooler	0.78	0.79	0.79	0.79	0.79	0.79
Z.E.C.C.	0.78	0.77	0.77	0.77	0.77	0.77
Sprinkling water	0.75	0.75	0.75	0.77	0.77	0.77
Covering with leaves	0.75	0.75	0.75	0.75	0.75	0.75
Open storage	0.74	0.73	0.73	0.75	0.73	0.74
Mean	0.78	0.77		0.77	0.77	
		SE	CD		SE	CD
A		7.76	-		8.10	-
B		1.34	3.92		1.40	4.09
AB		1.90	-		1.98	-

A - Sources B - Storage systems

In the season first, bittergourd in cooler (0.79 g) showed more or less the same mineral content as that of fresh bittergourd (0.81 g). However mineral content of 0.77 g was observed for bittergourd stored in cool chamber which was on par with walk-in-cooler. Samples kept in the other three storage systems recorded significantly lower values. Value obtained for samples stored by sprinkling water method or leaf covering were similar (0.75 g). This was on par with the values (0.73) obtained for samples stored by open storage. The bittergourd collected from the two sources recorded no significant difference in the total mineral content after storage.

In the second season highest value of 0.79 g for minerals was observed in samples kept in cooler while the value obtained for fresh bittergourd was 0.82 g. Bittergourd stored in cool chamber as well as in cooler recorded same value for mineral content. Sample kept in the remaining three recorded significantly lower values. A comparison of mineral content for bittergourd procured from both the sources revealed similarity.

During both season highest value was recorded for bhindi stored in walk-in-cooler was more or less same to the samples in zero energy cool chamber. From the results it was evident that cool chamber stands almost similar to cooler in retention of minerals during storage. Difference between samples stored from both sources and in the two seasons were negligible.

Brinjal

The mineral retention of brinjal stored under different storage method is presented in Table 29.

Table 29 Influence of storage on the total mineral content (g) of brinjal

Storage systems	Season I			Season II		
	Local	Research station	Mean (%)	Local	Research station	Mean (%)
Fresh	0.30	0.32	0.31	0.31	0.31	0.31
Walk-in-cooler	0.29	0.28	0.27	0.31	0.29	0.30
Z.E.C.C.	0.26	0.26	0.26	0.28	0.27	0.27
Sprinkling water	0.27	0.24	0.26	0.26	0.26	0.26
Covering with leaves	0.27	0.23	0.25	0.25	0.25	0.25
Open storage	0.24	0.24	0.24	0.25	0.25	0.25
Mean	0.27	0.26		0.28	0.28	
		SE	CD		SE	CD
A		5.58	-		6.02	-
B		9.67	2.82		1.04	3.04
AB		1.37	-		1.48	-

A - Sources B - Storage systems

As depicted in Table 29 the fresh sample had a mineral content of 0.31 during both the seasons. The highest retention of mineral during storage was observed in brinjal stored under walk-in-cooler 0.27 and 0.30 g during first and second seasons respectively which was almost similar to fresh sample. Brinjal stored in cool chamber recorded mineral content as 0.26 g and similar value was recorded for samples stored by sprinkling water method during first season. While during the second season samples stored in zero energy cool chamber registered mineral value as 0.27 g which was significantly different from the values obtained for samples stored by sprinkling water method. As per the values there was no significant difference noted between the values obtained for samples stored by leaf coverage (0.25 g) and kept in open storage (0.24 g). Same values (0.25 g) were obtained for the samples in open storage and leaf covering for the second season. Samples procurred from the two sources recorded no marked difference in the first and second season.

It was clearly evident that the efficiency of mineral retention in the samples stored in zero energy cool chamber were compatable with the value of the samples kept in walk-in-cooler during both seasons. Samples kept in the remaining three storage methods recorded lowest values. The difference for mineral values between the samples procured from two sources were negligible.

Snakegourd

Influence of storage on the total mineral content of snakegourd are presented in Table 30.

Table 30 Effect of storage on total mineral content (g) of snakegourd

Storage systems	Season I			Season II		
	Local	Research station	Mean (%)	Local	Research station	Mean (%)
Fresh	0.55	0.54	0.54	0.51	0.50	0.50
Walk-in-cooler	0.51	0.49	0.50	0.51	0.49	0.50
Z.E.C.C.	0.45	0.45	0.45	0.47	0.47	0.47
Sprinkling water	0.43	0.41	0.42	0.45	0.44	0.46
Covering with leaves	0.42	0.39	0.40	0.39	0.39	0.39
Open storage	0.44	0.37	0.40	0.41	0.38	0.40
Mean	0.47	0.44		0.46	0.45	
		SE	CD		SE	CD
A		9.54	-		9.09	-
B		1.65	4.83		1.56	4.55
AB		2.34	-		2.20	-

A - Sources B - Storage systems

A highest value of 0.50 g was observed in the samples stored in cooler during both the seasons which was almost similar to fresh. Whereas it was 0.45 and 0.47 for samples stored in cool chamber in first and second seasons. This loss was found to be minimum compared to remaining storage methods. Samples stored by the three storage systems such as sprinkling water, covering with leaves and open storage of snakegourd registered significantly lower values of mineral content. The difference for mineral retention between the two sources were not significant in both the seasons.

In snakegourd also the highest efficiency of mineral retention was observed in the samples kept in walk-in-cooler almost similar to the samples kept in zero energy cool chamber on the ninth day during both the seasons. In the three traditional storage methods the stored samples recorded poor mineral content on the 7th day in season I and on the 5th day during season II.

Considering the performance of vegetables stored under different methods in this study, samples kept walk-in-cooler recorded the maximum retention. It is already a known fact that refrigeration is the most effective method in the retention of nutrients when perishable foods are stored. Cool chamber was effective as second highest in mineral conservation, a low cost method affordable to local farmers. The construction is also simple at the same time it showed an efficiency compatable with walk-in-cooler. But the samples in other three commonly used storage methods reported very low mineral retention. However variation in seasons and sources recorded almost no significant difference. Tressler and Evers (1957) reported that loss of minerals appear to be inseparable with storage.

4.3.3 Influence of storage on fibre content of vegetables

Vegetables provide fair amounts of fibre which helps to nutralise the acid content of food during digestion. However during storage this constituents is found to increase affecting the taste and palatability of the food. Increased fibre content was food is observed to reduce the consumer acceptance. It also helps in determining the market span and storage life of vegetables. So in this experiment estimation of fibre content is also included to find out the efficiency of the selected storage systems. In perishable crops like vegetables as the fibre content increases the storage efficiency decreases. The results obtained in this study are discussed below.

Amaranthus

Table 31 details the fibre content of amaranthus stored under different storage media.

Average fibre content of 1.35 g was observed in fresh amaranthus during Season I. There was significant difference in fibre content recorded in leaves stored under different systems. Lowest fibre content (1.67 g) was observed in amaranthus stored in walk-in-cooler followed by the samples (1.78 g) stored in zero energy cool chamber. The highest fibre content was observed in samples kept for open storage (2.07g) which was significantly higher than the fibre content of leaves stored by all the other storage systems. No significant difference of fibre content was observed between two sources.

Table 31 Influence of storage on fibre content (g) of amaranthus

Storage systems	Season I			Season II		
	Local	Research station	Mean (%)	Local	Research station	Mean (%)
Fresh	1.16	1.53	1.35	1.27	1.30	1.28
Walk-in-cooler	1.53	1.80	1.67	1.43	1.80	1.62
Z.E.C.C.	1.67	1.90	1.78	1.50	1.83	1.67
Sprinkling water	1.77	1.90	1.83	1.70	2.03	1.87
Covering with leaves	1.70	2.17	1.93	1.57	2.40	1.98
Open storage	1.90	2.23	2.07	1.77	2.63	2.20
Mean	1.62	1.92		1.54	2.00	
		SE	CD		SE	CD
A		5.713	-		6.781	-
B		9.896	0.289		0.117	0.343
AB		0.139	-		0.166	-

A - Sources B - Storage systems

During season II the same pattern of increase in fibre content was observed in all the samples stored under different methods. In this season also no marked difference was observed in the fibre content of leaves between two sources. Data was collected on the fourth day for the two sets of samples stored in walk-in-cooler as well as in cool-chamber and on the second day for the leaves stored under the remaining three storage system during season-I and season-II.

Lowest variation in fibre was observed on the fourth day in the samples stored in walk-in-cooler followed by the samples stored in cool chamber. Where as fibre concentration on the second day itself was higher in samples stored under the remaining three atmospheric storage methods.

Bhindi

Table 31 details the changes occurred in fibre content of bhindi stored under different storage media.

Table 32 Influence of storage on fibre (g) content of bhindi

Storage systems	Season I			Season II		
	Local	Research station	Mean (%)	Local	Research station	Mean (%)
Fresh	1.25	1.45	1.35	1.25	1.297	1.27
Walk-in-cooler	1.74	1.80	1.80	1.46	1.52	1.44
Z.E.C.C.	1.85	2.28	2.06	1.51	1.65	1.58
Sprinkling water	2.28	2.15	2.22	2.02	2.51	2.26
Covering with leaves	2.27	2.22	2.25	2.05	2.13	2.09
Open storage	2.30	2.56	2.43	2.29	2.48	2.39
Mean	1.95	2.08		1.76	1.93	
		SE	CD		SE	CD
A		6.50	-		5.43	0.16
B		0.11	0.33		9.40	0.27
AB		0.16	-		0.13	-

A - Sources B - Storage systems

As presented in Table there was marked increase in fibre content during season I. The highest value for fibre content (2.43g) was obtained on the fourth day in the samples stored by open storage. Lowest value was obtained in walk-in-cooler (1.8g). In this ranking order last but one was found to better samples stored in cool chamber (2.06 g) during seventh day of storage in the first season. The fresh value was 1.35 g. The difference for fibre content in bhindi stored as well as fresh samples were significantly different. There was no significant difference observed in the fibre content between the two sources in the first season.

During season-II also the same storage pattern was followed for both the systems. Bhindi collected from local farm (1.76) showed minimum fibre content than research station sample (1.93). However the data was collected on the third day for the samples stored by sprinkling water, covering with leaves and also by open storage.

Analysis of data further indicates that the stored samples in cool-chamber recorded lowest variation in fibre content even on the seventh day of storage, indicating that, this storage system is compatable where the observation on fibre content was more or less similar with walk-in-cooler on the same day. While the other three storage system revealed very high variation in the fibre content of the samples stored during fourth and third day of storage itself in Season I and II.

