Affordable Cold Storage for Preservation of Tomatoes before exporting to the Market

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***Abstract*— A refrigerated storehouse is the most effective system of conserving vegetable quality like tomatoes, but its high cost deters relinquishment by the planter, smallholder directors, and entrepreneurs. Several low-cost cooling styles have been developed, but they cannot maintain the recommended deep freeze- storehouse temperature. Numerous 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 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 poses a challenge to farmers for fruit and vegetable like tomatoes 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. Tomatoes are perishable fruit that makes them deteriorate fleetly during the post-harvest chain. Thus, it is required to give an affordable refrigeration storehouse system to enhance the quality and shelf life of the tomato for rural as well as unborn use. In the following companion, the reader will learn how solar cold storehouses may be used for the preservation of tomatoes and will be affordable to growers and smallholders, producers as well as entrepreneurs.**

***Keywords*— Tomatoes, cold storage, and solar power**

I. INTRODUCTION

Tomato is considered one of the most important vegetable crops worldwide for fresh request and reused products due to its health and profitable significance. West Bengal has secured the first rank in vegetable products and tomato is one of the most consumed vegetables in the study area. [1]. It has been reported that tomato fruit has a considerable value of the most important antioxidants similar to the 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, lower blood pressure and cholesterol [3]. Likewise, tomatoes are classified as climactic fruit and deteriorate fleetly after crop due to soft textures and their vulnerability to microbial infection. Tomatoes are gathered at colorful maturity stages, including green mature, swell, turning, light red, and full red. The most favored stages for consumers are the light and full red stages, which decay extensively after crop. 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 30 and 40%, contributing towards a significant portion of a 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 tomato for unborn use maintain postharvest quality and protract the shelf life of tomatoes. Solar cold storehouse may be used for the preservation of tomatoes and it'll be affordable to growers because of its availability and low costing concerning others.

Fig 1. Wastage of tomatoes due to lack of affordable cold storage

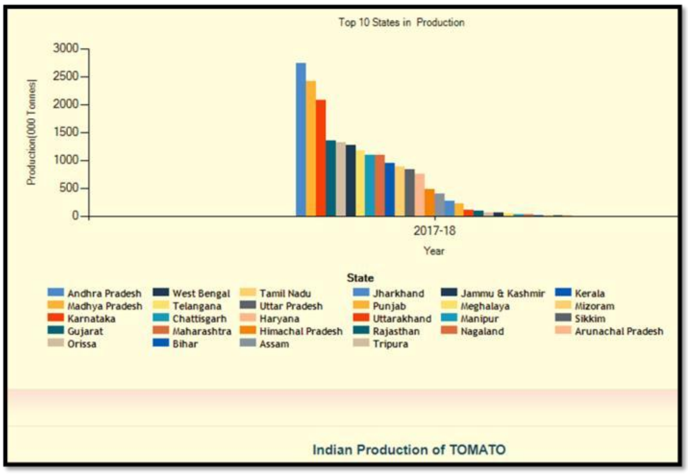

Fig. 2 [7]

II. 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
	PURBA BARDHAMAN	2.97	50.50	2.98	62.45

Horticultural Statistics at a Glance 2018

Production of tomatoes in the District. Cooch Behar

From the above statistics, it can be observed that the state of 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 for mass production of tomatoes.

III. Principles of Refrigeration

Refrigeration is the process of removing heat from an area or a substance and usually is done by an artificial means of lowering the temperature. A cold storage house system like any other refrigerating system of the same magnitude employs the vapour absorption refrigeration system. This Vapour Absorption Refrigeration System is the modification of the vapour compression refrigeration systems. However, unlike vapour compression refrigeration systems, the input to absorption systems is in the form of 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 systems, vapour absorption refrigeration systems have also been commercialized and are widely used in various refrigeration and air conditioning applications. Since these systems run on low-grade thermal energy, they are preferred when low-grade energy such as waste heat or solar energy is available. Since traditional absorption systems generally use naturally accepted refrigerants such as water or ammonia they are environment friendly.

