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Development of moveable cold storage structure for fruits and vegetables

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Abstract
In the present study, a moveable cold storage structure was developed and its performance was evaluated by determining the cooling efficiency. Based on design considerations, crate size and its capacity, the size of the storage structure was fabricated. Based on cooling load 0.8 TR Air conditioner with Sub-Zero temperature controller was installed. The cold storage was evaluated under no-load condition at 8, 12 and 16°C, respectively. The average temperature and RH maintained inside the cold storage was 8.79 °C & 75.30 %, 12.82 °C & 74.78 % and 16.90 °C & 75.20% corresponding to 8, 12 and 16°C. The average cooling efficiency of the developed cold storage at three set temperatures was 91.26, 89.69 and 87.06 %, respectively. This storage will helps to increase shelf life of fruits and vegetables and sold in off season to fetch higher prices.

Keywords: cold storage, temperature, relative humidity, cooling efficiency

1. Introduction

India ranks first in the world in production of fruits and vegetables, accounting 10 and 15 per cent, respectively, of total global production. The total production is estimated at 295 million tonnes. The fruits production is 93 million tonnes, whereas production of vegetables is around 175 million tonnes [1] (Anonymous. 2017). The estimated losses in fruits and vegetables are higher and reached from 30 to 40 per cent [2, 3] (CIPHET, 2010). Wastage of fruits and vegetables due to poor post-harvest management and lack of cold chain facilities have been estimated to cost up to Rs 500 billion annually. Besides, quality of a sizable quantity of produce also deteriorates by the time it reaches the consumer. These percentages are not acceptable and adversely affect the Indian economy. The post-harvest losses vary depending on crops, agricultural practices, climate, etc., storage is usually the primary reason in most cases. Most harvested fruits and vegetables are stored in traditional methods without any scientific design, it cannot protect commodity against pests and decay [4] (Verma and Singh, 2004). As a result, a bulk of stored commodities is lost to insect infestation, rotting and mould growth. In the absence of a cold storage and related cold chain facilities, the farmers are being forced to sell their produce immediately after harvest which results in glut situations and low price. The country also experiences wide fluctuations in prices of horticultural produce, particularly potatoes, tomato and onions. This makes cold storage industry a very important and essential industry. It is reported that only 10-11% of fruits and vegetables cultivated in India use cold storage due to the expense involved and lack of suitable facilities.

Fresh fruits and vegetables start to deteriorate as soon as they are harvested and lose weight, texture, flavor, nutritive value, and appeal with the advancement of time. Cooling significantly slows down the rate of deterioration, thereby increasing the storage life of the produce. The more quickly the product is cooled, the longer it will remain marketable. Every commodity requires unique combination of temperature and relative humidity. Commercially, fresh produces are stored at recommended temperatures to get maximum possible shelf life and transport to longer distance.

Conventional methods of pre-cooling are not so much effective in reducing temperature and as a result fresh produce still deteriorates substantially within few days, especially during the hot summer months. Lower-cost cold storage options can benefit market growers by helping preserve produce freshness and quality for a few additional days. Produce losses can be significantly reduced, especially for growers transitioning to a higher level of production who have excess produce to carry over from one day's market to the next[4] (John, 2009). Evaporative cooling works by running warmer air through a cooler water pad that takes the heat out of the air, essentially working like sweat in the human body. Modern cold storage units control the temperature and humidity using a variety of technologies. CoolBot controllers and evaporative cooling are popular methods among small-scale farmers to maintain storage at low costs (Harris, 1987) [5]. The CoolBot works by manipulating an AC unit to act as a compressor, enabling the AC to achieve much lower temperatures than intended. Maintaining the constant temperature with modern insulation materials, efficient refrigeration technology and renewable energy, farmers can have affordable and sustainable food storage systems.

Cold storage is used to preserve fruits and vegetables. Once they are kept in the cold storage, they can store about few weeks to few months with minimum spoilage rate. Cold stores intended for long term holding of produce are designed close to production areas. During harvest season, produces stored in bulk, without marketing. During off season the chambers are periodically opened and product released to market (National Horticultural Board. 2015) [6]. Cold storage is a vital link between the production and consumption of perishable products. Apart from the conservation of perishables, the cold storages also help in increasing the marketing period of these commodities and ensure availability to the consumer over a long period.

Refrigeration provides temperature differential for processes like food preservation, food processing, storage application etc (Arora & Dhanpat Rai, 2008; Umesh *et al.*, 2015) [7, 8]. Refrigeration slows down the chemical and biological processes in foods, the accompanying deterioration and the loss of quality. Cooling is defined as decrease in temperature of a substance or medium below the temperature of its environment. Low temperatures and high humidity requires storing most of the fruits and vegetables (Wilson *et al*, 1995) [9]. Most fruit and vegetable crops retain better quality at high relative humidity (80 to 95%), but at this humidity, disease growth is encouraged. The cool temperatures in storage rooms help to reduce disease growth, but sanitation and other preventative methods are also required. Maintaining high relative humidity in storage is complicated by the fact that refrigeration removes moistur (Wilson *et al*, 1995) [9].