Bittergourd

Table 33 elucidates the changes in fibre content of bittergourd collected from two different sources under five storage system during the two seasons.

Table 33 Influence of storage on fibre content (g) of bittergourd

Storage systems	Season I			Season II		
	Local	Research station	Mean (%)	Local	Research station	Mean (%)
Fresh	0.81	0.81	0.81	0.83	0.83	0.83
Walk-in-cooler	0.92	0.93	0.93	0.90	0.94	0.92
Z.E.C.C.	0.94	1.01	0.98	0.93	0.43	0.93
Sprinkling water	1.09	1.11	1.10	1.17	1.12	1.15
Covering with leaves	1.63	1.01	1.02	1.03	1.07	1.05
Open storage	1.11	1.15	1.13	1.11	1.14	1.13
Mean	0.98	1.01		0.10	0.01	
		SE	CD		SE	CD
A		2.17			1.99	
B		3.76	0.11		3.45	0.10
AB		5.31			4.88	

A - Sources B - Storage systems

As indicated in Table there was an increase in the fibre content of samples stored in all the five storage systems. During season-I the higher variation in fibre content (1.13g) was observed in samples stored by open storage. While lowest variation was noted in the samples stored in cool chamber (0.9g). This variation was found to be on par with the samples stored in walk-in-cooler (0.93g). In the other three storage systems very high fibre content was recorded. However there was no significant difference observed between the two sources such as local farm and research station in the fibre content of the stored samples. The data was collected on the eighth day for samples kept in cooler and cool chamber during seasons I and II whereas for other storage media data was elicited on the fifth day during season-I and third day during season-II.

During season-II also the same pattern of increase in fibre content after storage was observed in bittergourd. It was concluded that eight day storage in the walk-in-cooler as well as in cool chamber resulted in the enhancement of fibre content. In the other three storage systems increase in fibre content was even more in lesser periods viz. on fifth and third days of storage during season I and season II respectively.

Brinjal

Influence of storage on fibre content of brinjal stored under different storage methods are presented in Table 34.

Table 34 Influence of storage on fibre content (g) of brinjal

Storage systems	Season I			Seasons II		
	Local	Research station	Mean (%)	Local	Research station	Mean (%)
Fresh	1.30	1.31	1.31	1.29	1.32	1.31
Walk-in-cooler	1.34	1.38	1.36	1.38	1.38	1.38
Z.E.C.C.	1.46	1.44	1.45	1.40	1.40	1.40
Sprinkling water	1.51	1.52	1.52	1.61	1.66	1.64
Covering with leaves	1.41	1.42	1.42	1.62	1.85	1.73
Open storage	1.52	1.68	1.60	1.72	1.86	1.79
Mean	1.42	1.46		1.50	1.58	
	CD	SE		CD	SE	
A		2.00			2.59	
B	0.10	3.47		0.13	4.49	
AB		4.91			6.35	

A - Sources B - Storage systems

As revealed in the Table lowest fibre content was observed in samples stored in walk-in-cooler which maintained the same status as fresh followed by the samples stored in zero energy cool chamber 1.36 g and 1.45 g respectively during a period of eight days storage. Highest value for fibre content was recorded in samples stored by open storage method (1.6g). Brinjal stored by water sprinkling and leaf covered methods recorded 1.52g and 1.42 g respectively for fibre after five days storage. Brinjal stored under the three atmospheric temperature storage recorded significant differences for fibre content on the fifth day during season-I. However there was no significant difference observed between the stored samples procured from the two sources.

During the second season enhancement of fibre content was similar in brinjal stored under different storage methods procured from both the sources. But the values on fibre related to the three locally practiced methods were that of the analysis on third day.

From the results lower fibre content and highest efficiency was observed in the samples stored in walk-in-cooler, followed by zero energy cool chamber. In the other three indigenous methods very high fibre content in brinjal was recorded. It was also noted that this difference was occured on the eighth day of storage for brinjal in zero energy cool chamber and walk-in-cooler where as the difference was recorded earlier in sprinkling water, leaf covering and open storage method ie. with five days and three days of storage in season I and II respectively.

Snakegourd

Table 36 included changes occured in the fibre content of snakegourd stored under different storage methods.

Table 35 Influence of storage on fibre content (g) of snakegourd

Storage systems	Season I			Season II		
	Local	Research station	Mean	Local	Research station	Mean
Fresh	0.78	0.82	0.80	0.68	0.68	0.68
Walk-in-cooler	0.85	0.91	0.88	0.82	0.89	0.86
Z.E.C.C.	0.86	0.95	0.95	0.83	0.93	0.88
Sprinkling water	0.94	1.67	1.30	0.99	0.99	0.99
Covering with leaves	0.99	1.80	1.40	0.98	0.98	0.98
Open storage	0.96	1.90	1.43	0.96	1.70	1.33
Mean	0.89	1.34		0.88	1.03	
	CD	SE		CD	SE	
A		2.57			2.78	
B	0.13	4.46		0.14	4.81	
AB		0.06			6.80	

A - Sources B - Storage systems

As per the Table the lowest value of 0.88g for fibre was recorded in the samples stored in walk-in-cooler and 0.86 zero energy cool chamber. Both systems did not show any significant difference in comparison with fresh. The fibre content was observed to be very high in samples stored by open storage (1.43 g). All the storage systems showed significant difference in the fibre content of samples stored during second season. There was no significant difference occurred in the samples procured from two sources during seasons I and II. Almost the same pattern of increase in fibre content was observed on the second season also.

From the results walk-in-cooler is found to have the highest efficiency in maintaining the fibre content of the stored snakegourd samples. Snakegourd stored in zero energy cool chamber showed almost the same efficiency to check increase in fibre content compared to cool chamber stored samples. In the remaining three storage methods fibre content was found to be increasing in higher rates. Fibre content of samples stored Z.E.C.C. was observed on ninth day during both seasons. However fibre levels were assessed on the seventh and fifth day in the samples stored in the remaining three atmospheric storage methods.

The results obtained from the analysis of fibre content of vegetables stored under different storage methods revealed highest efficiency in conserving fibre in sample stored in walk-in-cooler closely followed by cool chamber. The cooler is an energy oriented device and need specialised person for its maintenance and fabrication. Since the zero energy cool chamber does not involve energy and can be handled by uneducated labourers, this is an advantage over the more efficient cooler. Vegetables stored in the three tradtional methods showed a more elevated fibre content upon storage.

This indicated the poor ability of these three conventional methods to regulate fibre formation.

Studies conducted by Pal *et al*. (1991) on carrot stored by spraying maleic hydroxide revealed that the crude fibre followed an upward trend during storage. Dickman *et al*. (1993) reported lower increase of fibre in water misted vegetables compared with samples stored without misting.

4.3.4 Influence of storage on ascorbic acid content of vegetables

Many vegetables are rich sources of ascorbic acid. Ascorbic acid is an important chemical parameter to study the storage performance of vegetables. Hence the ascorbic acid retention of vegetables such as amaranthus, bhindi, bittergourd, and brinjal stored under different storage methods viz. walk-in-cooler, zero energy cool chamber, sprinkling water, covering with leaves and open storage were assessed. The results obtained are discussed below.

Amaranthus

Table 36 elucidates influence of storage on ascorbic acid content of amaranthus.

Table 36 Influence of storage on ascorbic acid content (mg) of amaranthus

Storage systems	Season I			Season II		
	Local	Research station	Mean	Local	Research station	Mean
Fresh	99.00	97.30	98.20	97.70	95.30	96.50
Walk-in-cooler	91.10	90.80	90.95	91.50	91.10	91.30
Z.E.C.C.	83.20	82.80	82.98	83.10	83.10	83.10
Sprinkling water	77.23	77.60	77.40	77.20	77.20	77.20
Covering with leaves	63.20	63.20	63.20	63.60	63.40	63.50
Open storage	59.50	59.30	59.40	59.60	59.40	59.50
Mean	78.90	78.50		78.80	78.30	
		SE	CD		SE	CD
A		0.21	-		0.34	-
B		0.36	1.04		0.59	1.71
AB		0.50	-		0.83	-

A - Sources B - Storage systems

As per the values obtained the highest ascorbic acid retention was observed in walk-in-cooler (90.95 mg). Amaranthus stored under cool chamber was found to contain ascorbic acid of 82.98 mg which was significantly different from the ascorbic acid level of sample stored in cooler. The lowest ascorbic acid value were recorded for vegetables kept in open storage (59.40 mg). Amaranthus stored under leaf covering was found to have lower ascorbic acid (63.2 mg) than the samples stored by sprinkling water (77.4mg). The latter recorded significant difference with the ascorbic acid values of samples stored by open storage method.

The same pattern of ascrobic acid retention during different methods of storage was observed during season II also. In both the seasons there was no significant difference between the two sources viz. samples procured from local farm and from Instructional farm. Ascorbic acid was estimated in stored samples on the fourth day kept in cooler, as well as in cool chamber and on second day in samples kept in sprinkling water method, covering leaves and open storage in two seasons.

The efficiency in retaining ascorbic acid of amaranthus on storage was found superior in walk-in-cooler. This advantage with zero energy cool chamber storage was also high when assessed on fourth day. Sprinkling water method was able to retain this nutrient to a satisfactory level whereas covering with leaves and open method performed poor in preventing ascorbic acid loss on the second day itself during both the seasons.

Bhindi

Ascorbic acid content of bhindi stored under different storage methods are detailed in Table 37.

Table 37 Influence of storage on ascorbic acid content (mg) of bhindi

Storage systems	Season I			Season II		
	Local	Research station	Mean	Local	Research station	Mean
Fresh	13.03	12.87	12.95	12.97	12.87	12.92
Walk-in-cooler	11.83	11.77	11.80	11.83	11.33	11.58
Z.E.C.C.	10.93	10.80	10.87	10.73	10.47	10.60
Sprinkling water	10.27	10.10	10.18	10.27	9.87	10.07
Covering with leaves	8.40	8.37	8.38	8.30	8.17	8.23
Open storage	7.77	7.67	7.72	7.67	7.37	7.52
Mean	10.37	10.26		10.29	10.01	
		SE	CD		SE	CD
A		5.93	-		6.11	0.18
B		0.10	0.3		0.11	0.31
AB		0.15	-		0.15	-

A - Sources B - Storage systems

As detailed in Table a reduction in ascorbic acid content was observed when compared to fresh samples. Samples procured from walk-in-cooler and cool chamber were estimated on the seventh day of storage. The same analysis was taken up in samples stored by the three atmosphere storage method on the fourth day itself during the first season and on the third day in the second season.

