Affordable cold storage for preservation of perishable agricultural products in the context of North Bengal

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Abstract - A cold storehouse is the most effective system of conserving perishable vegetable quality like tomatoes, potatoes cabbage, eggplant carrot, etc., but its high cost deters relinquishment by the planter, smallholder, producer, and entrepreneurs. Several low-cost cooling devices have been developed, but they cannot maintain the recommended storehouse temperature. Various types of fruit and vegetables taste best when they're gathered completely ripe and also consumed or reused. Leafy vegetables and sauces also don't keep long after the crop. With fruit and vegetables from the home garden, speedy consumption and further processing are no problem, but consumers also want a certain shelf life in addition to good quality and full aroma for bought products. This pretense is a challenge to farmers for fruit and vegetable because the metabolism of the products continues indeed after the crop when gathered in the optimal condition, the quality of the gathered material decreases continuously - it loses taste and constituents and changes its appearance and thickness until it's at some point is no longer comestible. Perishable products deteriorate fleetly during the post-harvest chain. Thus, it is required to give an affordable cold storehouse system to enhance the quality and shelf life of the perishable agricultural products for rural as well as urban use. In the following acquaintance, the reader will learn how solar cold storehouses may be used for the preservation of perishable products and will be affordable to growers and smallholders, producers as well as entrepreneurs.

Keywords - **cold storage, perishable products, solar power, tomatoes vegetable.**

INTRODUCTION

Vegetables are considered one of the most important perishable products worldwide for fresh requests and reused due to their health and profitable significance. West Bengal has secured the 1st rank in vegetable products [1]. Fresh vegetables are similar to the organism, with the action still going on after today, they are respiration out of which water is deficient in emission, and there are other chemical changes. Vegetable gets also get worse due to temperature and high humidity. Leafy vegetables are quickly spoiled by tuber and root crops. Every year in our country thousands of tonnes of vegetables are quickly spoiled without proper maintenance A food regimen wealthy in veggies and culmination can decrease blood pressure, lessen the chance of coronary heart sickness and stroke, save you a few styles of cancer, decrease the chance of eye and digestive problems, and feature a wonderful impact upon blood sugar, which could assist maintain urge for food in Vegetables are vital for human fitness due to their vitamins, minerals, phytochemical compounds, and nutritional fiber content material. Especially antioxidant vitamins and nutritional fiber content material have vital roles in human fitness. It has been reported that tomato fruit has a considerable value in the most important antioxidants similar to lycopene, carotenoids, vitamin C, and minerals, which can play a vital part in suppressing the development of some mortal conditions including prostate, colon, and bone cancers [2]. Also, consumption of about 100 g of tomato can supply the mortal body with 40% of the recommended diurnal lozenge of vitamin C which can enhance the vulnerable system, and lower blood pressure and cholesterol [3]. Vegetable products are classified as climactic products and deteriorate fleetly after crop due to soft textures and their vulnerability to microbial infection. Vegetables are gathered at colorful maturity stages, including green mature, swell, turning, and light red. Fruit and vegetable quality is substantially affected by postharvest conditions similar to transportation and storehouse conditions [4]. Post-harvest losses of fruits and vegetables are estimated to be between 15 and 40%, contributing to a significant portion of the total loss due to lack of storage facilities and poor infrastructure. Several methods are available for the preservation of food, the most common being preservation through heat exclusion [5]. A reduction in energy consumption and the utilization of sustainable and renewable energy technologies are essential to meet the increasing demand for cooling, using environmentally friendly methods [6]. Thus, it is required to give an affordable refrigeration storehouse system to enhance the quality and shelf life of the perishable vegetable for unborn use maintain postharvest quality and protract the shelf life of products. Solar-powered cold storehouse may be used for the preservation of the perishable product and it'll be affordable to growers and producers because of its availability, and affordability.