Design and operation of cold store, mainly depends on the two important parameters, relative humidity and (Tassou and Xiang, 1998) [10]. Water vapour pressure difference between the store air and the surface of the produce that drives the transpiration process. In order to minimize weight loss, it is important to maintain the store air with higher relative humidity typically 90% (Wilson *et al*, 1995) [9]. The relative humidity in refrigerated storage must be within the optimum range for the commodit (Lisa and Kader, 2004; Janet and Richard, 2000) [11, 12].

To store diversity of fruits and vegetables over a long season, small-scale vegetable producers need to use energy efficient cold storage methods to reduce costs and extend the revenue period while maintaining produce quality and freshness. In order to increase of shelf life of fruits and vegetables, a moveable on-farm cold storage structure was designed based on vapour compression refrigeration cycle.

2. Materials and methods

2.1 Design Consideration

2.1.1 Size of the storage structure

Crate size and stacking: Design of one tonne capacity cold storage based on the available crate size and its capacity. Crates of size 53.5 x 36.0 x 30.0cm were used to keep the material. Each crate had a capacity to store about 30 kg of fruits and vegetables. In single layer seven crates were placed and stacking up to five layers. A total of 35 crates or 1000 kg fruits and vegetables can be placed in the designed storage structure. The crate size and its stacking inside the storage are shown in Fig. 1. For operation and easy handling the storage structure should be within 2m.

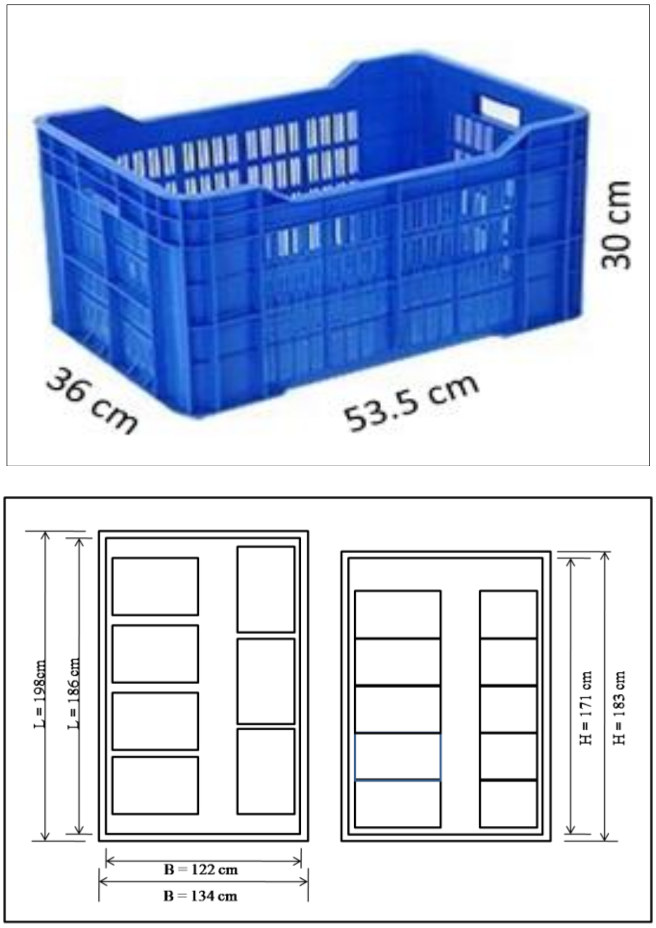

Fig 1: Size of the crate used and its stacking inside the cold storage.

Based on the above considerations, the storage structure with inner and outer dimensions 186 x122 x 171cm and 198 x 134 x 183 cm, respectively was designed.

2.1.2 Fabrication of storage unit

Portable cold storage unit consists of main frame, walls, floor ceiling, door, moving unit and cooling system (Fig 2a and Fig 2b).

Main frame: The base of the frame is fabricated by 75 x 40 mm M.S. Channel and the remaining frame was fabricated by welding angle iron of 3 x 3 cm cross section to get good strength for holding one tonne capacity produce and its own dead load.(weight of the cold store).

Walls, floor, ceiling and door: Thickness of wall, floor, ceiling and door of the storage unit was kept 60 mm. These units of storage structure were made of galvanized iron sheet, glass wool and polycarbonate sheet. The outer layer of galvanized iron sheet was mainly used to give strength to the storage unit whereas; glass wool and polycarbonate sheet were used as insulating material to reduce the heat flow from outside to inside storage unit and vice-versa. Glass wool was sandwiched between the GI sheet and polycarbonate.

Moving Unit: This unit was made portable cold storage by using three iron wheels having load capacity of 800 kg each, in order to handle more than one tonne designed capacity. Front wheel was fixed with the angle bar to facilitate easy turning. Handle was made of iron pipe connected to the front wheel for pulling the unit.

