International Journal of Statistics and Applied Mathematics

ISSN: 2456-1452
Maths 2023; SP-8(4): 519-522

https://www.mathsjournal.com
Received: 24-06-2023
Accepted: 25-07-2023

Deep P Patel
Assistant Professor, Department of Food Processing Technology, ADIT, CVMU, Anand, Gujarat, India

Neha Prajapat
Ph.D. Scholar, Department of Processing and Food Engineering, CTAE, MPUAT, Udaipur, Rajasthan, India

Divyesh Rameshbhai Vaghela
Assistant Professor, Department of Agricultural Engineering, Parul University, Vadodara, Gujarat, India

Sanjay Kumar Jain
Professor, Department of Processing and Food Engineering, CTAE, MPUAT, Udaipur, Rajasthan, India

Corresponding Author:
Deep P Patel
Assistant Professor, Department of Food Processing Technology, ADIT, CVMU, Anand, Gujarat, India

Evaluation of techno-economic feasibility of the developed portable solar-assisted evaporative cool chamber

Deep P Patel, Neha Prajapat, Divyesh Rameshbhai Vaghela and Sanjay Kumar Jain

Abstract

A portable solar-assisted evaporative cool chamber with a storage capacity of 250 kg of fruits and vegetables was developed and powered by two solar photovoltaic panels of 100 W, a 12 V battery of 150 Ah capacity, a charge controller, two DC exhaust fans of 7.4 W and a DC submersible water pump of 9 W. The highest temperature drop of 17 ºC and relative humidity rise of 70.1 per cent with saturation efficiency of 98.48 per cent was observed during the testing of the developed ECC (evaporative cool chamber), which was quite promising for the storage of fruits and vegetables. For commercialization of the developed technology, it is essential to know whether the technology is economically viable or not. Therefore, the main focus of the current investigation was to evaluate the techno-economic aspects of the portable solar-assisted evaporative cool chamber. This evaluation included key factors such as net present worth (NPW), payback period, and benefit-cost ratio.

Keywords: Evaporative cooling, fruits and vegetables, economic feasibility, NPW, payback period

1. Introduction

The Indian horticulture sector contributes about 33 percent to the agriculture Gross Value Added (GVA), making a very significant contribution to the Indian economy. The sector saw increased cultivation and harvesting of various fruits, vegetables, and ornamental crops, bolstered by advancements in farming practices and technologies. India's favourable climate conditions and diverse agro-ecological regions further supported horticultural expansion (Ministry of Agriculture, MoA, 2022) [5]. During 2021-22, India produced 107.24 Million metric tonnes of fruits and 204.84 Million metric tonnes of vegetables. The area under cultivation of fruits stood at 7.05 Million hectares, while vegetables were cultivated at 11.35 Million hectares (National Horticulture Board, NHB, 2022) [6].

The perishable foods have a short shelf life and are likely to spoil, decay, or become unsafe to consume if not properly stored. Fruits, vegetables, meat, fish and dairy products contain 65 to 95 per cent moisture are a few examples of perishable products (Jain *et al.*, 2011) [4]. This high moisture content of the horticultural produce makes them perishable and the loss of nutritional value and sensory attributes starts immediately after harvest (Chinenye *et al.*, 2013) [2]. Therefore, horticulture produce requires immediate attention to preserve its freshness and shelf life which can be accomplished in low-temperature storage having higher relative humidity.

The farmers usually face difficulty disposing of their produce in summer when it spoils quickly because of the temperature variations and low relative humidity. During that period, the power crisis is also at its peak. For each increment of 10 ºC above optimum temperature, the rate of spoilage increases by 2 to 3-fold (Singh and Satapathy, 2006) [8]. The vital activities of the tissues, for example, transpiration, respiration and ripening proceed even after harvest. The handling, transporting, storage, and processing of perishables affect postharvest losses, including mechanical damage and physiological and biological degradation (Emana *et al.*, 2017) [3].