ESTIMATION OF SOLAR COLD STORAGE FOR A PARTICULAR PERISHABLE PRODUCT

In this paper for estimation of solar cold storage, tomato is considered as a perishable product. It has been reported that tomato fruit has a considerable value in the most important antioxidants similar to lycopene, carotenoids, vitamin C, and minerals which can play a vital part in suppressing the development of some mortal conditions including prostate, colon, and bone cancers. Also, consumption of about 100 g of tomato can supply the mortal body with 40% of the recommended diurnal lozenge of vitamin C which can

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enhance the vulnerable system, and lower blood pressure and cholesterol.

Fig. 1. Wastage of Perishable products due to lack of low cost cold storage.

Fig. 2. Wastage of tomatoes due to lack of affordable cold storage.

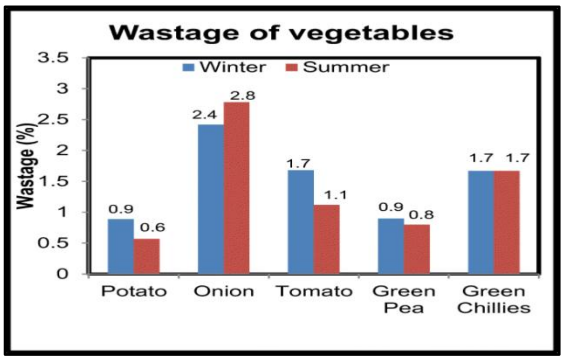

Fig. 3. Wastage statistics of Perishable products in India[7].

States	Area (000' ha)	Production (000' tonnes)
Uttar Pradesh	1256.27 IInd	27703.82 IInd
West Bengal	1490.39 Ist	29545.23 Ist
Bihar	872.55 IIIrd	16699.84 IIIrd
Orissa	613.62	8466.17
Tamil Nadu	235.77	6082.54
Gujarat	626.26	12552.15 IVth
Karnataka	430.925	7044.888
Maharashtra	649.79 IVth	11283.23
Andra Pradesh	259.83	7091.37
Punjab	249.32	5207.36
Rajasthan	178.01	2047.13
All India Total	10099.82	185883.22

Source: Indian horticulture database, (2018-19)

Fig 4. Production of vegetables in leading states of India (2018-19).

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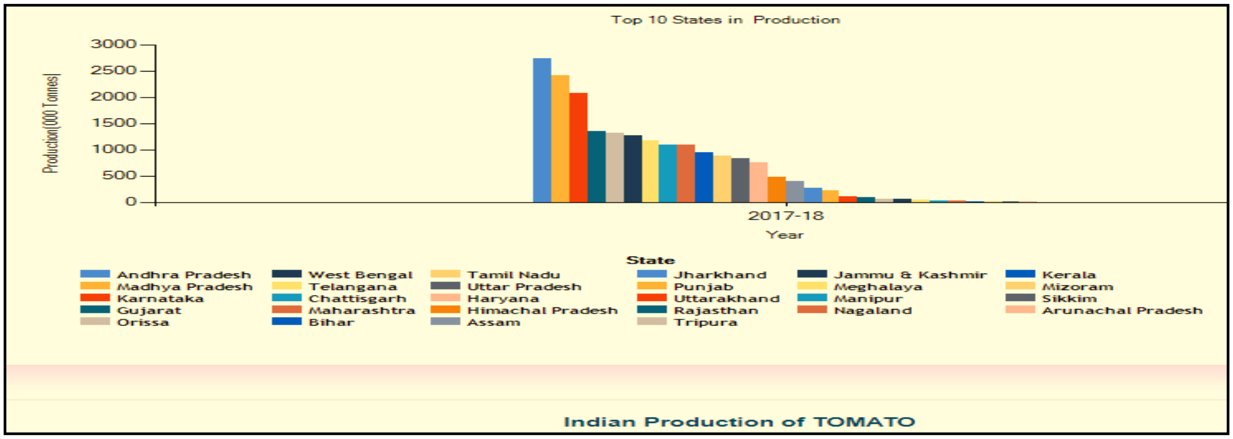

Fig. 5. Indian Production of TOMATO (Source: National Horticulture Board).

Table 1. Area and production of tomato for major producing districts in west Bengal.