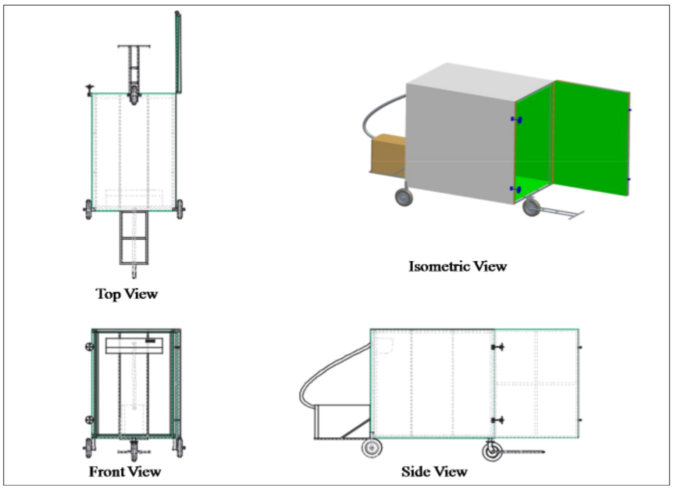

Fig 2a: Line diagram of developed cold storage.

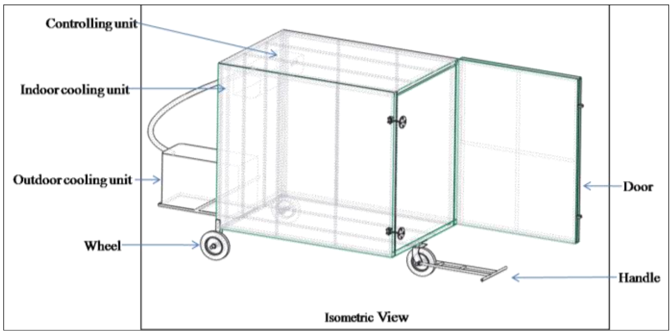

Fig 2b: Isometric view of developed cold storage.

2.2 Cooling System Design

2.2.1 Load calculation: Design or installation of cooling system depends on the cooling load required to cool the storage space. Which in term depends upon cooling load for produce, structural heat gain, heat of respiration, heat produced by air renewal and heat produced by equipments.

Structural heat gain: It constitutes the heat transmission into the cold store through walls, ceiling and floor. It consists of 3 mm thick GI sheet, 50 mm thick glass wool and 3 mm thick polycarbonate sheet from outer to inner surfaces respectively. Assuming the inside temperature of cold store was 0˚C and outside temperature as 45˚C, structural heat gain was calculated by steady state equation.

$$Q = UA\Delta t \text{ -----------------} \quad (1)$$

A = outer area of the section, m^2, U = overall heat transfer, W/m^2K,
Δt = difference between outside air temperature and inside air temperature, K,
The overall coefficient of heat transfer (U) of the wall, floor or ceiling can be calculated by the following equation

$$U = \frac{1}{\frac{1}{h_{in}} + \frac{X_1}{K_1} + \frac{X_2}{K_2} + \frac{X_3}{K_3} + \frac{1}{h_{out}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

Taking, Coefficient of heat transfer, h_i= 9.3 W/m^2K and h_o= 20 W/m^2K. (A value of 9.33 W/m^2K for h_{in} and h_{out} is frequently used for still air[14]. If the outer surface is exposed to 24.0km/h wind, h_{out} is increased to 20 W/m^2K (ASHRAE, 1998).

$$U = \frac{1}{\frac{1}{9.33} + \frac{0.003}{18} + \frac{0.05}{0.036} + \frac{0.003}{0.7} + \frac{1}{20}} = 0.645\ W/m^2K$$

A= total surface area of heat transmission (m^2).
Total area of a cuboid (A) was calculated as 2(l*b + b*h + h*l), where l(1.98m), b(1.34m), h(1.83m) are length, breadth and height of the storage structure, respectively.
Total surface area = 2 (1.98*1.34 + 1.34*1.83 +1.83*1.98) = 17.45m^2

$Q_1 = 0.645 \times 17.45 \times (318.16 – 273.16) = 506.48W$

Load due to produce: For calculation purpose, tomato was selected as a produce to be stored. Heat removed to cool produce from the initial temperature (field heat) to some lower temperature (storage temperature) is given as

$$Q_2 = MCp\ (T_1 – T_2) \text{ ---------------} \quad (3)$$

T_1-initial temperature (30°C); T_2-final temperature (0°C); M-mass of produce (kg); Cp-specific heat of produce (kJ/kg°K).
For tomato
Cp = 4.02 kJ/kg°K for green, Cp = 4.08 kJ/kg°K for ripe[15] (Brecht, 2008).
= 1000 × 4020 × (30 – 0) = 120600000 J/d = 120600000 / (24 × 60 × 60)
Q_2 = 1395.83 W

Heat of respiration (mW/kg)
Heat of respiration was calculated based on value given by[16] (Niranjan *et al*., 1993).
For green tomato – 126.6 × 10^{-3} J/kg.s at 25°C
Q_3 = 1000 × 0.1266 × 3600 × 24 = 10938240 J/d = 126.6 J/s = 126.6 W
For ripe tomato – 143.1 × 10^{-3} J/kg.s at 25°C (Heat of respiration of green and ripe tomato is 126.6 × 10^{-3} J/kg.s and 143.1 J/kg.s at 25°C ().
Q_3 = 1000 × 0.1431 × 3600 × 24 = 12363840 J/d= 143.1 J/s = 143.1 W