The highest retention of ascorbic acid was observed in bhindi stored in walk-in-cooler (11.80 mg and 11.55 mg) followed by samples stored in cool chamber and by sprinkling water. However samples stored by open storage registered the lowest value for ascorbic acid. This nutrient level was drastically reduced to 7.72 mg and 7.52 mg at first and second seasons as against 12.95 mg and 12.92 mg in the fresh vegetable. Samples stored by covering leaves also gave significantly lower values of ascorbic acid. The same trend was observed in the second season also. The difference between local sources and research station were also found to be negligible during first season, but locally collected (10.9) bhindi contain more ascorbic acid than Instructional Farm (10.01) samples.

As evidenced by the data capability of zero energy cool chamber to prevent loss of ascrobic acid upon storage was next to the refrigeration method - walk-in-cooler. Sprinkling water method also maintained ascorbic acid values of bhindi to satisfactory levels. Whereas when covered with leaves the ascorbic acid retention was found to be lower and openly stored sample gave the least retention.

Bittergourd

Effect of storage on ascorbic acid content on the eighth day in samples stored in walk-in-cooler and cool chamber while similar results were observed on the 5th day and third day in samples stored with leaves, water sprinkles and open storage. Details are presented in Table 38.

Table 38 Influence of storage on ascorbic acid content (mg) of bittergourd

Storage systems	Season i			Season II		
	Local	Research station	Mean	Local	Research station	Mean
Fresh	88.23	87.93	88.08	88.20	88.03	88.12
Walk-in-cooler	80.43	80.53	80.73	81.17	80.90	81.03
Z.E.C.C.	73.83	73.50	73.67	73.60	73.70	73.70
Sprinkling water	68.56	68.50	68.52	68.70	68.50	68.60
Covering with leaves	56.10	56.40	56.25	56.20	56.50	56.30
Open storage	52.80	52.47	52.63	52.90	52.60	52.70
Mean	70.07	69.89		70.10	70.0	
		SE	CD		SE	CD
A		0.13	-		0.12	-
B		0.22	0.64		0.20	0.596
AB		0.31	-		0.29	-

A - Sources B - Storage systems

From the data the highest score of 80.73 mg was observed in samples stored in cooler followed by 73.67mg in samples stored in cool chamber. Ascorbic acid level of fresh bittergourd was found to be 88.08 mg during the first season.

The lowest value for ascorbic acid (52.63 mg) was observed in samples stored by open storage. Samples stored in leaf covered method had a ascorbic acid level of 56.25 mg and a higher value (68.52 mg) was observed in samples stored by sprinkling water method. During February-March season also similar trend in ascorbic acid retention was observed. Samples collected from the two sources such as local farm and Instructional farm was on par with each other in ascorbic acid level.

From the results it was concluded that the highest ascorbic acid retention was observed in samples stored in cooler followed by cool chamber stored samples on the eighth day of storage. During the two seasons samples kept in the remaining three storage methods recorded poor retention of ascorbic acid even with in five days and three days of storage in first and second seasons respectively.

Brinjal

Table 39 depicts the changes occurred in ascorbic acid content of brinjal stored under five different storage media during first and second seasons.

Table 39 Influence of storage on ascorbic acid content (mg) of brinjal

Storage systems	Season I			Season II		
	Local	Research station	Mean	Local	Research station	Mean
Fresh	11.93	11.93	11.93	12.07	12.00	12.03
Walk-in-cooler	11.10	11.03	11.07	11.03	11.10	11.07
Z.E.C.C.	10.10	9.90	10.00	10.20	10.13	10.17
Sprinkling water	9.43	9.37	9.40	9.37	9.13	9.25
Covering with leaves	7.63	7.66	7.62	7.43	7.53	7.48
Open storage	7.30	6.97	7.13	7.27	7.30	7.28
Mean	9.58	9.47		9.56	9.53	
		SE	CD		SE	CD
A		6.02	-		6.51	-
B		0.10	0.30		0.11	0.33
AB		0.15	-		0.16	-

A - Sources B - Storage systems

Brinjal collected from research station and local sources showed reduced ascorbic acid level due to storage. There was significant difference in ascorbic acid level observed during both the seasons compared with ascorbic acid level of 11.93 mg and 12.03 mg of fresh samples during first and second seasons respectively. The samples were analysed on the eighth day for both the brinjal samples stored in cooler and cool chamber, which recorded the highest value (11.07 mg) for walk-in-cooler followed by samples kept in zero energy cool chamber (10.00 mg). There was significant difference observed among the samples stored by sprinkling water, leaf covering and open storage on the fourth day of storage itself. The same trend was observed during the second season also. Samples procured from two sources such as local farm and Research Station were on par with each other on their ascorbic acid content.

As per the results prevention of ascorbic acid of brinjal during storage was most effective when stored in walk-in-cooler immediately followed by zero energy cool chamber. Ascorbic acid retention was better in sprinkling water method when among the three room temperature storage practices studied. While ascorbic acid levels were highly affected by storage by both leaf covered and openly stored brinjal.

The results reveal that the highest ascorbic acid retention was observed in samples kept in walk-in-cooler followed by samples kept in cool chamber. At the same time cool chamber storage presented a highly beneficial result in preventing ascorbic acid loss among the non energy oriented methods. Samples of open storage and covering with leaves showed very poor retention in ascorbic acid for all the vegetables stored. Seasons as well as sources of procurement were found to have no effect on the assorbic acid levels of the stored vegetables.

According to Devadas *et al*. (1965) the refrigerator stored amaranthus recorded lowest ascorbic acid loss ie. 8% followed by samples kept in Janata refrigeration (18.1%) and the highest loss of 22.9% was recorded in moist cloth covered amaranthus. Studies conducted by Pushpamma and Joshi (1970) found maximum loss of ascorbic acid in samples stored by open storage and minimum in freezing. The above reports coinside with the result of the present study. Janata refrigeration also works based on evaporative cooling method similar to zero energy cool chamber. Lowest ascorbic acid level of vegetables kept in open temperature may be due to relatively higher utilisation acid in respiration process (Ghorai and Sethi, 1996).

Influence of storage on the chemical constituents such as moisture, total mineral, fibre and Ascorbic acid content of stored vegetables under the experiment showed highest efficiency in vegetables kept in walk-in-cooler followed by the samples in cool chamber with regard to ascorbic acid retention, the efficiency of cool chamber was well comparable to refrigerated cooler. Compared to all the other three storage methods at room temperature the zero energy cool chamber showed highest effiency in retaining nutrients and in reducing fibre content.

Ghorai and Sethi (1996) reports that at low temperature minimum loss in chemical constituents may be due to low physiological metabolic and enzyme activities as compared to ambient storage. Phadins and Annapoorna (1980) opined that the janatha refrigerator operated on evaporative cooling method was the best method, for retaining nutrient during storage of green vegetables. According to Roy and Khurdiya (1982) in cool chamber the moisture content, TSS and acidity retention was more than ambient temperature storage.

Vant Hoff, the Dutch chemist showed that the rate of chemical reaction increases with increase in temperatures.

From these it can be summarised that zero energy cool chamber is good method for storing vegetables in which the chemical loss was low and comparable to the samples in walk-in-cooler for which huge capital is needed for constrution and maintenance. However the zero energy cool chamber is a very low cost storage structure based on natural cooling by evaporation of water. Because of the reason this device may be a feasible method for the local vegetable growers for storing excess vegetables prior to marketing.

4.4 Influence of storage on microbial spoilage of stored vegetables

One of the main losses occuring during the pre-harvest period is spoilage due to pathogens. Serious losses occur due to disease caused by fungi bacteria and infestation caused by storage pest. Pimentel (1983) estimates that 10-21 per cent post-harvest loss occur due to pathogens. According to Chowdhary (1968) higher losses occur in vegetables chiefly due to transit loss caused by fungi. As reported by Pantastico (1977) the increase in number of handling was found to increase in percentage of spoilage. The shelf life quality of vegetables depend very much on microbial safety. Hence it was necessary to find out whether there was any development of spoilage microflora in the vegetable during the short term storage period.

Microbial examination was carried out on the day of shelf life assessment for condamination by yeast, fungus and bacteria. Spoilage of vegetables due to organisms were detected only in brinjal and bittergourd stored by sprinkling water method. Vegetables under all the other storage methods observed no visible presence of micro organism within the short span of study. In both these vegetables white cottony growth was observed on the surface. The laboratory examination of the growth was identified as infection caused by fungi Rhizopus nigrins. The reason for fungal attack in brinjal and bittergourd stored by sprinkling water to retain freshness can be attributed to water logging by over sprinkling that caused fungal growth. The infection was occured during first season (September-October) during which the atmospheric humidity was higher than the second spell at February and March.

Experiment also reveals that vegetables stored in zero energy cool chamber that retained humidity at a level of more than 95% was surprisingly free from fungal invasion during the observation period. This enables us to speculate that the appropriate sanitary measures followed by chlorine spray prior to storage of vegetables in the cool chamber have influenced the germicidal action.

4.5 Shelf life days of vegetables with different storage system

Vegetable is within its shelf life when its physical quality is generally accepted for its intended use by the consumers. The quality of vegetables depends upon several factors which when combined determine acceptability of the produce to the buyer or consumer. Vegetable quality is an unstable character which has to be maintained over a period of time. This will benefit every one in production consumption chain.

Vegetables may be stored temporarily in order to maintain quality before sale and consumption. Storage life will differ depending on the pre and post harvest treatment received by vegetables as reported by Herads (1992).

The successful shelf life days of five vegetables such as amaranthus, bhindi, bittergourd, brinjal and snakegourd stored under walk-in-cooler, zero energy cool chamber, sprinkling water, covering with leaves and open storage are discussed below. The shelf life was recorded on the basis of weight loss including spoilage when upto 10 per cent decrease was observed at good acceptance level.

Amaranthus

Leafy vegetables lose its fresh appearance soon after harvest. Table 41 summarises the maximum period upto which amaranthus could be stored in different treatments Table 41.