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 eventuality of solar energy to meet these requirements
- Estimate effectiveness of three types of solar refrigeration

Types of solar refrigeration:

- Photovoltaic Operated Refrigeration Cycle
- Solar Mechanical Refrigeration
- 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

Considerations:

Should match voltage imposed on PV array to the motor characteristics and power requirements of the refrigeration cycle

Forgiven operating conditions (solar radiation and module temperature), single voltage provides maximum power output.

Must find compressor motor nearly matched to the electric characteristics of the PV module.[8]

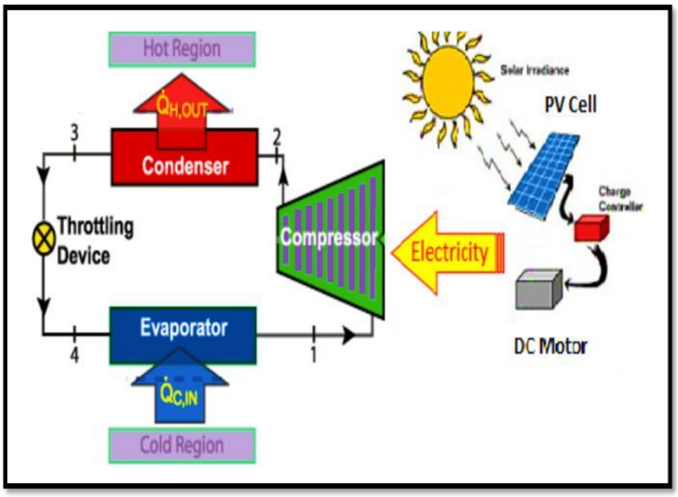

FIG. 3 PHOTOVOLTAIC OPERATED REFRIGERATION CYCLE [9]

Solar 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.

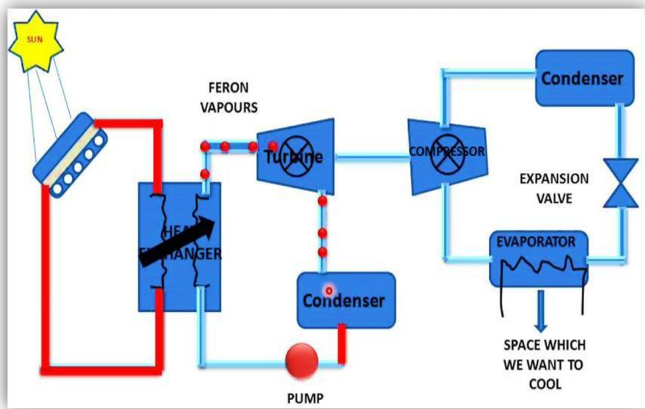

Fig. 4 Solar Mechanical Refrigeration

Absorption Refrigeration:

- Condenser, throttle, evaporator function the same way
- Replaces compressor with "thermal compression system".
- Ammonia is working fluid
- Insignificant mechanical power input (pump instead of compressor).
- Absorption into a water solution allows it to be pumped.
- Desorbed in generator (rectifier required to separate water).
- Heat into the generator provided by solar collectors
- The pressurization is completed by dissolving the refrigerant in the absorbent, in the absorber section.
- Subsequently, the solution is pumped to high pressure with an ordinary liquid pump.
- In this way, the refrigerant vapour is compressed without the need for large amounts of mechanical energy that the vapor-compression air conditioning systems demand.