				A: Area in '000 Ha P: Production in '000 MT	
States	**District**	**2015-16**		**2016-17**	
		Area	**Production**	**Area**	**Production**
West Bengal	**COOCH BEHAR**	3.31	148.75	3.32	153.24
	24 PARAGANAS NORTH	4.18	134.53	4.19	135.95
	NADIA	4.80	109.14	4.82	115.84
	MURSHIDABAD	4.87	101.56	4.88	101.89
	ALIPURDUAR	3.39	100.52	3.40	100.75
	24 PARAGANAS SOUTH	4.94	92.19	4.95	93.25
	PURULIA	5.54	80.50	5.55	80.70
	MEDINIPUR WEST	4.21	70.66	4.21	71.56

*Horticultural Statistics at a Glance 2018

Production Of Tomatoes In The District Cooch Behar

From the Horticultural Statistics, it can be observed that the state, West Bengal is in 6th position in India in the production of tomatoes, and the district Coochbehar is in the 1st position in West Bengal in the production of tomatoes. But due to the lack of post-harvesting management, the farmers are reluctant to produce tomatoes in large quantities. So, proper post-harvesting technic like refrigerated cold storage within the budget will motivate them to mass production of tomatoes.

Yearly Profit Loss Analysis

From the above Table 1, it can be observed that the yearly average production of tomatoes is 150 thousand tons.

From horticulture statistics, it was also observed that every year losses of tomatoes are around 14% to 17% due to lack of cold storage. Now if here we consider 15%, then yearly losses = 150 x 1000 x 15 % = 22500 Qnt. = Rs. 56,25,00,000 (Loss).

[Yearly average market price of tomatoes = Rs.2500/Qnt.]

Storage Conditions And Ecology

How active the metabolism of fruit and vegetables is indeed after the crop can be seen from the growing of half-green tomatoes. For growing tomatoes, the storehouse temperature is 4.5°C to 7°C, relative moisture 85% to 90%, and cold storehouse life needed about 1 to 1.5 weeks. For mature (green) tomatoes, storehouse temperature is needed about 5.5°C to15.5°C, relative moisture 90%, and storehouse life of 4 to 8 weeks.

The design of Cold Storage largely depends on:

- Product to be stored
- Temperature and moisture conditions to be maintained\
- Volume of the product
- Period of Storage

HEAT LOAD CALCULATIONS

Cold storage capacity for 10000 kg (10 ton) tomatoes requires a storage volume of approximately 1200 ft^3, because nearly 50-70 % of the total volume is utilized for storage purposes. For this purpose one storage of size, 20 ft *x* 10ft *x* 6ft (1200 ft^3) is considered. If the height of the cold storage is 6ft then the base of the cold storage will be 20ft *x* 10 ft.

TRANSMISSION LOAD

This is the thermal energy transferred through the roof, walls, and floor into the cold room. Consider the ambient air is 30°C at 50% RH, and the internal air is 5°C at 90% RH. The walls, roof, and floor are all insulated with polyurethane with a U value of 0.028W/ft^2-°C.

To calculate the transmission load, following formula will be used:

$$Q = UA\left(\frac{To - Ti}{1000}\right)x24$$

Where, Q = kW-hr/day heat load, U = U value of overall heat transfer coefficient (W/ft^{2}-°C), A = surface area of walls roof and floor (ft^2), T_i = The air temperature inside the room in (°C), T_o = The ambient external air temperature in (°C), 24 = Hours in a day.

To calculate "Area" is fairly easy, it is just the size of each internal wall, so drop the numbers in to find the area of each wall, roof, and floor. Side 1 = 20ft *x* 6ft = 120ft^2; Side 2 = 20ft *x* 6ft= 120ft^2; Side 3 = 10ft *x* 6ft = 60ft^2; Side 4 = 10ft *x* 6ft = 60ft^2, Roof = 20ft *x* 10ft = 200ft^2; Floor = 20ft *x* 10ft = 200ft^2.

Then, it can run these numbers in the formula to calculate the floor separately from the walls and roof as the temperature difference is different under the floor so the heat transfer will therefore be different.