Table 41 Shelf life days of amaranthus with different storage system

Storage systems	Season I		Season II	
	Research station	Local source	Research station	Local source
Walk-in-cooler	7	7	7	7
Zero Energy Cool Chamber (Z.E.C.C.)	4	4	4	4
Sprinkling water	2	2	2	2
Covering with leaves	1	1	1	1
Open storage	1	1	1	1

Shelf life of amaranthus was greatly influenced by various storage coditions. Amaranthus stored under walk-in-cool showed a maximum shelf life of seven days in both seasons.

The fresh appearance was almost retained. Around 10 per cent amaranthus showed wilted appearance and become soft and pliable.

To the surprise amaranthus could be stored fresh upto four days in zero energy cool chamber at the two experiment season. The freshness observed was almost identical to that of amaranthus stored in walk in cooler.

In the other room temperature storage methods amaranthus showed very poor shelf quality, when observed at onset of very next day of storage. Around 20% of the vegetable showed signs of wilting with dark green patches on the leaves. In sprinkling water method, leaf end started decaying by end of second day while open stored and leaf covered amaranthus showed signs of drying by first day itself. Wrinkles were also observed on the surface of leaves. The shelf life days were identical at both seasons.

When the life of amaranthus was limited hardly to one day in room temperature storages, the same extended to four days in cool chamber and seven days in walk-in-cooler. This result supports the findings of Roy and Khurdiya (1982) who reported that shelf life of leafy vegetables was increased to three days by storing in zero energy cool chamber as compared to less than a day at room temperature.

The freshness and crispness of amaranthus stored in zero energy cool chamber was as good as the refrigerated amaranthus whereas the produce in the open basket storage and covering with leaf reached the stage crossing the limit of acceptability even when the first days storage was advance. Water sprinkling could extend the shelf life upto two days.

Bhindi

Bhindi is a vegetable grown through out India. Being a summer crop, the fruits have poor shelf life under ambient conditions. Table 42 presents the shelf life duration of bhindi under five storage systems during two seasons.

Table 42 Shelf life days of bhindi with different storage systems

Storage systems	Season I		Season II	
	Research station	Local source	Research station	Local source
Walk-in-cooler	10	10	10	10
Zero Energy Cool Chamber (Z.E.C.C.)	7	7	7	7
Sprinkling water	4	4	3	3
Covering with leaves	4	4	3	3
Open storage	4	4	3	3

On perusal of the pooled data in Table 42 it revealed that when a shelf life of 10 days was recorded in refrigerated storage (walk-in-cooler) the zero energy cool chamber could successfully store the produce for 7 days. There was no difference in storage days at the two seasons under these systems. Around this period, fruits become hard and unmarketable due to development of fibrous texture. Shelf life of bhindi in the other treatments were limited to four days in the first season and three days in the second season. The produce stored in all these three methods showed discolouration of fruits surface. Besides, due to hard and fibrous texture more than 15% samples reached a stage of discard.

The results obtained in this the study is in tune with the results obtained by Singh *et al.* (1980) and Kalra *et al.* (1988). Their studies revealed 7 days of shelf life in zero energy cool chamber, against a shelf life of three day under room temperature condition. This results emphasis the feasibility of zero energy cool chamber as a low cost method for short term storage of bhindi. Seasonal variation was observed in shelf life of bhindi stored under environmental conditions with that of refrigerated and cool chamber storages. These methods exhibited similar shelf life days in first and second seasons. While the rest three methods gave lesser shelf period of bhindi during second season with higher atmospheric temperature.

Bittergourd

Shelf life of bittergourd observed during September-October (Season I) and February-March period (Season II) are presented in Table 43.

Table 43 Shelf life days of bittergourd with different storage systems

Storage systems	Season I		Season II	
	Research station	Local source	Research station	Local source
Walk-in-cooler	12	12	12	12
Zero Energy Cool Chamber (Z.E.C.C.)	8	8	8	8
Sprinkling water	5	5	3	3
Covering with leaves	5	5	3	3
Open storage	5	5	3	3

Table 43 presents data on acceptable shelf life of bittergourd as influenced by treatments. The highest shelf life was observed in walk in cooler (12 days) followed by zero energy cool chamber (8 days) during both seasons. After this period, around 10 per cent fruits in these systems showed light yellow colouration which caused loss of acceptance. Bittergourd stored under ambient conditions viz. sprinkling water, covering leaf and open basket recorded early signs of ripening with a shelf life of only five days in the first season and three days during second season. The fresh shiny green colour of bittergourd was quickly turned to light yellow in these storage methods. The tissues became soft and mushy. Around 10% loss was observed in each system within the short duration of 3 to 5 days.

Among the different treatments, bittergourd stored in walk-in-cooler exhibited maximum shelf life. The low cost evaporative cooling method (cool chamber) almost doubled the storage period of bittergourd (8 days) as against 3 to 5 days in the open environment storages. Another observation was that the three common storage systems showed seasonal differences on shelf life when the February-March period (season II) recorded lower storage days. Where as in Z.E.C.C. and the cooler the same shelf life was noted.

Brinjal

Brinjal suffer from rapid loss of moisture leading to withering and loss of fresh appeal. The shelf life of brinjal in different storage systems are presented in Table 44.

Table 44 Shelf life days of brinjal with different storage systems

Storage systems	Season I		Season II	
	Research station	Local source	Research station	Local source
Walk-in-cooler	12	12	12	12
Zero Energy Cool Chamber (Z.E.C.C.)	8	8	8	8
Sprinkling water	5	5	4	4
Covering with leaves	5	5	4	4
Open storage	5	5	4	4

Shelf life of brinjal varies from 4 to 12 days depending on treatment and season. Brinjal stored in walk-in-cooler showed maximum shelf life of 12 days. An acceptable storage life of 8 days was recorded in zero energy cool chamber during both seasons against minimum shelf life of 5 days and 4 days in first and second season respectively in the room temperature storage viz. sprinkling water, covering leaf and open storage. More over with the above said shelf life days in cooler and cool chamber, the glossy appearence of skin disappeared and brinjal become wrinkled. Brinjal stored under ambient temperature conditions exhibited pale yellow colouration in the skin beyond its satisfactory shelf life period of five days during first season and 4 days during second season. The wrinkled skin was observed as a sign of excess water loss from the commodity.

As reported by Choudhary (1968) the harvested brinjal can be kept for 7-10 days in good condition at 10°F-13°F and 85-90% relative humidity.

In the present trial it was emphasised that zero energy cool chamber proved to be efficient for successful storage of brinjal upto 8 days. However the shelf life of brinjal stored under ambient temperature was only five days and four days in first and second seasons respectively. Similar to the early results, it was noted that the season fluctuation with storage methods was not reflected in the case of cool chamber storage and also in the refrigerated system which is an electrically controlled method.

Snakegourd

The shelf life 8 days of snakegourd with different storage methods is given in Table 45.

Table 45 Shelf life days of snakegourd with different storage system

Storage systems	Season I		Season II	
	Research station	Local source	Research station	Local source
Walk-in-cooler	13	13	13	13
Zero Energy Cool Chamber (Z.E.C.C.)	9	9	9	9
Sprinkling water	7	7	5	5
Covering with leaves	7	7	5	5
Open storage	7	7	5	5

As agreed to the general fact, walk-in-cooler gave the highest shelf life (13 days). Snakegourd stored in zero energy cool chamber maintained a shelf life period of 9 days during the experimental periods as against 7 days and 5 days respectively in two seasons with sprinkling water covering with leaf and open basket stroage systems.

Beyond the last day of satisfactory shelf life fresh greencolour of the produce in walk-in-cooler and cool chamber was diminished and texture was turning soft. While this change was noticed on the 9th day in zero energy cool chamber, the same change along with yellowish discolouration of the tips had occured as early as fifth day in the second season and seventh day in the first season comparable to other storage methods. Seasonal variation of shelf life days observed in methods viz. sprinkling water, covering leaf and open storage was more in the case of snakegourd.

The main factor responsible for the increased shelf life in vegetables is its storage conditions. Influence of storage conditions on the shelf life of five different vegetables in this experiment showed that walk-in-cooler had the highest efficiency in preserving the quality of fresh vegetables. According to Woolrich (1965) and wills *et al.* (1981) refrigeration is the most efficient short term storage method which reduces physiological activity and increases shelf life of vegetables. But the rising cost of refrigeration equipment is working as a damper for quick addition of new cool storage facility (Sethi 1987). Among the low cost and simple storage methods zero energy cool chamber proved its efficiency to be the best with a closer ability with the high technology oriented and costly system walk-in-cooler for its storability of vegetables. This device was able to extend the freshness of vegetables for a period between 7 to 9 days in most vegetables stored and 4 days for amaranthus. Thangaraj and Irulappa (1988) and Saibaba (1990) recommends the low cost zero energy cool chamber for short term storage of vegetables. According to Madan *et al*. (1993) the storage life of fresh vegetables is considerably increased by keeping in the cool chamber immediately after harvest. Joshi *et al*. (1993) reported that storage in cool chamber increased the shelf life of potato. Waskar and Yadav (1997) suggested the low cost storage structure, zero energy cool chamber for short term storage for bittergourd to extend its shelf life. Philip (1981) opined that low temperature and high humidity in storage reduces the state of physiological activities and thereby shelf life of fruits increased.

The three ambient temperature storages viz. sprinkling water, covering leaf and open storage were found to be either less effective or poor in keeping vegetables fresh as evidenced by present experiment.

Reports on studies conducted by Roy and Khurdiya (1982) also shows that ambient temperature storage condition give least storage life in fruits compared to those stored in cool chamber and cold storage.

According to Patel and Katradia (1984) extension of shelf life of vegetables may be possible by checking the transpiration respiration rates. The higher relative humidity and lower temperature maintained by evaporative cooling principle in side zero energy cool chamber in checking the trespiration and respiration rates of vegetables and this enabled in increasing shelf life of vegetables stored in zero energy cool chamber in comparison to the poor shelf life with other low cost methods.

Studies conducted by several workers revealed that the efficiency of zero energy cool chamber can be further increased if vegetables and fruits subjected to any of the storage treatments prior to keeping in zero energy cool chamber. This is evidenced by Thangaraja and Irulappa (1988) who found better shelf life in fruits when waxing and cool chamber storage was done in combination. Investigation under taken by Kaulgad and Waskar (1994) to extend the shelf life of bar fruits up to 15 days when treated with waxol packed and stored in zero energy cool chamber on the contrary to shelf life room temperature was hardly 6 days.