By improving the storability of perishables and preventing microorganisms from extending their shelf life, cold storage facilities play a significant role and will decrease post-harvest losses (Basediya *et al.*, 2011) [1]. The storing of perishables will contribute to a continuous and regular supply chain ecosystem. The developed countries have good infrastructure and effective storage systems for perishables. Refrigerated storage is one of the excellent methods for keeping fruits and vegetables fresh, but it is energy-intensive and expensive (Patel *et al.*, 2022) [7]. However, these technologies are expensive for small farmers and vendors to adopt in developing countries.

Most of the vendors are part of the informal market. They sell fruits and vegetables on the street, roadsides, bus stands, or by carrying the goods door to door with their pushcarts or head loads. These people cannot afford these storage facilities even on a rental basis. It is essential to make available to vendors/farmers an appropriate integrated, low-cost system of post-harvest management right from the pre-harvest stage till the product reaches the consumer (Patel *et al.*, 2022) [7]. To overcome the issue of on-farm storage, a low-cost, energy-efficient and environmentally benign evaporative cooling system is required.

In light of the above facts, researchers have developed a portable solar-assisted evaporative cool chamber for storing fruits and vegetables. The performance of ECC was evaluated under various operating conditions, showing promising results in reducing temperature and increasing relative humidity. This favourable outcome contributes to extending the shelf life of perishables. However, the main focus of the present study lies in assessing the techno-economic aspect of the portable solar-assisted evaporative cool chamber. The aim is to analyze its feasibility and determine the trade-off between its technological capabilities and economic viability.

2. Materials and Methods

2.1 Raw Material

In the present study, four fruits (banana, apple, papaya and orange) and four vegetables (tomato, cucumber, okra, brinjal) were selected for storage in the developed evaporative cool chamber and the feasibility of the ECC was assessed.

Fig 1: Developed portable solar assisted evaporative cool chamber

2.2 Techno-Economic Feasibility

For the commercialization of any new technology, it is essential to know whether the technology is economically viable or not. Therefore, the economics of the developed unit was also carried out. Different indicators were used for the economic analysis of the developed unit:

1. Net present worth (NPW)
2. Benefit-cost ratio (B/C ratio)
3. Payback period

2.2.1 Net present worth (NPW)

The most straightforward discounted cash flow measure of project worth is the net present worth (NPW). The present value of the future returns is determined through discounting. Discounting is a technique by which future benefits and cost streams can be reduced to their present worth. The discounting rate is the interest rate assumed for discounting.

The present worth is used to determine the future income that might have been generated and how it is justified in investing today to receive that income stream. After deducting capital investment from gross benefit, what is left over is a residual that is available to recover the investment made in the project. The residual is the net benefit stream. The net present worth may be computed by subtracting the total discounted present worth of the cost stream from that of the benefit stream. The gross cost was subtracted from the gross benefit or the investment cost from the net benefit to obtain the incremental net benefit. The mathematical statement for net present worth can be written as Equation (1) (Zizlavsky, 2014):

$$\text{NPW} = \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} \quad ....(1)$$

Where,

C_t = Cost in each year, Rs

B_t = Benefit in each year, Rs

t = 1, 2, 3…………n, years

i = Discount of interest rate, per cent

2.2.2 Benefit-cost ratio

It is ratio of present worth of the benefit stream and present worth of the cost stream. A benefit-cost ratio of 1 or greater is desired for formal selection criterion for measure of worth of present product.

In practice, it is more common to compute the benefit-cost ratio using gross cost and gross present worth of the net benefit with the present worth of the investment cost plus the operation and maintenance cost. The ratio will be computed by taking the present worth of the gross benefit less associated cost and then comparing it with the present worth of the process cost. The associated cost is the value of goods and services over and above those included in the process/system costs needed to make the immediate products or services available for use or sale. Project economic cost is the sum of installation costs, operation and maintenance costs and replacement costs. The mathematical benefit-cost ratio can be expressed as following Equation (2) suggested by (Zizlavsky, 2014):

$$\text{Benefit-cost ratio} = \frac{\sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}} \quad .....(2)$$

2.2.3 Payback period

The payback period is the length of time from the beginning of the project until the net value of the incremental production stream reaches the total amount of the capital investment. It shows the length of time between cumulative net cash outflow recovered in yearly net cash inflows. The payback period was calculated using the following Equation (3),

$$\text{Payback period} = \frac{\text{Total investment}}{\text{Net profit}} \quad (3)$$

3. Results and Discussion

3.1 Techno-economics of Developed Portable Solar Assisted Evaporative Cool Chamber

Economic indicators used for the economic feasibility of the developed evaporative cool chamber (ECC) were net present worth (NPW), benefit-cost ratio (B/C ratio) and payback period.