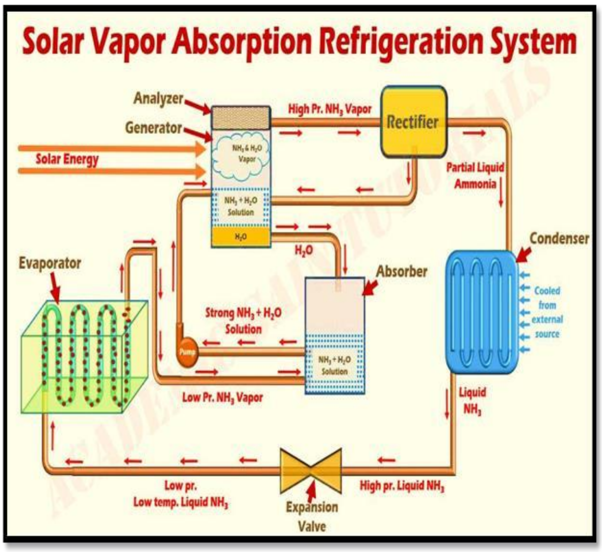

Fig. 5 Processes of vapour absorption refrigeration system

Fig. 6 Mini Cold storage with Solar Panel

IV. 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 to1.5 weeks. For mature (green) tomatoes, storehouse temperature is needed about12.5°C to15.5°C, relative moisture 90%, and storehouse life 3 to 4 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 1000 kg (1 ton) tomatoes requires a storage volume of approximately 120 ft^3 because nearly 50-60 % of the total volume is utilized for storage purposes. For this purpose one storage of size, 6ft x 5ft x 4ft (120 ft^3) is considered. If the height of the cold storage is 4ft then the base of the cold storage will be 6ft x5ft.

Transmission load

- The dimensions of the cold store may be 6ft long, 5ft wide, and 4ft high.
- Consider the ambient air is 30°c at 50% RH, The internal air is 5°C at 90% RH
- The walls, roof, and floor are all insulated with 0.26ft polyurethane with a U value of 0.028W/ft^2. °C

To calculate the transmission load following formula will be used

$$Q = UA\left(\frac{To - Ti}{24x1000}\right)$$

-Q= kWh/day heat load

- U = U value of insulation (value is known) (W/ft^2. °C)
- A = surface area of walls roof and floor (ft^2)
- Ti = The air temperature inside the room in (°C)
- To = The ambient external air temperature in (°C)

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 = 6ft x 4ft = 24ft^2
Side 2 = 6ft x 4ft= 24ft^2
Side 3 = 5ft x 4ft = 20ft^2
Side 4 = 5ft x 4ft = 20ft^2
Roof = 5ft x 6ft = 30ft^2
Floor = 5ft x 6ft = 30ft^2

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

Walls and roof

$$Q = UA\left(\frac{To - Ti}{24x1000}\right)$$

$$Q = 0.028x118\left(\frac{30 - 5}{24x1000}\right)$$

$$Q = 2(\text{approx.})\ \text{kWh/day}$$

[$118ft^2 = 24ft^2 + 24ft^2 + 20ft^2 + 20ft^2 + 30ft^2$]

Floor

$$Q = UA(\frac{To - Ti}{24x1000})$$

$$Q = 0.028X30(\frac{10-5}{24x1000})$$

$$Q = 0.1\ kWh/day$$

If the bottom isn't isolated then it is needed to use a different formula grounded on empirical data.

Total daily transmission heat gains = 2kWh/day + 0.1kWh/day = 2.1kWh/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, it 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.

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 1000kg of new tomatoes arriving each day at a temperature of 25°C and a specific heat capacity of 3.60kJ/kg.°C

The following formula can be used

$$Q = mXCp(\frac{Ti - Tsh}{3600})$$

- Q = kWh/day
- CP = Specific Heat Capacity of tomatoes (kJ/kg.°C)
- m = the mass of new tomatoes each day in (kg)
- Ti = the initial entering temperature of the products in(°C)
- Tsh = the temperature within the storehouse in(°C)

Calculation

$$Q = mXCp(\frac{Ti - Tsh}{3600})$$

$$Q = 1000X3.60(\frac{25-5}{3600})$$

$$Q = 20\ kWh/day$$

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 down their deterioration and save them for longer.

For this illustration, here it is taken as 1.91 kJ/ kg per 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 of1000 kg of tomatoes

To calculate this the formula is -

$$Q = (\frac{mXresp}{3600})$$

- Q = kWh/day
- m = mass of tomatoes in storage (kg)
- resp = the respiration heat of the tomatoes (1.91kJ/kg)

$$Q = (\frac{1000X1.91}{3600})$$

Q = 0.52kWh/day

For the product section, it'll sum together the product exchange of 20 kWh/day and respiration load of 0.52kWh/day to get a total product load of 20.52 kWh/day.