Another important findings of this study was that the two seasons presented a difference in the shelf life duration under room temperature storage methods. Whereas shelf life was constant in walk in cooler and cool chamber irrespective of seasonal difference. In all the experiments better shelf life was observed in September-October period (season I) at ambient storage conditions. This can be explained by the extreme weather conditions that prevailed during February-March period (season II). The fact that the seasonal variation was not observed in walk-in-cooler and cool chamber stored vegetables can be attributed to the mechanism of maintaining almost similar temperature and humidity conditions in these methods overcoming the weather changes. In walk-in-cooler the temperature is kept at a constant level with the mechanical help of a thermostat, while maintenance of constant temperature in the case of cool chamber even at a variation in atmospheric weather parameters is a favourable research finding where evaporation of water by natural air flow causes cooling inside the chamber by drawing out the inside heat. Thus it can be concluded that zero energy cool chamber can be effectively utilised as a low cost method for short term storage of vegetables.

4.6 Range of weather parameters in zero energy cool chamber and ambient conditions during experiment

Zero energy cool chamber is a low cost storage system based on the basic principles of evaporative cooling.

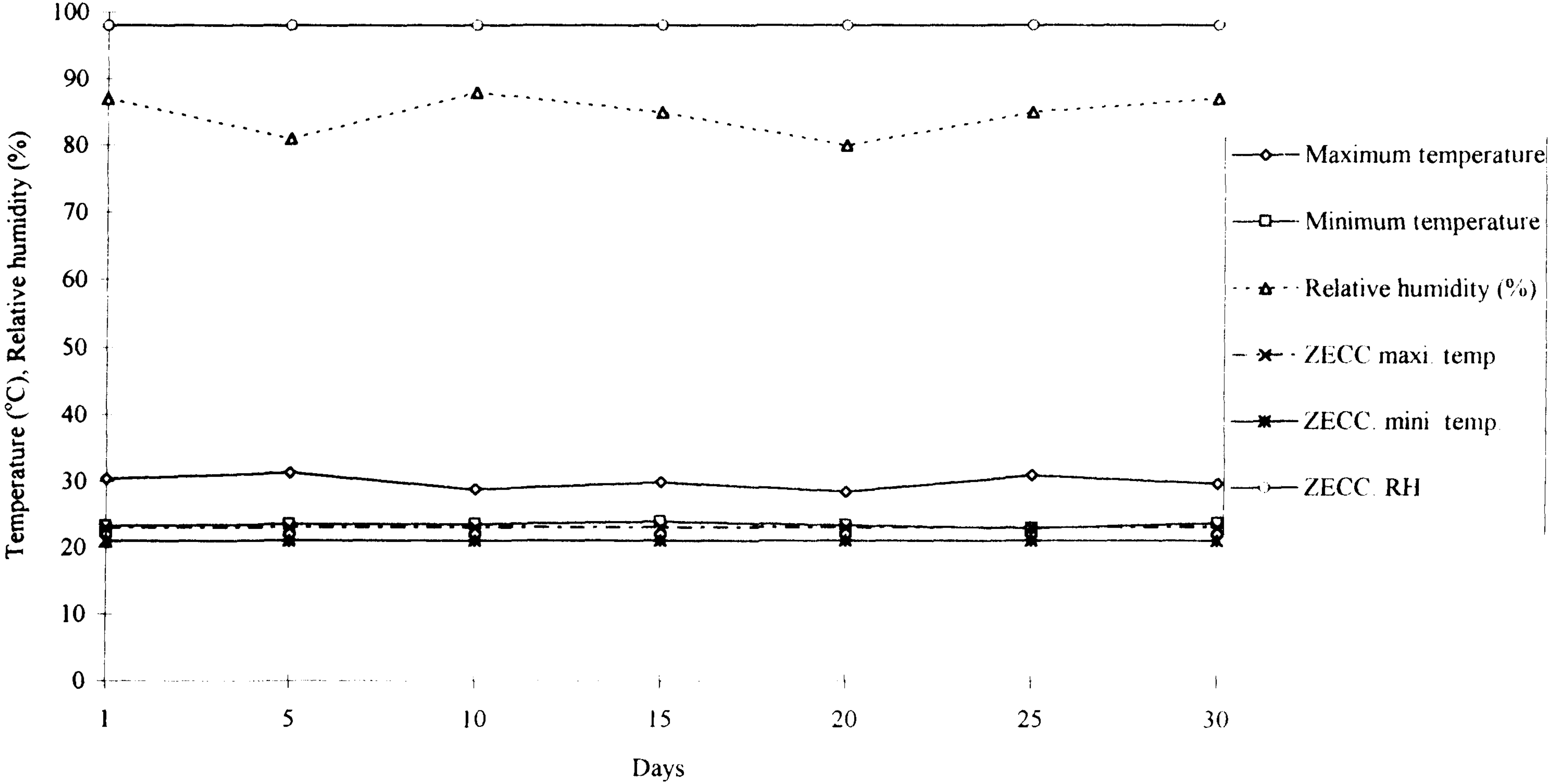
Evaporative cooling is a well defined principle that helps to bring down the temperature of any closed space by using water to vaporise under ambient condition, making use of internal heat. The efficiency of evaporative cooling depends on the material through which water evaporates. The rate of evaporation decides the quantum of cooling that can be obtained. To get a picture of the temperature and relative humidity due to evaporation of water from the support media (sand) the average maximum and minimum temperature and relative humidity inside the cool chamber in comparison with ambient condition during the days of experiment were recorded and are given in Table 46 and illustrated in Fig. 1 and 2.

Table 46 The average weather parameters recorded within the chamber and outside

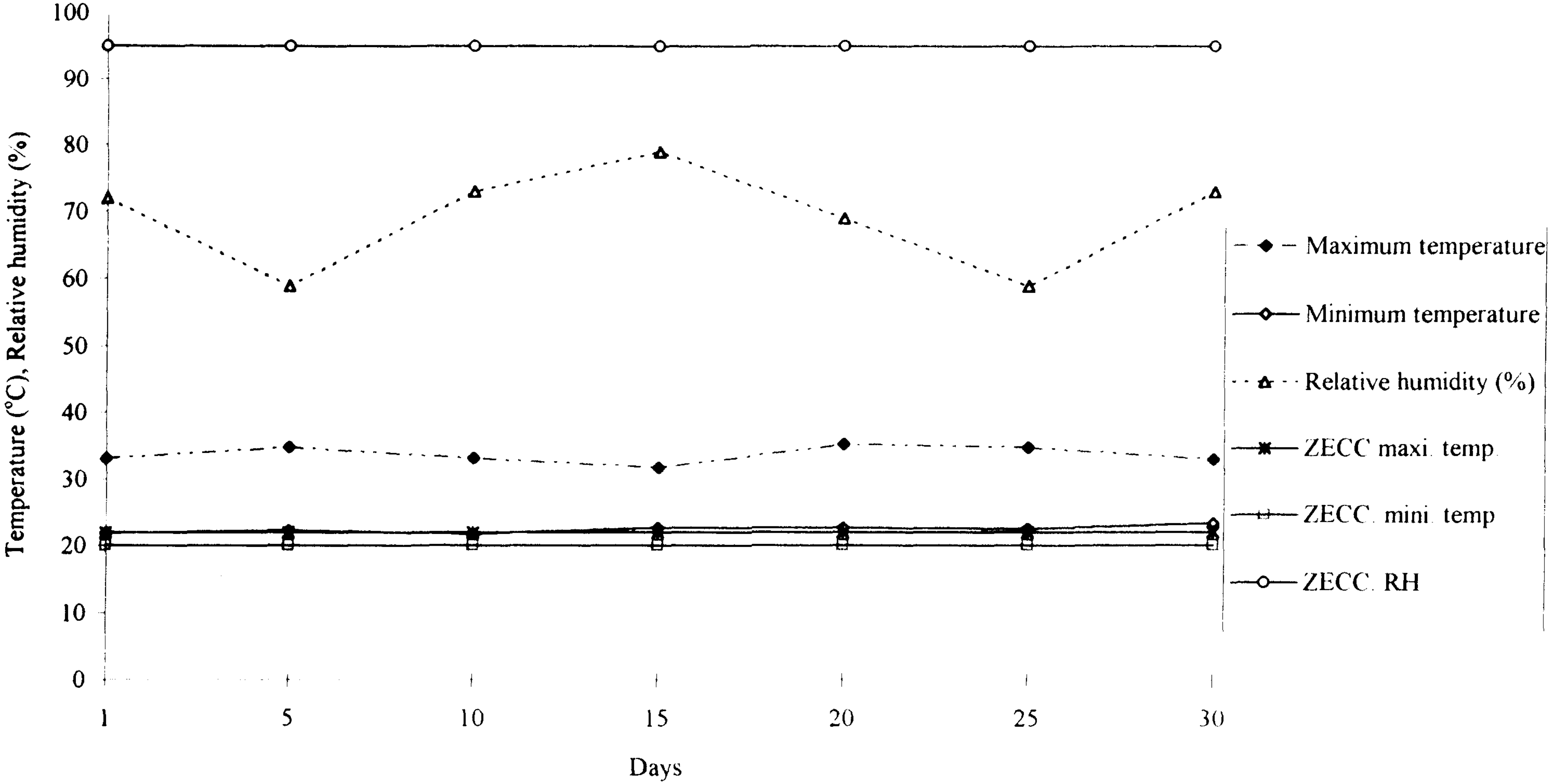
Weather parameters	Season I		Season II	
	Inside the zero energy cool chamber	Outside the zero energy cool chamber	Inside the zero enery cool chamber	Outside the zero energy cool chamber
Temperature (Max.-Min°C)	23°C-21°C	30°C-24°C	22°C-20°C	33°C-25°C
Relative humidity (%)	98	87	95	69
Sunshine hours	-	3.6	-	8.4

It was seen that the average minimum temperature in the cool chamber was considerably low compared to the outside temperature throughout the period of experiment. During the

Temperature and relative humidity in zero energy cool chamber and outside during first season (September - October)



Temperature and relative humidity in zero energy cool chamber and outside during second season (February - March)



first season (September-October) when the maximum ambient (outside) temperature was 30°C while the maximum cool chamber temperature was maintained at 23°C. Like wise in the second season (February-March) the maximum temperature recorded outside was as high as 33°C, inside the cool chamber the temperature was lowered to 22°C. When the average minimum outside temperature was 24°C and 25°C it was found that inside the zero energy cool chamber it was only 21°C and 20°C during the first and second season respectively.