Heat produced by air renewal
Outside air enters to the storage chamber when operator opens the door. It gives heat to the store if the fresh air is warmer than that in the store. A volume of air equal to the fresh air supplied to the store also removed from it. The temperature and relative humidity of this discharging air are those prevailing in the store. Hence, V m^3/d of air with heat content i_1 is supplied to the store while the same amount of air with heat content i_2 is removed from it. The amount of heat is then:

$$Q_4 = V_a\ X\ (i_1 - i_2)\ x\ \rho \text{ ------------------} \quad (4)$$

Where:
V_a = amount of fresh air.m^3/d (4.85 m^3), air will be change 2 times,
Δi = difference in enthalpy between storage air and outside air,
ρ= air density, kg/m^3,
i_1 = 39.28 kJ/kg (DBT of cold air = 288.16K,

R.H. = 90% to be maintained) and
i_2 = 100.76 kJ/kg (DBT of outside air = 313.16K, R.H. = 50% to be assumed)
The enthalpy and air density can be obtained from psychometric chart at known air temperatures and relative humidity.
Q_4 = (4.85 × 2) × (100.76 – 39.28) × 1.11 = 661.16 kJ/d = 7.66 W

Heat produced by equipment related load
The heat produced by leaks in the structure, lighting, people and open doors is not easy to determine. This amount of heat is usually added as a percentage to the components of the total heat supplied in accordance with the items Q_1 to Q_4. This is 5% for large stores and 10% for small once; hence:
$Q_5 = 0.05 \text{ to } 0.1 \sum_{i=1}^{i=5} Qi = 0.1(Q_1 + Q_2 + Q_3 + Q_4)$
Q_5 = 0.1(506.48 + 1395.83 + 143.1 + 7.66)
Q_5 = 205.83W

Cooling load
The total heat supply or heat production in the store is:

$Q_{total} = Q_1 + Q_2 + Q_3 + Q_4 + Q_5$, W
= 506.48 + 1395.83 + 143.1 + 7.66+205.30 = 2258.37 W

This amount of heat has to be evacuated from the store in order to reach and maintain the required conditions. This heat is therefore equivalent to the cooling requirement of the store. However, the installed cooling capacity in a mechanically cooled store is always kept greater than Q_{total} for safety reasons, because, extra heat must be evacuated to cool the walls, roof and floor, Allowance must be made for necessary repairs to the cooling system, The insulation efficiency of the walls, roof and floor may be reduced if the insulation is wet and the efficiency of the compressor falls.
Total cooling load = 1.2 × Q_{total} (references)
= 1.2 × 2258.37 = 2710.04 W
= 2710.04 / (1.163 x 60) = 38.836 kcal/min
= 38.836 / 50 = 0.77 TR (tonnes of refrigeration)

2.2.2 Cooling system
Based on cooling load as above 0.8TR standard wall-mounted room air conditioner can provide a low-cost cooling source, but it reduces the temperature only up to 16°C. This limitation can be overcome by using Sub-Zero controllers (SZ-7510/69-E, India). These are single set point controllers. They are specially designed for refrigeration applications wherein the compressor cuts off at set point and is restarted at a temperature of set point differential. This can be used for several applications with a measuring range from –40°C to 50°C.
A smaller air conditioner may be sufficient to cool the same size room enough to take the field heat off a wide range of fruits and vegetables and significantly improve produce quality as compared to storage at ambient conditions. It should be noted that different produce has different optimum storage temperatures. Many produce items do best at very cold temperatures, just above freezing, but other produce typically handled by market growers do best at higher temperatures.

2.2.3 Working principle of Air conditioner
There are two main parts of the split air conditioner: the indoor unit and the outdoor unit. Apart from these two major parts there is copper tubing connecting the indoor and the outdoor units.

Outdoor Unit
The outdoor unit is installed outside the room to be air conditioned in the open space. In outdoor unit lots of heat is generated inside the compressor and the condenser, hence there should be sufficient flow of the air around it. The outdoor unit contains the important parts of the split AC like compressor, condenser, expansion valve etc.

Compressor: The compressor is most important part of the any air conditioner. It compresses the refrigerant and increases its pressure before sending it to the condenser. During this process lot of heat is generated in the compressor, which has to be removed by cooling fan.

Condenser: The condenser used in the outdoor unit of split air conditioners is the coiled copper tubing with one or more rows depending on the size of the air conditioning unit and the compressor. The high temperature and high pressure refrigerant from the compressor comes in the condenser where it has to give up the heat.

Condenser Cooling Fan: The cooling fan is located in front of the compressor and the condenser coil. The heat generated within the compressor has to be thrown out. Further, the refrigerant within the condenser coil has to be cooled so that after expansion its temperature becomes low enough to produce the cooling effect.