The various assumptions for the determination of cost economics of the developed portable solar-assisted ECC are given in Table 1. The capacity of the ECC is 250 kg of fruits and vegetables. It is assumed that the storage unit will be used for 120 days (4 months) a year during summer season only as it can't work as effective as during the winter and monsoon season due to high relative humidity and low temperature in ambient conditions.

One assumption was made that the vendor is buying 250 kg of fruits and vegetables on the first day and selling 150 kg of fruits and vegetables in a day for 120 days. The remaining quantity of 100 kg was stored inside the ECC and sold the next day. To make the storage quantity 250 kg, the vendor bought only 150 kg of fruits and vegetables from the market every day. Generally, due to stress/fear of spoilage, vendors sell their products at lower rates in the evening. ECC will provide a solution to this problem by storing the leftover products inside the chamber.

The life of the unit was assumed to be 10 years. The discounting rate, depreciation, rate of interest on fixed and working capital and repair and maintenance costs were assumed as 10 per cent per annum. The battery will be changed after every 3 years of operation.

Table 1: Basic assumptions for economic analysis of developed portable solar assisted evaporative cool chamber

Assumptions made to calculate the economics	Quantity/Rate	Unit
Selling of fruits and vegetable per day	150	kg/day
Operating days per year	120	Days
Handling of fruits and vegetables per year	18,000	kg/year
Working capital for purchase of raw materials (fruits and vegetables)	1,00,000	Rs
Life of unit	10	Years
Discounting rate	10	Per cent
Depreciation, based on initial investment	10	Per cent
Rate of interest on fixed capital and working capital	10	Per cent
Repair and maintenance, based on initial investment	10	Per cent

Table 2 summarizes the average purchase and sale prices of fruits and vegetables, as per information received from fruits and vegetables vendors of seven major cities of India (Ahmadabad, Bangalore, Chennai, Jaipur, Mumbai, Delhi and Bhopal).

Table 2: Rates of fruits and vegetables in market of Udaipur

Sr. No.	Fruits and vegetables	Buying rates (Rs.)	Selling rates (Rs.)
1	Tomato	20	25
2	Okra	40	60
3	Brinjal	20	30
4	Cucumber	30	40
5	Banana	25	35
6	Apple	80	100
7	Papaya	25	35
8	Orange	40	50
Mean Rate (Rs)		35	46.87

Table 3: Fixed and variable cost and other indicators for economic analysis of portable solar assisted evaporative cool chamber

A. Fixed cost (Investment)	Rate	Unit
Installed cost of portable solar assisted evaporative cool chamber	65,000	Rs
Total cost (A)	65,000	Rs
Variable cost		
Raw material @35 Rs/kg for 18,000 kg	6,30,000	Rs
Battery replacement @15,000 Rs/unit (once in three year)	5,000	Rs/year
Labour charges @450 Rs/day for 120 days	54,000	Rs/year
Interest on fixed capital @ 10 per cent	6,500	Rs/year
Interest on working capital @ 10 per cent	10,000	Rs/year
Depreciation @ 10 per cent of fixed cost	6,500	Rs/year
Maintenance cost @ 10 per cent of fixed cost	6,500	Rs/year
Total cost (B)	7,18,500	Rs/year
Profitability		
Net sell price of fruits and vegetables	46.87	Rs/kg
Net sell price of fruits and vegetables (18,000 kg) per year (C)	8,43,660	Rs/year
Net annual saving (D)=C-B	1,25,160	Rs/year
Net present worth (NPW) after 10 years	9,81,067	Rs

Table 4: Techno economic feasibility of portable solar assisted evaporative cool chamber

Parameters	Values	Unit
Benefit-cost ratio	1.17	
Payback period	6.23 ≈ 7	Months
Annual income	1,25,160	Rs/year

The net present worth for the system was determined based on present investment, the interest rate considered for the system, and the profit earned each year. The life of the machine was assumed to be 10 years; thus, the NPW for the machine was Rs. 9,81,067. The net present worth calculated for the next 10 years is presented in Table 5.