In the case of relative humidity the zero energy cool chamber had maintained a high level of 95% and 98% during the experiment in the first and second seasons respectively. The corresponding atmospheric humidity was recorded respectively at 87% and 69% in the first and second season.

The present data on temperature and relative humidity effect throws light on the promising use of this simple and cheap storage structure to maintain a low temperature and high relative humidity than that of the climatic situation at all times. At the maximum level there was a successful decrease by 7°C in the cool chamber during September-October study period and even greater reduction by 11°C during the extreme weather condition at February-March (season II). The temperature fluctuation, at the minimum level was 3°C during the first season and 5°C in the second season. From this data, it can also be inferred that at higher outside temperature a higher variation between cool chamber and atmospheric weather condition were effected.

To discuss on the wide difference observed in temperature and relative humidity inside and outside the chamber, the evaporation of water vapour from the interior area of cool chamber in turn draw the internal heat, thus lowering the inside temperature. This was a favourable result drawn through the experiment for the application of this method under the high temperature and humid conditions of Kerala. It could be studied that when an increase of 9% humidity was prevailed during the first season in the cool chamber, the results at the summer season was more favourable with almost three fold increase in relative humidity as that of September-October season. The increase in relative humidity in this period was 26% than that of outside.

The variation of maximum and minimum temperatures between the periods in cool chamber and atmosphere was not much prominent, but higher differences were seen during the time of higher atmospheric temperature ie. February-March. There was only 1°C difference in cool chamber temperature with season whereas outside temperature variation between seasons was 3°C. This finding corroborates with the principle that the higher the temperature better the cooling effect.

The sunshine hours was recorded to be 3.6 in September-October month (first season) where as it was 8.4 during February-March (Second season). It was evidenced from the table that when the sunshine hours was more, the inside relative humidity was maintained higher and temperature was kept lower compared to days with lesser sunshine hours.

It was interesting to note that apart from making a low temperature and high humidity in both seasons the fluctuation in maximum and minimum temperature and relative humidity inside the cool chamber was very narrow compared to the outside temperature and relative humidity at different duration. Hence this storage condition can be considered highly desirable to check spoilage of physiologically active fruits and vegetables.

The present study was conducted in a comparatively cooler place of the State. The results can be proved to be more efficient if done in locations having higher temperature where the rate of evaporation will be high.

Popularisation of zero energy cool chamber among vegetable growers

Improvement in farming technology has increased the production of many vegetables. But due to defective handling and storage this increased production is not being rightly channelised. In order to overcome this lacunae there is a need for improved technology which is economically feasible. At the same time such information should reach up to the base level who form the producing category of this crop. Thus a one day lecture-cum-demonstration class was conducted among twenty five selected farmers with the aim of popularising the low-cost device. Initially a survey was conducted among the respondents using a questionnaire in order to find out the economics of their vegetable cultivation and storage practices followed.

Details on the economics of vegetable cultivation and post-harvest storage practices of the respondents

A survey was conducted using an interview schedule among selected vegetable growers of the nearby panchayat to learn the post harvest handling practices followed. Information collected through the survey revealed that 80% of the respondents have taken up vegetable cultivation as their main source of income. All of them cultivate mainly vegetables. The annual profit from the sales of vegetables produced in an acre of land estimated to be around Rs.12000 to 24000 per year. It could be understood from the survey that all the growers carry out their cultivation in the leashold. None of the selected vegetable growers possessed own land for the cultivation. Group cultivation method is followed by cent per cent of the respondents.

Enquiring on their post-harvest storage practices, it was learnt that they do not follow any particular storage practice to reduce post-harvest loss. It was clear from the data pooled that the farmers were totally unaware of efficient and low-cost methods. Regarding the practice of harvest and sales, it was understood that 100% of respondents harvest their vegetables during early morning. All the growers followed the practice of packing vegetables in jutesacs except amaranthus. Amaranthus was packed by tying up with banana leaves. The interview also revealed that the farmers do not pay attention or care to keep the vegetables free from damages.

Information obtained revealed that generally all the vegetable cultivators sell the vegetables soon after harvest. Vegetables are sold in the main market which is fifty kilometers away. Every grower reported that they transport the vegetables by van or auto depending on the quantity to be transported.

It was also noted from the survey that none of the respondents were exposed to any type of information on scientific storage of vegetables by Governmental agencies or departments. The growers were found to be unaware of low cost storage technologies which are feasible at their level. This fact enthused the investigator to arrange an education programme on this line to the selected farmers.

Conduct of education programme

The central objective of the one day education programme is to give information regarding proper storage of vegetables with special reference to low cost storage device viz. zero energy cool chamber, generated in the present experiment. It was also expected to popularise the simple technology among vegetable growers of the locality. The education programme planned combined lecture and demonstration session on storage of vegetables. Twenty five participants were selected whose main income is from vegetable growing. The class was conducted in the department of Home Science where the experiment was carried out.

Lecture session

A general theoretical information on post harvest spoilage causes of vegetables and importance of proper storage to maintain freshness of vegetables were discussed through an informal lecture. Different low cost storage methods emphasizing evaporative cooling method were tought to them. The investigator explained in detail the working principle, raw materials required and construction and operation details of zero energy cool chamber. The cost of construction and particulars regarding dimensions were throughly detailed to them. They were also instructed about the points to be noted while selecting the site for construction of the chamber and precautions to be taken while storing vegetables in order to attain better results.

Demonstration

Demonstration on storage of vegetables was conducted at the site where zero energy cool chamber was constructed and maintained in operation by the investigator. Demonstration of disinfecting, cooling the chamber and storage of vegetables were carried out with the active participation of all the twenty five farmers. Sprinkling water at intervels were carried out by the participants.

As a part of the demonstration, previously stored vegetables that were remaining in the chamber for a period of five days were shown to the participants to be examined. Doubts raised by the participants were cleared at the end of the demonstration. Important points of demonstrations were explained once again. Questions were asked to each participant to confirm whether they grasped the construction and operation procedures in the right manner. Farmers were more attentive in the demonstration class compared to lecture class. The vegetable growers expressed their interest to try out storage with larger quantity vegetables and test the feasibility to coincide with their requirements. The participants were assured of the advantages of the cheap and simple storage method.

Evaluation of education programme

An educational effort is generally assessed on the basis of gain in knowledge of the participants. According to Bloom (1950) gain in knowledge includes all those behaviours and test situations which emphasize the remembering either by recall of the ideas and materials on some phenomena. Accordingly a pre-test to measure the existing knowledge and post test to quantify the knowledge gain using the same evaluation schedule was conducted. This can be considered as a measuring scale for the prefixed hypothesis of the results to be obtained. The effective change obtained as a result of the programme made the goal of the work fruitful. The objective of the evaluation was to study the level of knowledge gained with respect to the recommended low cost storage technology.

Knowledge gain of respondents regarding storage of vegetables and use of zero energy cool chambers

Before conducting the training on low cost storage methods and zero energy cool chamber, information was collected by circulating the evaluation schedule consisted of 16 statements among them. Each statement was provided with three responses 'Yes', 'No' and don't know, Each correct answer was provided with a score of 1, wrong and neutral answers were given '0'. The total score for each statements could be twenty five to the maximum extend when adding up scores of the total participants.

The sixteen statements formed were grouped into two categories viz. low cost storage methods and use of zero energy cool chamber.

These statements were again circulated immediately after the one day education programme. Score for each statement before and after the training programme were compared to find out variation in scores due to training. The results are presented in Tables 47 and 48.

Six statements were asked to find out the gain in knowledge on possibility of use of low cost methods for vegetable storage.

Table 47 Knowledge of respondents on low cost storage methods

Statements	Pre test		Post test	
	Score	Percentage	Score	Percentage
1. Freshness of vegetables can be retained by adopting low cost storage methods	15	60	25	100
2. Vegetables can be kept fresh by sprinkling water	17	68	24	96
3. Vegetables can be kept fresh for short period by wrapping in moist cloth	16	64	24	96
4. The principle of evaporative cooling is highly useful for storage of vegetables	0	0	25	100
5. Janatha refrigerator is a household storage method based on evaporative cooling	15	60	25	100
6. Aware of zero energy and cool chamber for storing vegetables	0	0	25	100

As revealed in Table 47, as a result of the classes, more participants has become more aware of low cost indegenous methods and its relevance in storing vegetables. All the respondents answered that the freshness of vegetables can be retained by adopting low cost storage methods, a system known to only 60 per cent of the participants before the class. Sprinkling water method for storage of vegetables was familiar to 68 per cent before conducting the class whereas it increased to 96 per cent after the lecture class. The method of wrapping vegetables in moist cloth to keep them fresh was known only to 64 per cent before training whereas after the training percentage score on this statement was increased to 96 per cent. All the twenty five respondents were unaware of evaporative cooling method for storage of vegetables. They were not heard of any storage method related with evaporative cooling principle. Once this aspect was explained to them and in the post test evaluation this fact was grasped by all the participants and thus gave positive answer. Previously only 20 per cent of the respondents were aware of janatha refrigerator. But there was an increase in the knowledge gain on this storage method to 100 per cent after the lecture class. A more serious fact was that none of them had heard about zero energy cool chamber until they were familiarised with it by the investigator. Even though researches had been carried out in different states and found the method to be highly feasible, it was unfortunate that the farmers had no idea about this storage method. After the training 100% of respondents could unanimously report that they know quite well about it.

Ten statements were framed to evaluate the knowledge attained on the use of zero energy cool chamber. Since all the participants could not attempt any of the statements as they had not heard about it earlier. Data regarding the post evaluation is shown in Table 48.