Expansion Valve: The expansion valve is usually copper capillary tubing with several rounds of coils. The high pressure and medium temperature refrigerant leaves the condenser and enters the expansion valve, where its temperature and pressure drops suddenly.

Indoor Unit
It is the indoor unit that produces the cooling effect inside the room. The indoor unit of the split air conditioner is a box type housing in which all the important parts of the air conditioner are enclosed.

Evaporator Coil or the Cooling Coil: The refrigerant from the expansion valve at very low temperature and very low pressure enters the cooling coil. Hot air is sucked by the blower and passes over the cooling coil which leads to the cooling of the air. This air is then blown to the room where the cooling effect has to be produced. The process of cooling the room continues until the set temperature was reached.
After absorbing the heat from the room, the temperature of the refrigerant inside the cooling coil becomes high and it flows back to the compressor unit. The refrigerant tubing supplying the refrigerant from the outdoor unit to the indoor unit and that supplying the refrigerant from indoor unit to the outdoor unit are both covered with the insulation tape.

Drain Pipe: Due to the low temperature refrigerant inside the cooling coil, when the room air is passed over the cooling coil, the temperature of the air becomes very low and reaches levels below its dew point temperature. Due to this the water vapor present in the air gets condensed and dew or water drops are formed on the surface of the cooling coil. These water drops are collected inside the indoor unit. The drain pipe is used to remove the water from this space and

connected to the water receiver kept inside the storage room for somewhat increase the relative humidity inside the cold store.
The cool air supplied by the blower is passed into the room through louvers. The louvers help changing the angle or direction in which the air needs to be supplied into the room as per the requirements. With louvers one easily changes the direction in which the maximum amount of the cooled air has to be passed.

Refrigerant: R-410A is often referred to as Puron used in this cooling system. It is a hydro-fluorocarbon (HFC), which does not damage the ozone layer; it also provides a better overall operation. It absorbs and releases the heat, making compressor run cooler so that it does not overheat. Additionally, it can work at a higher pressure. Systems that use R-410A also use synthetic oil for lubrication, rather than mineral oil. The synthetic oil is more soluble, making the whole system more efficient. Therefore, it is approved for new residential air conditioners.

2.3 Performance evaluation of cold storage
The developed portable cold storage structure was evaluated for its performance at different temperatures. It was operated for the three set temperatures (8, 12 and 16 °C) for 24 h. The system performance was evaluated for no-load (without commodity) condition, where the following observations were recorded at hourly interval for 24 h. Temperature and relative humidity achieved inside cold store and corresponding observations of outside environment were recorded. Also, power consumption of cooling system was measured to determine energy input to the system. The performance of cold storage at above mentioned temperatures to study the storage life of tomato.

2.3.1 Temperature and Relative Humidity Determination
The temperature and relative humidity were recorded using two temperature-humidity data logger manufactured with sensitivity of ± 0.5°C and ± 1% for temperature and relative humidity, respectively. One was kept inside the cold storage and other was kept outside in shade to avoid direct radiation. Cold storage structure was set at operated three individual temperatures each for 24 hours, and the temperature and the relative humidity during each set condition were recorded. In order to determine the wet bulb, a psychrometric chart was used.

2.3.2 Cooling Efficiency
The developed cold storage effectiveness was based on the cooling efficiency. The cooling efficiency of storage structure was calculated by use of different temperature values (Harris, 1987).

$$Cooling\ Efficiency\ (\%) = \frac{T1 - T2}{T1 - T3} \quad (5)$$

Where:
$T1$ = dry bulb temperature (ambient), °C
$T2$ = dry bulb temperature (cooling chamber), °C
$T3$ = wet-bulb temperature (cooling chamber), °C.

3 Results and discussion
3.1 Temperature and Relative Humidity Measurement
Cold storage was operated at three different temperatures (8, 12 & 16°C) for 24 hours. The temperature and relative humidity achieved inside and outside (ambient) the developed cold storage is shown in table 1.
The temperature and relative humidity achieved inside cold storage are presented in Fig. 3a, Fig.3b and Fig. 3c. At 8°C the temperature and relative humidity of inside and outside the cold storage ranges from 8.5 to 9.20 °C & 70.10 to 78.30% and 26.5 to 40.7 °C & 25.3 to 61.10%. At 12 °C, the temperature and relative humidity of inside and outside the cold storage ranges from 12.50 to 13.20 °C & 68.2 to 79.30% and 28.7 to 42.1°C & 25.80 to 46%. At 16 °C, the temperature and relative humidity of inside and outside the cold storage ranges from 16.5 to 17.40°C & 70.10 to 80.80% and 29.5 to 43.9 °C & 21.60 to 51.10%. The average cooling efficiency of the developed cold storage for three setting temperatures was 91.26, 89.69 and 87.06 %, respectively.
The temperature drop and variation in relative humidity of cold storage operated at three different temperatures are presented in Fig. 3d. The values are ranged from 18.0-31.50°C & 15.3-48.90%, 16.2-28.9°C & 32.2-47.6% and 13.0-26.5°C & 24.0-51.1%, respectively for three operating temperatures.