Table 5: Calculations for the Net Present Worth after 10 years

Year	Cash outflow	PW of cash outflow	Cash inflow	PW of cash inflow	NPW
	65000	65000	0	0	-65000
1	718500	653182	843660	766964	113782
2	718500	593802	843660	697240	103438
3	718500	539820	843660	633854	94035
4	718500	490745	843660	576231	85486
5	718500	446132	843660	523846	77715
6	718500	405575	843660	476224	70650
7	718500	368704	843660	432931	64227
8	718500	335186	843660	393574	58388
9	718500	304714	843660	357794	53080
10	0	0	843660	325267	325267
		4202859		5183925	981067

The benefit-cost ratio was calculated as 1.17 with a payback period of 7 months. Therefore, based on the values of techno-economic indicators, it can be inferred that the developed portable solar-assisted evaporative cool chamber for storing fruits and vegetables is economically viable.

4. Conclusion

The developed portable solar-assisted evaporative cool chamber, with a storage capacity of 250 kg, was found to be economically viable. It effectively lowered the inside temperature by up to 17 ºC and increased the relative humidity by 70.1 per cent, making it a promising technology for short-term storage of fruits or vegetables in hot and dry conditions.

The cost economics analysis for the developed evaporative cool chamber resulted in a net present worth of Rs. 9,81,067 after 10 years, a benefit-cost ratio of 1.17, and a payback period of 7 months. These findings indicate that the developed unit is economically feasible.

In conclusion, adopting this technology would be beneficial not only to small-scale farmers and vendors but also to those living in hilly regions or areas with deficient electricity availability.

5. Acknowledgement

The author (Deep P. Patel) thanks his major advisor, Dr. S. K. Jain, for his encouragement in many fruitful discussions on this research. The authors appreciate the College of Technology and Engineering, MPUAT, Udaipur, providing technical support. The author (Deep P. Patel) gratefully acknowledged the research fellowship from the Council of Scientific and Industrial Research (CSIR) (Govt. of India).

6. References

1. Basediya A, Samuel DVK, Beera V. Evaporative cooling system for storage of fruits and vegetables-a review. Journal of food science and technology. 2013;50:429-442.
2. Chinenye NM, Manuwa SI, Olukunle OJ, Oluwalana IB. Development of an active evaporative cooling system for short-term storage of fruits and vegetable in a tropical climate. Agricultural Engineering International: CIGR Journal. 2013;15(4):307-313.
3. Emana B, Afari-Sefa V, Nenguwo N, Ayana A, Kebede D, Mohammed H. Characterization of pre-and postharvest losses of tomato supply chain in Ethiopia. Agriculture & Food Security. 2017;6(1):1-11.
4. Jain SK, Verma RC, Murdia LK, Jain HK, Sharma GP. Optimization of process parameters for osmotic dehydration of papaya cubes. Journal of food science and technology. 2011;48:211-217.
5. Ministry of Agriculture (MoA). Annual report; c2022.
6. National Horticulture Board (NHB). Annual report; c2022.
7. Patel DP, Jain SK, Lakhawat SS, Wadhawan N. A low-cost storage for horticulture commodities for enhancing farmer's income: An overview on evaporative cooling. Journal of Food Process Engineering. 2022;45(10):e14134.
8. Singh RKP, Satapathy KK. Performance evaluation of zero energy cool chamber in hilly region. Agricultural Engineering Today. 2006;30(5and6):47-56.
9. Žižlavský O. Net present value approach: method for economic assessment of innovation projects. Procedia-Social and Behavioral Sciences. 2014;156:506-512.