International Journal of Agriculture Sciences
ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 11, Issue 20, 2019, pp.-9154-9159.
Available online at https://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000217

Research Article

ECONOMIC ANALYSIS OF INCLINED SOLAR DRYER FOR DRYING OF FRUIT AND VEGETABLES

POONIA S.*, SINGH A.K., SANTRA P. AND JAIN D.
ICAR-Central Arid Zone and Research Institute, Jodhpur, 342 003, Rajasthan, India
*Corresponding Author: Email - poonia.surendra@gmail.com

Received: October 04, 2019; Revised: October 25, 2019; Accepted: October 26, 2019; Published: October 30, 2019

Abstract: This research paper describes the performance evaluation and economic analysis of solar dryer for drying of perishable agricultural produces. The dryer was fabricated using locally available materials, e.g. galvanized iron sheet, M.S. angle, glass and S.S. wire mesh. The provision of tilting the dryer helps receive maximum solar radiation round the year at Jodhpur, India as optimally inclined surface receive 22.8% more solar radiation as compared to horizontal surface. Therefore, optimally tilted solar dryer has been used for this study. Different types of fruit and vegetables were dried in the solar dryer during the year 2017. During the drying process, moisture content of tomato was reduced from 95% (wet basis) to about 5%, in spinach 93% to 5%, in carrot 71% to 12%, in ber 80% to 20% and in lasoda/gonda it was reduced from 85% to 10% within 2 days in solar dryer for tomato, spinach, carrot and gonda and 10 days for ber. The efficiency of the dryer was found to be 17.57 %. The economic evaluation of the solar dryer (cost Rs 9000 and life of dryer = 10 years) revealed which high value of IRR (84.4 percent) and low value of payback period (1.42 years) make the dryer unit very cost efficient. The economic indicator benefit-cost- ratio was found 2.09, which shows the potential of using solar dryers in place of conventional dryers. The economic attributes namely net present worth (` 41830) and annuity (` 5635) of the system revealed its economic viability. The use of inclined solar dryer in remote locations/rural areas can go a long way in reducing post-harvest losses as well as carbon emission. The use of solar dryer will prove to be a great boon for farmers of arid region of Rajasthan.

Keywords: *Solar dryer, Solar radiation, Tilt angle, Cost benefit ratio, Life cycle cost*

Citation: Poonia S., *et al*., (2019) Economic Analysis of Inclined Solar Dryer for Drying of Fruit and Vegetables. International Journal of Agriculture Sciences, ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 11, Issue 20, pp.- 9154-9159.

Academic Editor / Reviewer: Dr A R Pimpale, Gibson E.

Introduction

In recent years, there is a global concern for the food and energy security of growing world population. For food security, either the crop production should increase or post-harvest losses should get reduced or both. The conventional energy sources e.g. coal, wood, oil, gas *etc*. should be conserved for energy security for which we must explore the renewable energy sources. If solar energy, one of the renewable energy sources, is effectively used for drying of crops, it will lead to both food as well as energy security. This is so because, crop drying is one of the effective means for reduction in the post-harvest losses by removing the excess moisture from it and there by achieving longer safe storage period and better product quality. Direct sun drying method has been practised since ancient time and it is still being widely used in developing countries. Although this method of drying is cheap, yet it is associated with the problems like contamination and uneven drying. In order to overcome these disadvantages, the drying process can be replaced with solar drying or industrial drying methods such as hot air. Mechanical drying which is mainly used in industrialized countries as an alternative to sun drying is not applicable to small farms in India. This is due to its high investment and operating costs. Fortunately, India is blessed with abundant solar energy [1]. During winter from November to February most of the Indian stations receive 4.0 to 6.3 kWhm-2 day-1 solar irradiance, while in summer season this value ranges from 5.0 to 7.4 kWhm-2 day-1. The arid and semi-arid parts of the country receive much higher radiation as compared to rest of the country with 6.0-7.4 kWhm-2 day-1 mean annual daily solar radiation having 8.9 average sunshine hours a day at Jodhpur, India [1]. Solar drying has been identified as a promising alternative to sun drying for drying of fruit and vegetables in developing countries like India because of its minimal operational cost in terms of fuel cost [2-3]. Utilization of solar energy for drying is advantageous because it uses a freely available renewable energy source besides being environment friendly and economically viable attributes make it to be accepted for use by rural farmers [4]. It is also a more convenient alternative for rural sector and other areas with scarce or irregular electricity supply. Studies conducted on solar drying have proved it is a good alternative for open sun drying for production of high quality dried products [5-7]. For any technology/system/enterprise, it is necessary to work out its economic viability so that the users of the technology may know the importance and can utilize the area under their command to their best advantage. Controlled environment solar drying of crops can be the most profitable in comparison with open sun drying due to better product quality and quantity and hence the attractive return. The controlled environment solar drying is a capital-intensive technology in terms of initial investment and operating cost in comparison to the traditional open sun drying [8]. Thus, it becomes necessary that the agriculture produce from the dryer is able to not only offset the higher cost of dried product but also register adequate profits. For any place profit should be sole criterion for drying produce. The temperature in a drying chamber should be maintained to an optimum level for a given crop for higher yield either by passive or active methods. The life cycle cost analysis of solar dryer depends on various factors such as initial investment for construction, operating cost, annual maintenance cost, finally annual cost of crops to be dried and life of solar dryer and its salvage value *etc* [8].