Table 1: Outside and inside of developed storage structure temperature and relative humidity at different setting temperature

Setting temperature		Temperature, °C			Relative humidity, %		
		Max.	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**
8 °C	Outside	40.70	26.50	33.77	61.1	25.3	40.86
	Inside	9.20	8.50	8.79	78.30	70.10	75.30
	Difference	31.50	18.00	24.79	48.90	15.30	33.95
12 °C	Outside	42.10	28.70	35.74	46.00	25.8	34.85
	Inside	13.20	12.50	12.82	79.30	68.20	74.78
	Difference	28.90	16.20	22.80	47.60	32.20	39.56
16 °C	Outside	43.90	29.50	36.22	51.10	21.60	36.26
	Inside	17.40	16.50	16.90	80.80	70.10	75.26
	Difference	26.50	13.00	19.30	51.10	24.00	38.81

From the Figs. clearly shows that the temperature of cold storage increased with increased in ambient temperature. The maximum temperature attained at noon. The maximum RH was observed during morning and evening hours.
The above results shows that, lower temperature and higher relative humidity which is an indication of the effectiveness of the cold storage in relating to its performance. The cold storage was able to achieve average temperature drop of 24.79, 22.80 & 19.30°C, respectively and increase in average relative humidity of 33.95, 39.56 & 38.81%. Same type of results reported by[17] (Sunmonu, *et. al*. 2014).
The average temperature maintained inside the developed storage structure at three different temperatures (8, 12 and 16 °C) were 8.79, 12.82 and 16.90°C, respectively. These results found that temperature inside the storage room was increased during sunshine hours.

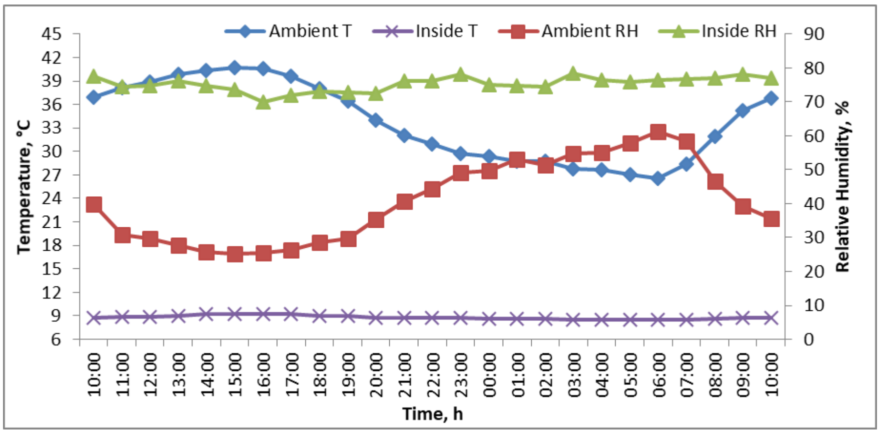

Fig 3a: Hourly variation of environment inside the cold storage at 8 °C.

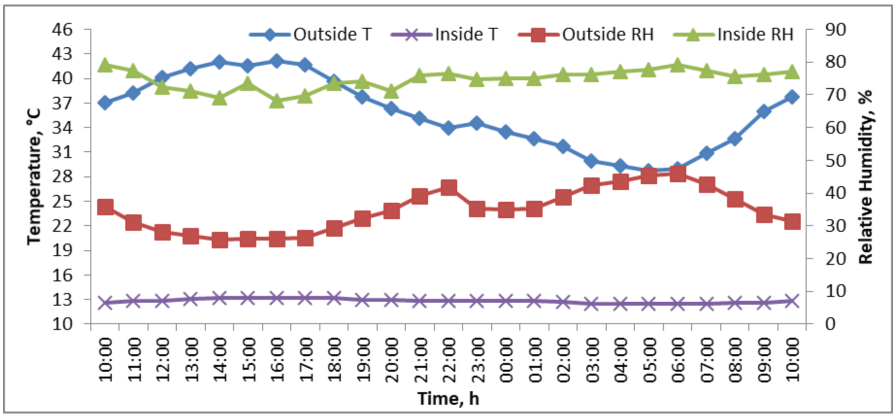

Fig 3b: Hourly variation of environment inside the cold storage at 12 °C.

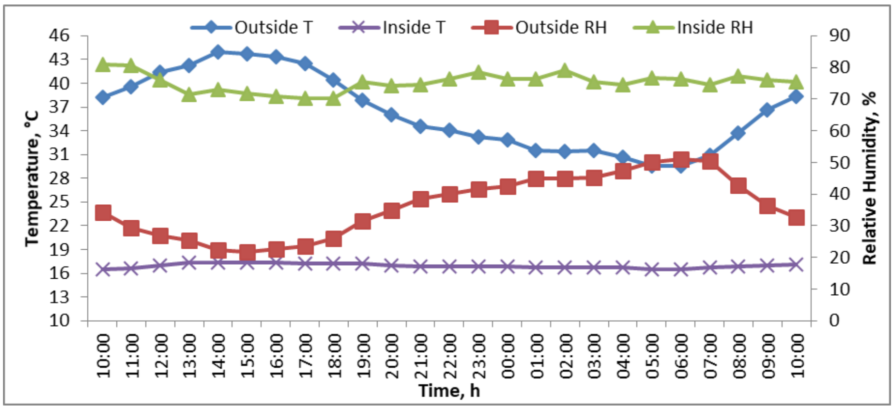

Fig 3c: Hourly variation of environment inside the cold storage at 16 °C.