WALLS AND ROOF

$$Q = UA\left(\frac{To - Ti}{1000}\right)x24$$

$$\mathrm{Q} = 0.028x560\left(\frac{30 - 5}{1000}\right)x24$$

$$Q = 10(\text{approx.})\text{kW} - \text{hr/day}$$

FLOOR

$$\mathrm{Q} = \mathrm{UA}\left(\frac{\mathrm{To} - \mathrm{Ti}}{1000}\right)x24$$

Consider ground temperature: $\mathrm{T_o} = 15°\mathrm{C}$

$$Q = 1.4\ \text{kW} - \text{hr/day}$$

If the bottom isn't isolated, then it is needed to use a different formula grounded on empirical data. Total daily transmission heat gains = 11.4 kWh/day, if the cold room is in the direct sun then it is needed to regard for the sun's energy also.

PRODUCT LOAD – PRODUCT EXCHANGE

Next, should be calculated the cooling load from the product exchange that being the heat brought into the cold room from new products which are at an advanced temperature.

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For this example here will be storing tomatoes, so it can look up the specific heat capacity of the tomatoes but do remember if it is required for freezing products then the products will have a different specific heat when cooling, freezing, and subcooling so it'll be needed to account and calculate this separately, but in this example, here it is just cooling.

There is 400kg of new tomatoes arriving each day at a temperature of 25°C and a specific heat capacity of 3.60 kJ/kg-°C; The following formula can be used:

$$Q = m\ x\ Cp\left[\frac{T_i - T_{sh}}{3600}\right]$$

Where, C_P = Specific Heat Capacity of tomatoes (kJ/kg-°C), and m = the mass of new tomatoes each day in (kg). Thus,

$$\boldsymbol{Q = 8\ \mathrm{kW - hr/day}}$$

PRODUCT LOAD – PRODUCT RESPIRATION

Next, to calculate the product respiration, this is the heat generated by living products similar to fruit and vegetables. These will induce heat as they're still alive, that's why it is required to cool them to decelerate their deterioration and save them for longer. For this illustration, here it has taken 1.91 kJ/kg/day as an average, but this rate changes over time and with temperature. In this illustration, here are using rules of thumb value just to simplify the computation since this cooling load isn't considered critical. If it were to calculate for a critical load they should use lesser perfection. In this illustration, the store maintains a hold of 10000 kg of tomatoes. To calculate this, the equation is given by:

$$\boldsymbol{Q = \left(\frac{m\ x\ \mathrm{Resp}}{3600}\right)}$$

Where, m = mass of tomatoes in storage (kg), and Resp = the respiration heat of the perishable product (1.91kJ/kg).

$$\boldsymbol{Q = 5.3\ \mathrm{kW - hr/day}}$$

For the product section, it'll sum together the product exchange of 8 kWh/day and respiration load of 5.3kWh/day to get a total product load of 13.3kWh/day.

TOTAL COOLING LOAD

To calculate the total cooling load here are all the values calculated; Transmission load: 11.4kWh/day; Product load: 13.3kWh/day; so, total = 24.7 kW-hr/day.

SAFETY FACTOR

It's typical to add 10 to 30 percent onto the computation to cover the safety factor, in this case, it is considered as 20 percent for illustration so well just multiply the cooling load by a safety factor of 1.2 to give a total cooling load of 29.64 kWh/day.

COOLING CAPACITY SIZING OF REFRIGERATION

It's projected that the unit to run about 15 hours per day which is fairly typical for this size and type of store. So the total cooling burden of 29.64 kWh per day, divided by 15 hours means the refrigeration unit conditions to have a capacity of about 2kW to sufficiently meet this cooling load [8].