There was surprising knowledge gain pertaining to the details of zero energy cool chamber, where as previously the participants were totally ignorant on these matters before the training. Eighty per cent of the respondents learnt that Z.E.C.C. is a non-energy oriented storage device. As an impact of the training 80% of the farmers could correctly answer, the working principle of zero energy cool chamber. After the demonstration and class 96% vegetable growers were highly agreeable to the statement that the zero energy cool chamber can be constructed and operated even by an unskilled person. This enables the investigator to have a feed back of the classes given that the respondents learnt each step in the construction and operation from a state of no previous exposure to it. Eighty eight per cent of respondents answered correctly that the site having a ventilation and airflow is the suitable place for construction of cool chamber. This reveals that they knew the basic principle that air flow will help evaporation of water that in turn effects cooling. Seventy ~~eight~~ six per cent of farmers become aware that high temperature and low humidity conditions give better results. Around 84% responded negatively to the question that falling of direct sunlight in to the chamber is beneficial. This points out that they knew the fact that shade is required for the chamber and that direct sun rays will lower the efficiency. Eighty per cent of the respondents answered correctly that the intialisation of temperature and humidity inside the chamber is important. The need for properly disinfecting the chamber prior to storage was also considered important by 92 per cent of the respondents. From the above answer we can understand that preparations prior to cooling is clear to them. Statement on storage of vegetables in adequately ventilated basket was found advisable to 96 per cent of the respondents. This is a proof that they knew dumping of vegetables in the chamber causes damage and ventilation is necessary for successful storage. Falling water drops on the vegetable was considered harmful to 88 per cent of the respondents. This helps us to assume that they are well aware of the care that should be taken during watering the chamber and they know that over saturation of the chamber with water will cause decay.

From the above results, it can be reported that majority of the respondents were able to understand throughly the construction working principle and storage of vegetable in the zero energy cool chamber. The lecture and demonstration class helped to teach the farmers who never had an earlier knowledge to the extent of making their confident to conduct and operate this effective storage system.

Views of participants about zero energy cool chamber

Being familiarised and taught the details of zero energy cool chamber as a low cost storage method, it was thought necessary to know the views and suggestions of the

Table 48 Knowledge gained by respondents on the use of zero energy cool chamber (Z.E.C.C.)

Sl. No.	Statements	Pre test Score	Pre test Percentage	Post test Score	Post test Percentage
1.	Z.E.C.C. is an non-energy oriented method unlike the refrigerated storage	0	-	20	80
2.	Z.E.C.C. works based on the principle of evaporative cooling	0	-	20	80
3.	The chamber can be constructed and operated even by an unskilled person	0	-	24	96
4.	A site having ventilation and airflow is required for construction of Z.E.C.C.	0	0	22	88
5.	The high temperature and low humidity conditions give better efficiency of Z.E.C.C.	0	-	19	76
6.	Falling of direct sunlight into the chamber is beneficial	0	0	21	84
7.	The initialisation of temperature and humidity inside the chamber is important	0	0	20	80
8.	The chamber should be disinfected prior to each storage	0	0	23	92
9.	The produce should be stored in adequately ventilated baskets	0	0	24	96
10.	Falling of water drops on the vegetables is not harmful	0	0	22	88

participants regarding the system on their practical use in order to make necessary recommendations in future research. Hence the respondents were further requested to list their positive and negative opinions and suggestions on the basis of their practical utility for short term storage of vegetables. The positive points putforth by the farmers are summarised and presented in Table 49.

On Table 49 exploring the effectiveness of this storage method, 84 per cent of the participants rightly agreed that zero energy cool chamber is an effective method for short term vegetable storage. They could clearly distinguish the benefits of this method from the usual indigenous storage practices they knew. Above this as high as 92 per cent of the farmerrs unanimously stated that this is a cheap method when compared with its effectiveness. Since the raw materials were easily obtainable and even reusable, the minimum cost required for its construction and maintenance was found reasonable to them. Sixty four per cent of participants expressed their wish to construct a cool chamber for their use. From this it is evident that the farmers could identify as the cool chamber storage to be more effective than the usual storage practices they follow. Among the farmers who wanted to construct this device, majority of them (60%) preferred to have the chamber in a common place. The farmers thought so, as a situation to overcome the problem of individual supervision and sprinkling

Table - 49 Positive views of respondents about zero energy cool Chamber. (Z-E-C-C)

Sl. No.	Statements	Score	Percentage
1.	Zero energy cool chamber as an effective method of storing vegetables.	21	84
2.	It is a cheap method of storage.	23	92
3.	Like to possess Zero energy cool chamber.	16	64
4.	Prefer to construct Zero energy cool chamber at a common place.	15	60
5.	Confident of constructing and maintaing Zero energy cool chamber.	23	92
6.	Maintanance of Zero energy cool chamber is useful in emergency situation	23	92

water at intervals for cooling. It could be considered as a success of the one day training to that 92% of them were highly confident of constructing the chamber by themselves and were also convinced on the operation procedures. Moreover it is also confirmed that zero energy cool chamber can be constructed and operated easily even by an unskilled person. Most of the participants (92%) had no doubt to state that maintenance of zero energy cool chamber would be a boon to the vegetable growers at the crisis of emergency situations like 'hartal' or 'bandh' during which storage of already harvested crop becomes a necessity. In these situations inability to sell out the harvested produce leads to interim storage requirements to safeguard the freshness of the vegetables and retain its marketability.

Negative remarks pointed out by the respondents are listed in Table 50.

Table 50 Negative views of respondents about zero energy cool chamber (Z.E.C.C.)

Statements	Score	Percentage
Operation of chamber is time consuming	6	24
Proper maintenance is a problem	8	32
Will be less efficient for the storage quantity	18	72

Regarding the operation procedure 24% of the respondents felt that operation is time consuming. This is due to the process of sprinkling water at intervals for cooling. After storing vegetables, attention is still required for the purpose of cooling. There is an improved method of drip system in watering the chamber that could be adopted to save labour and water at a little extra cost. Added to this 32% of the farmers also felt that maintaining the chamber in good condition even when not operated, is a problem. Unless the chamber is continuously maintained in good condition it will be difficult to operate immediately as and when required. Hence this has to be continuously maintained and kept. While going in to more practical aspects, 72% participants further raised doubt on bulk storage efficiency of the chamber. This doubt was raised by the respondents mainly because of the draw back they usually face with the storage practices they follow ie. storage in sack or covering with leaf and similar practices. In these methods lack of proper aeration and more loading height usually resulted in heavy storage losses. However in the chamber for large quantity storage requirements packing of vegetables in adequately ventilated wooden bars inside the chamber would be helpful in over coming this problem. Such arrangement will enable the cooling effect to reach evenly all sections of the stored lot and also provides aeration. In this way larger quantity storage can also be made effective.

From the above pooled data it may be confirmed that the respondents are in favour of the practical usefulness of this storage method. The participants responses were very encouraging and are interested in its wide scale use but for certain simple draw backs that can be overlooked.

SUMMARY

SUMMARY

The feasibility of zero energy cool chamber for short term storage under the high temperature and humid conditions of Kerala was investigated by studying storage behaviour and shelf life of five vegetables, viz., amaranthus, bhindi, bittergourd, brinjal and snakegourd. A comparative storage performance was drawn from storing these vegetables in walk-in-cooler, zero energy cool chamber, by sprinkling water, covering with leaves and by open basket storage. Experiment was conducted in two seasons with vegetables collected from two sources - Instructional Farm (research station) and local farmers. With the aim of popularisation of zero energy cool chamber, education through theoretical explanation and demonstration. was carried out on this low cost storage technology to selected vegetable growers of the locality.

Influence of storage on different physical parameters such as appearance, colour and texture were rated on a five point scale with the use of a score card.

From the experiment it was evident that walk-in-cooler was most efficient to retain fresh appearence of all the stored vegetables. Zero energy cool chamber was also advantageous as it preserved the freshness of vegetables well. The other three methods showed very low efficiency in

maintaining the physical appearance. The freshness level was observed better when storage was carried out in the first season.

The results on colour retention with storage was observed to be good both in walk-in-cooler and zero energy cool chamber while colour was faded when vegetables were stored in remaining three methods. The local sources recorded better colour retention during first season compared to research station sample. While at the second season the two sources showed almost similar characters. Between the five storage systems also the same pattern of colour retention was observed during both seasons.

The walk-in-cooler stored vegetables exhibited the better texture. Texture of vegetables in zero energy cool chamber was almost similar to that of walk-in-cooler.

The three storage methods viz. sprinkling water, covering leaves and open storage contributed poor texture profile with storage. During first season vegetables from local farmer gave better texture compared to the crops from research station, while no difference was revealed in second season.

All the physical qualities of vegetables were protected by zero energy cool chamber, almost closer to the refrigerated storage, viz walk-in-cooler. Comparing with the three room temperature storage methods, zero energy cool chamber is thus an effective method for short term storage in safeguarding the physical qualities of vegetables.

The physiological weight loss during storage revealed that next to walk-in-cooler, weight loss was significantly reduced in zero energy cool chamber. Compared to other three ambient condition storage, open storage suffered the maximum weight loss. Thus in the present search for a low cost storage method for minimum weight loss of vegetables, zero energy cool chamber is distinguished as a successful low cost medium to limit weight loss.

The chemical changes on storage such as moisture, total mineral, fibre and ascorbic acid were assessed.

The findings showed that moisture retention was maximum when stored in walk-in-cooler. It was also proved that the moisture loss could be minimised to a considerable level by using zero energy cool chamber for storage. Open storage and covering with leaves were highly susceptable to moisture loss than the sprinkling water method.

Best moisture retention was achieved in zero energy cool chamber for all the vegetables experimented at two seasons, compared to sprinkling water method, covering with leaves and open storage method.

Considering the mineral retention of vegetables on storage in five different methods, mineral loss was minimum in walk-in-cooler and zero energy cool chamber. But samples in other three methods resulted in lower mineral retention. Variation in seasons and sources recorded no significant difference.

Increase in fibre content was lowest with vegetables stored in walk-in-cooler. There was no increase when stored in zero energy cool chamber. While samples stored in the rest three methods such as sprinkling water, covering leaves and open storage recorded higher increase in fibre content.

Generally there was a marked loss in ascorbic acid content due to storage. Among the five methods of storage walk-in-cooler recorded minimum loss followed by zero energy cool chamber. Ascorbic acid loss was maximum in openly stored vegetables. This observation was regardless of source or season.

Results show that the minimum alteration in chemical composition was registered with storage in zero energy cool chamber in comparison to atmospheric storage methods. Chemical changes in zero energy cool chamber were quite moderate in relation to that of the refrigerated cool storage in walk-in-cooler.

In the study of microbial attact in stored vegetables the spoilage by fungus was observed in brinjal and bittergourd stored by sprinkling water method. Experiment also revealed that vegetables stored in zero energy cool chamber with a relative humidity of 95 per cent was surprisingly free from fungal invasion during the observation period.