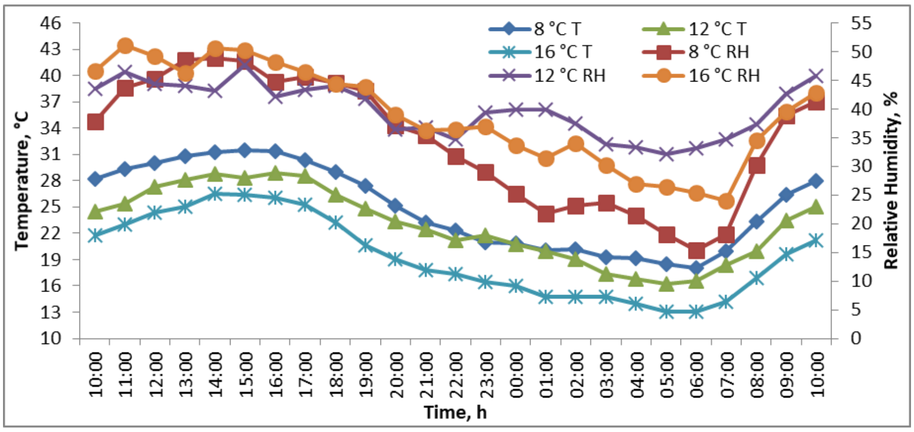

Fig 3d: Temperature drop and variation in relative humidity at different operating temperature.

3.2 Efficiency of the cold storage

The efficiency of cold storage for three different operating temperatures is presented in figure 4. The values range from 89.67-92.63%, 88.10-89.42% and 85.09-89.49%, respectively. The average efficiency of the cold storage is 91.26, 89.69 and 87.05%, respectively for three different operating temperatures. Same type of result reported by[17] (Sunmonu, *et. al*. 2014).

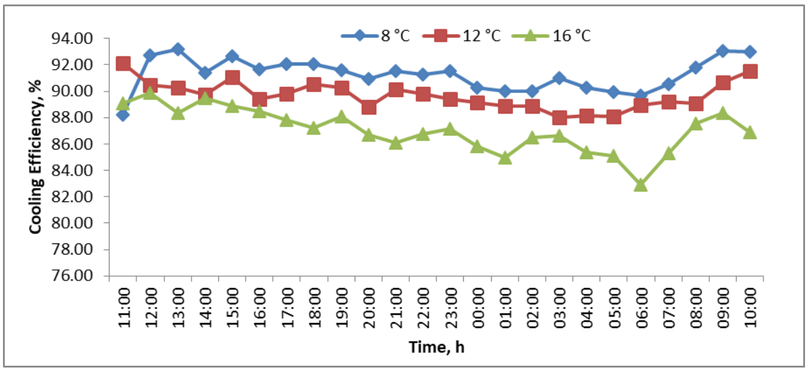

Fig 4: Cooling efficiency of developed cold storage.

3.3 Power consumption

The hourly power consumption at different operating temperatures (8, 12 and 16 °C) was shown in (Fig. 5a). The average hourly power consumption for operating cold storage was 0.35, 0.33 and 0.31 kWh at 8, 12 and 16 °C, respectively. The total power consumption for operating cold storage at 8, 12 and 16 °C was 8.35, 7.95 and 7.55 kWh, respectively (Fig.5b). From the Figs. observed that, the power consumption increased, as the operating temperature decreases and also observed that the power consumption was maximum at noon hours compared to morning and evening hours.

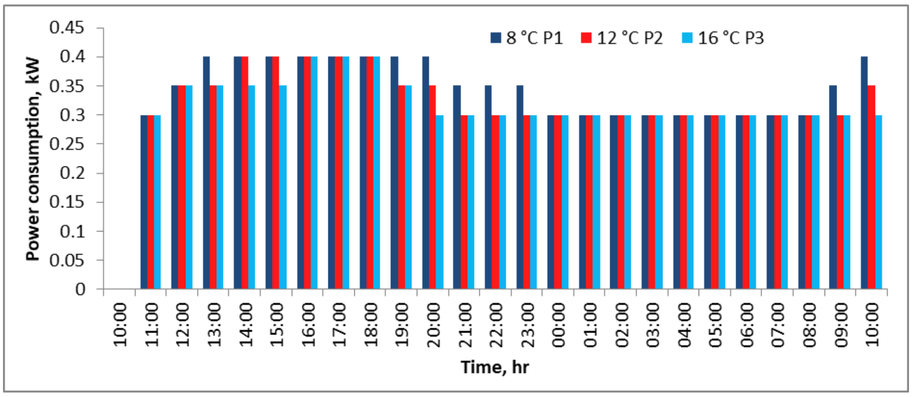

Fig 5a: Hourly power consumption of developed cold storage.