Total cooling load

To calculate the total cooling load here all the values calculated

Transmission load: 2.1kWh/day
Product load: 20.52 kWh/day

Total = 22.62 kWh/day

Safety Factor

Safety factors should also apply to the computation to regard crimes and variations from design. It's typical to add 10 to 30 percent onto the computation to cover this, 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 27.1 kWh/ day.

Refrigeration cooling capacity sizing

The last thing that should be demanded to do is calculate the refrigeration capacity to handle this burden, a common approach is to a normal of the total day-to-day cooling burden by the run time of the refrigeration unit. For this, it's projected that the unit to run about 14 hours per day which is fairly typical for this size and type of store. So the total cooling burden of 27.1 kWh per day, divided by 14 hours means the refrigeration unit conditions to have a capacity of about 2kW to sufficiently meet this cooling load. [10]

V. PRICE OF 2KW SOLAR SYSTEM

Below is the ultimate 2021 price list Inclusive of all Levies of 2kw on-grid, solar system.

2kW On Grid Solar System

The On-grid solar system works with the grid and net-metering is applicable on the 2kw solar system. 2kW solar system is the most extensively chosen solar system installed each over India.

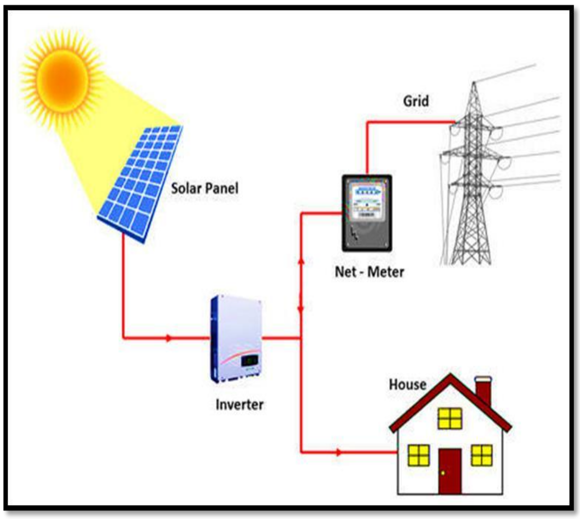

Fig. 7 Grid cum Solar System

Technical Information:	
Particulars	***Description***
Solar system capacity	2kW
Solar panel Quantity	6 No.s
Solar Inverter	2kW – On grid inverter
Accessories	Fasteners, Cable Tie, Crimping Tool, Earthing Kit, Lighting Arrestor
System warranty	**25 years**
MC4 connector	2 Pair
DC wire	30 meters
AC wire	20 meters
Space Required	Approx. 200 sqft
Average generation	8 units per day
Total cost	1,02,872

[11]

Advantages of 2kW On-Grid Solar System

- Costs less compared to other types of the solar system
- Save electricity bills up to 100 percent
- Eligible for over to 70% of government subventions on solar
- Exploit 100 percent solar power produced by 2kW solar panels
- Export the excess solar power to the electricity grid
- No limitation of loads, run all connected load with grid sharing

. • Life 25-30 times [12]

What Solar Panels Do at Night?

At present time, as the solar panels can produce power during the day, the question also develops" how will solar panels supply power overnight when there's no sunlight?" The primary results may help to resolve that problem. Solar- plus- storehouse technology allows solar panel systems to store excess electricity to the battery or supply to the grid and consumed overnight when solar panel product is dormant, either connected to the electric grid sever or a battery. Thanks to grid connections and solar energy storehouses, solar panels are a sustainable round-the-timepiece energy result. It will also solve the problem of battery demand for storehouses. Near future, if Silicon can be replaced with the material whose band-gap is equal to energy provided by moonlight then solar panels or say, Lunar Panel can be used at night for electricity generation.

VI. 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 qualified and experienced person. The above calculation is not complete but it will serve two purposes. It allows the reader to make a similar type of calculation for the storage capacity and thereby obtain an approximate refrigeration requirement. It moreover helps the reader to appreciate the number of factors that have to be taken into account for calculating the heat load and also gives some idea of relative importance design procedure used can be applied to scale up the capacity. This paper assists the economic analysis for manufacturing solar absorption refrigeration for mini cold storage like tomatoes, fruits, and vegetables.

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