Influence of storage conditions in the shelf life of five different vegetables under experiment found walk-in-cooler with the highest efficiency in preserving the quality of fresh vegetables. Among the low cost and simple storage methods zero energy cool chamber proved its best efficiency with closer performance to that of walk-in-cooler in its storability. This device was capable to extend the freshness of vegetables for a period of seven to nine days in most of the vegetables and four days with amaranthus as against three to seven days and one day respectively in atmospheric storage methods. A seasonal variation in shelf life was also observed in the case of room temperature storage methods. Whereas shelf life was constant in walk-in-cooler and zero energy cool chamber irrespective of season.

In a critical study of weather parameters, temperature showed a successful decrease by 7°C at the maximum level in the cool chamber during September-October period (Season-I) and even greater reduction by 11°C during February-March period (Season-II). The temperature fluctuation at minimum level was 3°C during first season and 5°C at second season. It could be studied that when an increase of 9 per cent relative humidity prevailed during first season in cool chamber and the results at the second season showed an increase of 26 per cent than that of outside relative humidity.

Data on sunshine hours evidenced that at duration of higher sunshine hours, the humidity inside the cool chamber was also higher. Similarly decrease in temperature of the chamber was also more during increased sunshine period compared to times of lesser sunshine hours.

It was also observed that the fluctuation in maximum-minimum temperature and relative humidity inside the cool chamber was very narrow in relation to outside fluctuation.

Hence this storage system can be considered highly desirable in the prevailing weather conditions of Kerala to check self deterioration of physiologically active fruits and vegetables. The technology can be proved to be more efficient at locations of Kerala having higher temperatures where the rate of evaporation also will be high.

The survery conducted among twenty five selected vegetables growers of Kalliyoor panchayat to learn their practices on vegetable cultivation and storage, revealed that they adopted group cultivation method. It was also found that they generally do not practice any storage method for the harvested producers. They had practically no knowledge on low cost storage methods. None of the respondents were exposed to evaporative cooling technology for storage of vegetables and had not even heard about zero energy cool chamber. While as an impact of the education programme by the investigator most of them turned to be well aware of simple and low cost vegetable storage methods including evaporative cooling method and zero energy cool chamber. Clear information on construction maintenance and operation of zero energy cool chamber was attained by them. Positive increase in the knowledge gain was recorded.

From the pooled data on their positive and negative views, it can be concluded that zero energy cool chamber turned out to be very effective to the farmers for short term storage of vegetables. The simple draw back pointed out by them was the time consumption on maintenance of the chamber. However this can be solved by adopting an improved watering system.

The rate of adoption tested clearly indicated that majority of the vegetable growers were interested to fabricate this storage structure for their use.

The results of the study offers scope for recommending zero energy cool chamber for adoption by households, farmers and traders for short term storage of the horticulture produce at different handling levels.

As recommendation for future work experiments based on this highly effective low cost storage structure for larger capacity storage has to be scrutinised in order to draw definite conclusion on the successful exploration of the device for effective post-harvest management of higher quantity produce. Sethi (1987) reports that existing methods for preventing and reducing post-harvest losses need to be modified. Emphasis may therefore be placed on the above aspects since it is likely to yield results on social as well as economical value.

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APPENDICES

SCORE CARD

DAY	APPEARANCE					COLOUR					TEXTURE				
	T1	T2	T3	T4	T5	T1	T2	T3	T4	T5	T1	T2	T3	T4	T5

5 - Excellent   4 - Good   3 - Satisfactory   2 - Poor   1 Very Poor

KERALA AGRICULTURAL UNIVERSITY

Department of Home Science

College of Agriculture

Vellayani

Trivandrum

QUESTIONNAIRE TO COLLECT INFORMATION ON ECONOMICS OF VEGETABLE CULTIVATION AND STORAGE METHODS FOLLOWED BY VEGETABLE GROWERS

Respondent No.

Name and address of vegetable grower

Age: Sex:

1. Is vegetable cultivation your main source of income

   Yes [ ] No [ ]

2. What is your annual profit from the sales of vegetables

   Rs. ....

3. Do you possess own land for cultivating vegetables

   Yes [ ] No [ ]

4. If no how do you attain land for this purpose

5. Which cultivation method do you follow?

   a) Individual cultivation [ ]

   b) Group cultivation [ ]

   c) Any other [ ]

5. Do you follow any post harvest storage practice in order to reduce loss?

Yes [ ] No [ ]

6. If yes which method do you commonly follow

7. When do you harvest vegetables

   a) Early morning
   b) Morning
   c) Afternoon
   d) Evening

8. Where do you sell the harvested crops

   a) At the cultivation spot
   b) In the nearby small market
   c) In the nearby main market
   d) Transport to distant places

9. When do you take harvested produce to the market

   a) Soon after harvest
   b) After few hours
   c) Next day
   d) At a gap of more than a day

10. What are the packaging methods you follow

   a) Packing in sacs
   b) Packing in bamboo baskets
   c) Covering and tying up with leaves

11. Mode of transportation of harvested vegetables

   a) By Auto

   b) By Van

   c) By bus

12. Have you ever received information on storage of vegetable from voluntry or governmental agencies

   Yes [ ]   No [ ]

13. Do you have any information on any low cost storage devices

   Yes [ ]   No [ ]

KERALA AGRICULTURAL UNIVERSITY

Department of Home Science

College of Agriculture

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EVALUATION SCHEDULE FOR TESTING KNOWLEDGE GAIN ON STORAGE OF VEGETABLES AND USE OF ZERO ENERGY COOL CHAMBER (Z.E.C.C.)

	Respondent No.	Yes	No	Don't know
1.	Freshness of vegetables can be retained by adopting low cost storage methods			
2.	Vegetables can be kept fresh by sprinkling water			
3.	Vegetables can be kept fresh for short period by wrapping in moist cloth			
4.	The principle of evaporation cooling is highly useful for storage of vegetables			
5.	Janatha refrigerator is a household storage method based on evaporative cooling			
6.	Have information about zero energy cool chamber for storing vegetables			
7.	Z.E.C.C. is an non energy oriented method unlike the refrigerated storage			
8.	Z.E.C.C. works based on the principle of evaporative cooling			
9.	This chamber can be constructed and operated even by an unskilled person			

Respondent No.	Yes	No	Don't know
10. A site having ventilation and air flow is required for construction of Z.E.C.C.			
11. The high temperature and low humidity conditions give better efficiency of Z.E.C.C.			
12. Falling of direct sunlight in to the chamber is beneficial			
13. The intialisation of temperature and humidity inside the chamber is important			
14. The chamber should be disinfected prior to each storage			
15. The produce should be stored in adequately ventilated baskets			
16. Falling water drops on the vegetables is not harmful			

ABSTRACT

STORAGE EFFICIENCY OF ZERO ENERGY COOL CHAMBER UNDER LOCAL CONDITIONS

By

ANJANA. V.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of

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ABSTRACT

The storage efficiency of zero energy cool chamber under local conditions was assessed by studying the physical, physiological, chemical and microbial changes on storage and shelf life of five vegetables viz. amaranthus, bhindi, bittergourd, brinjal and snakegourd. Storage system namely walk-in-cooler, zero energy cool chamber, sprinkling water, covering with leaves and open storage were experimented with vegetables from two sources viz. Instructional Farm (research station) and local farm at two seasons.

The results obtained on physical quality changes of vegetables such as appearance, colour and texture due to storage revealed lesser rate of changes in these physical parameters with vegetables stored under walk-in-cooler followed by zero energy cool chamber compared to storage by other common methods namely sprinkling water, covering with leaves and open basket storage. Among the low cost methods of storage zero energy cool chamber was found to be most effective and its efficiency was found at almost comparable to the refrigerated and high cost oriented method walk-in-cooler in preserving the freshness of vegetables.

The physiological loss in weight was found to be minimum in vegetables stored in walk-in-cooler. Use of zero energy cool chamber was significantly effective in checking weight loss during storage. The percentage loss in weight of vegetables was high in the other three methods particularly the open storage.

The chemical factors assessed include moisture, total mineral, fibre and ascorbic acid content of fresh as well as stored samples. The results gave higher moisture, total mineral and ascorbic acid retention in walk-in-cooler stored vegetables followed by that of zero energy cool chamber. The efficiency of zero energy cool chamber was found to be much higher compared to the remaining three low cost and simple storage methods.

Increase in fibre content was minimum in walk-in-cooler and cool chamber. Higher concentration of fibre was noticed in sprinkling water method, covering with leaf and open storage. Thus it can be clearly stated that next to walk-in-cooler zero energy cool chamber efficient to check the changes occurring in all the chemical parameter on storage.

Inspite of increased relative humidity inside the chamber there was no microbial spoilage observed in vegetables stored under zero energy cool chamber during the study period. Fungal attack was noticed in water sprinkled vegetables.

Shelf life duration of vegetables was considerably more in zero energy cool chamber as against lesser days in atmospheric temperature storages. Thus the possibility to extend the storage days of vegetables by adopting the zero energy cool chamber method is clearly indicated.

The maximum and minimum temperature inside the chamber was much below the ambient conditions. The relative humidity inside the chamber was higher than atmospheric humidity. It was also observed that the seasonal fluctuation in temperature and relative humidity was very narrow in respect to fluctuation observed in the atmosphere during the two seasons, promising a fairly steady storage effect.

Popularisation of zero energy cool chamber as a low cost storage device was carried out among selected vegetable growers of the locality through a one day education programme including demonstration. An evaluation conducted revealed that the local farmers also were totally unaware of low cost storage techniques to reduce post-harvest losses were able to learn scientific aspects of many of the low cost storage methods including use of zero energy cool chamber. Practical and theoretical informations regarding the construction and operation of the storage device were well grasped by the participants. Their responses in general was very encouraging and most of them have evinced a keen interest in collecting more information.

The views of the respondents enlightened that they are highly supportive of the effectiveness of zero energy cool chamber eventhough few respondents felt that this operation and maintenance procedure in time consuming.

In our country commercial cold storages are yet to make as an aid in large scale preservation of perishables because of heavy costs incurred. Thus the importance of a low cost cooking technology for horticultural crop meeting the requirements of rural conditions for prolonging the shelf life of fresh produce is keenly felt.

The investigation threw light on the efficiency of zero energy cool chamber as a low cost technology for short term storage of vegetables that is highly feasible under the climatic conditions of Kerala. The local vegetable growers expressed their interest in using this simple low cost method as a result of popularisation of the device among them.