PRINCIPLES OF REFRIGERATION

Removing heat from a place or a thing is the process of refrigeration, which is often accomplished by artificially reducing the temperature. A cold storage house system uses the vapour absorption refrigeration system, much like any other refrigeration system of comparable size. A variation on the vapour compression refrigeration systems is the vapour absorption refrigeration system. The input to absorption systems, as opposed to vapour compression refrigeration systems, is heat. Hence these systems are also called heat-activated or thermal energy-driven systems. Since conventional absorption systems use liquids for the absorption of the refrigerant system, these are also sometimes called wet absorption systems. Parallel to vapour compression refrigeration structures, vapour absorption refrigeration structures have additionally been commercialized and are extensively utilized in diverse refrigeration and air conditioning applications. Since those structures run on low-grade thermal power, they're desired while low-grade power including waste warmness or solar power is available. Since conventional absorption structures typically use usual refrigerants including water or ammonia they're surroundings friendly.

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SOLAR REFRIGERATION

A refrigerator that runs on electricity supplied by Solar Energy is known as solar refrigeration. Solar-powered refrigerators may be most generally used in the coming generation.

NEED FOR SOLAR REFRIGERATION:

- Need refrigeration in areas not connected to a power grid
- Need to minimize environmental impact and energy cost
- Estimate the eventuality of solar energy to meet these requirements
- Estimate the effectiveness of different types of solar refrigeration

DIFFERENT TYPES OF SOLAR REFRIGERATION

- Photovoltaic Operated Refrigeration Cycle
- Solar Power Mechanical Refrigeration
- Solar Vapour Absorption Refrigeration

PHOTOVOLTAIC OPERATED REFRIGERATION CYCLE

Vapor compression cycle system with a power input from Photovoltaic cells. DC electric power output system from PV runs the compressor of a conventional cycle (Fig. 6).

CONSIDERATIONS

Should match voltage imposed on PV array to the motor characteristics and power requirements of the refrigeration cycle. For a given operating condition (solar radiation and module temperature), a single voltage provides maximum power output. Must find compressor motor nearly matched to the electric characteristics of the PV module [9].

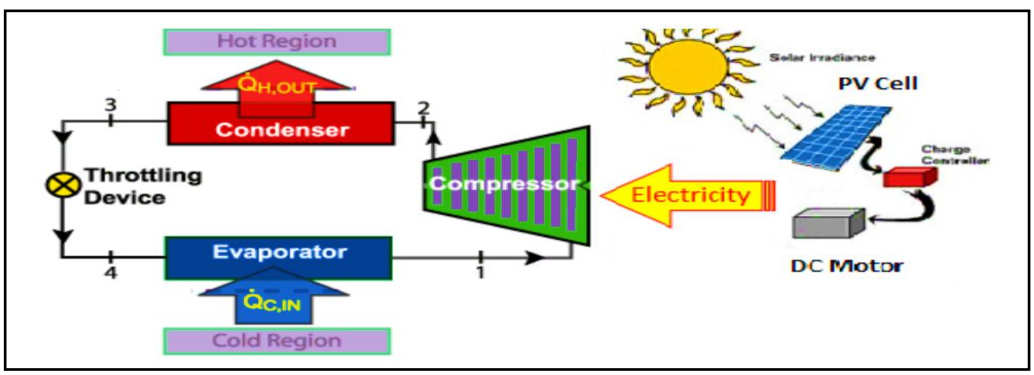

Fig. 6. Photovoltaic Operated Refrigeration Cycle [10].

SOLAR POWER MECHANICAL REFRIGERATION

Vapor compression cycle with a power input from solar Rankine cycle.

CONSIDERATIONS

Efficiency optimization based on delivery temperature, the efficiency of the Rankine cycle increases with increased heat exchanger temperature, the efficiency of solar collectors decreases with an increase in temperature.

CONCLUSION

A good deal of experience is required to make a perfect calculation of a cold store's refrigeration requirement and this should therefore only be done by a well-qualified and experienced person. Although the above computation is not comprehensive, it will still be useful for two things. It enables the reader to perform a similar sort of calculation for various perishable product types and storage capacities to determine an approximation of the required number of refrigerated storehouses. Additionally, it aids the reader in understanding the multitude of variables that must be taken into account when calculating the heat load and provides

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some insight into the relative weight of the design process that can be utilised to scale up the capacity. The economic study for producing a solar refrigeration system for a small cold storage facility for perishable goods like tomatoes, fruits, other vegetables, etc. is helped by this project.

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