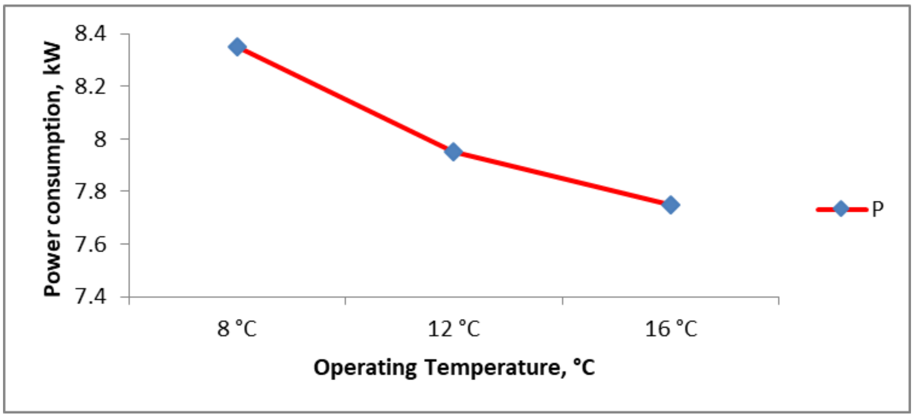

Fig 5b: Total power consumption of cold storage at different operating temperatures.

4 Conclusion

This research focussed on the development of portable cold storage for cooling fruits and vegetable. The average temperature was maintained inside the developed cold storage at 8, 12 & 16°C was 8.79, 12.82 and 16.90°C The findings from this research would help to increase the storage life of most of the fruits and vegetables. The cold storage was able to achieve average temperature drop of 24.79, 22.80 & 19.30°C, respectively and increase in average relative humidity of 33.95, 39.56 & 38.81%. The developed cold storage intended for long term holding of produce are designed close to produce areas. They will source produce during harvest season and store in bulk, without undertaking any sale. During off season periods, the chambers are periodically opened and product released to market to get higher price.

5. References

1. Anonymous. Horticulture production in India estimated at record 295 million tonnes in | India News - Times of India 2017.
2. Singh RB, Kushwaha RK, Verma Sunil Kumar. An economic appraisal of post-harvest losses in vegetable in Uttar Pradesh. Indian Journal of Agricultural Economics 2008; 63(3): 378.
3. CIPHET (Central Institute of Post-Harvest Engineering and Technology). Estimation of Quantitative Harvest and Post-harvest Losses of Major Agricultural Produce in India All India Coordinated Research Project on Post-harvest Technology, CIPHET (ICAR), Ludhiana, 2010.
4. Verma, Ajay, Singh KP. An economic analysis of post-harvest losses in fresh vegetables. Indian Journal of Agricultural Marketing. 2004; 18(1):136-139.
5. John W. Low-cost cold storage room for market growers. Cooperative extension service. University of Kentucky College of agriculture. AEN 2009; 96:1-4.
6. Harris NC. Modern air conditioning practice, Edn. 3, Vol. 49, McGraw-Hill Book Co., New York, 1987.
7. National horticultural board. Guidelines & minimum system standards for implementation in cold-chain components. National centre for cold chain development. 2015, 1-100.
8. Arora Dhanpat R. Refrigeration and Air Conditioning, Eighth ed. Dhanpatrai & Co. (P) LTD. New Delhi. 2000.
9. Umesh Sangale V, Priyanka J, Seloskar GR. Thermoelectric refrigeration by Using Solar Energy for Domestic Appliance. International Journal of Research in Advent Technology. 2015; 3(1):72-75.
10. Wilson LG, Boyette, MD, Estes EA. Postharvest handling and cooling of fresh fruits, vegetables and flowers for small farms. North Carolina cooperative extension, Leaflets. 1995, 800-804.
11. Tassou SA, Xiang W. Modelling the environment within a wet air cooled vegetable store. Journal of Food Engineering. 1998; 38:169-187.
12. Lisa K, Kader AA. Small-scale postharvest handling practices: A manual for horticultural crops (4th Edition). Postharvest horticultural series No.8, University of California –Davis, 2002, 1-257
13. Janet B. and Richard E. Postharvest handling of fruits and vegetables. The national sustainable agriculture information centre USDA’s rural business - cooperative service, Appropriate Technology Transfer for Rural Areas, 2000, 1-19.
14. ASHRAE. ASHRAE Handbook, Refrigeration. American society of heating, Refrigeration and air Conditioning Engineers, Inc. SI Edition, 1998.
15. Niranjan R, Ronaldo AF, Karen LBG. Mathematical relationship for the heat of respiration as a function of produce temperature. Postharvest biology and technology. 1993; 3:173-178.
16. Sunmonu MO, Falua KJ, David AO. Development of a Low-lost refrigerator for fruits and vegetables storage. International Journal of Basic and Applied Science. 2014; 2(3):85-93.