The techno-economic analysis of typical solar dryers with different kinds of energy sources has been reported by [9] who found that the plastic solar collectors of life 5-10 years are the cheapest among all the energy systems. The payback period of a solar tunnel drier is 4 years for basic mode drier and 3 to 4 years for optimum mode driers [7]. A dryer based on photo-voltaic and thermal energy sources was used in forced convection mode for grapes drying [8]. The system payback period is about 1.25 years with initial investment of Rs 27,400.

The cost of drying of the grapes is Rs 4.52 per kg [8]. Sengar and Kothari [10] carried out economic evaluation of greenhouse for cultivation of rose nursery and four economic indicators such as net present worth, internal rate of return, benefit cost ratio and payback period were calculated. NPW of investment made on greenhouse, the internal rate of return, the benefit cost ratio, when rose nursery grown inside the greenhouse were Rs 453221/-, 53 %, 4.5, respectively. Sachidanada *et al*. [11] analyzed the performance of biomass fired drier for copra drying and the results indicated that biomass fired dryer took 22 hours to reduce initial moisture content from 57.4% (Wb) to 6.8% (Wb). The benefit cost ratio is calculated to be 1.4 and 1.19 for two driers tested for quality copra production. Bala and Morshed [12] analyzed and investigated the performance of solar tunnel dryer for drying mushrooms. The temperature in drying chamber varied from 37 to 66.5°C and the payback period of the dryer is 3.8 years. An estimate of drying potential of certain crops such as, tobacco, tea, coffee, grapes raisin, small cardamom, chilli, coriander seeds, ginger, turmeric, black pepper, and onion flakes *etc.* along with CO_2 emission reduction potential of solar dryer for India [13]. With this in view, an inclined solar dryer was designed and developed at ICAR-Central Arid Zone Research Institute, Jodhpur to dry perishable agricultural produces. The provision of tilting the dryer helps receive maximum solar radiation round the year at Jodhpur, India and optimally inclined surface receives 22.8% more solar radiation as compared to horizontal surface. Therefore, optimally tilted solar dryer has been used for this study. The economic analyses of an inclined dryer have also been carried out in order to study the real-time possibilities for its use in drying process. The objective of the dryer is mainly for the welfare of the marginalized and small farmers who cannot afford hi-tech facilities and equipment's to preserve their agricultural products and eliminate the unwanted and unpredictable food spoilage due to lack of facilities in the arid region.

Materials and Methods

Principle of inclined solar dryer

The solar dryer is based on the principle of flat plate solar collector and greenhouse effect. The solar radiation falls on the transparent glass sheet and enter the collector and get converted into long wave thermal radiations, which is not transparent to glass surface and thus these get trapped inside and increase the inside temperature to a great extent. However, the tilt of the dryer has to be set according to the seasonal variation of tilt angle, which is given as,

Declination angle = 23.45[360(284+n/365)] (1)

Where n = number of days of the year, January 1, being the first day of the year.

Tilt angle = latitude ± declination angle.

The tilt remains equal to latitude (26.18° for Jodhpur) on March 21 and September 23. The average tilt angle for twelve months is given in [Table-1]

Table-1 *Average tilt angle for different months of the year*

SN	Day of month	Tilt angle (degree)
1	Jan-15	48.45
2	Feb-15	39.8
3	Mar-16	28.6
4	Apr-15	16.77
5	May-15	7.39
6	Jun-14	2.87
7	Jul-14	4.66
8	Aug-13	10.85
9	Sep-12	21.96
10	Oct-12	33.9
11	Nov-11	44.09
12	Dec-11	48.15

Performance of the natural convection solar dryer is very good during the summer but it is very poor during winter in northern parts of India and takes longer time for dehydration of fruits and vegetables because its absorbing surface is horizontal and so receive much less radiation compared to optimally inclined surface. Solar radiation received at Jodhpur on horizontal surfaces and optimally inclined surface is shown in [Table-2]. From [Table-2], it is clear that solar radiation received on an inclined surface is 69.36 % more than a horizontal surface during the month of December and an inclined surface receives 43.8% and 22.76% more radiation than a horizontal surface during the winter season (October-March) and round the year, respectively. Therefore, optimally tilted solar dryer has been used for this study. The tilt of solar dryer is adjusted once in a fortnight as per elevation of the sun.

Table-2 *Mean daily solar radiation (kWhm^{-2} day^{-1}) on horizontal and optimally inclined surfaces at Jodhpur*

S	Month	Solar radiation (kWhm^{-2} day^{-1})		
		Horizontal surface	Inclined surface	Increase over horizontal surface (%)
1	January	4.61	7.25	57.23
2	February	5.44	7.68	41.07
3	March	6.39	7.27	13.74
4	April	7.08	7.23	2.04
5	May	7.39	7.39	0
6	June	6.92	6.92	0
7	July	5.86	5.86	0
8	August	5.42	5.46	0.87
9	September	5.97	6.41	7.39
10	October	5.69	7.24	27.07
11	November	4.81	7.42	54.33
12	December	4.33	7.34	69.36
	Mean	5.83	6.96	22.76

Design of solar dryer

An inclined solar dryer was designed and fabricated at the workshop of ICAR-Central Arid Zone Research Institute, Jodhpur, India. The solar dryer (1280 mm x 980 mm) based on the natural convection operation principle mainly consists of a rectangular box made of galvanised steel sheet (22 gauge) with two drying trays. A glass roof (area of collector 1.25 m^2) of clear window glass (4mm thick) is provided at the top of box and a layer of dried pearl millet stems for insulation is provided at the base [Fig-1].

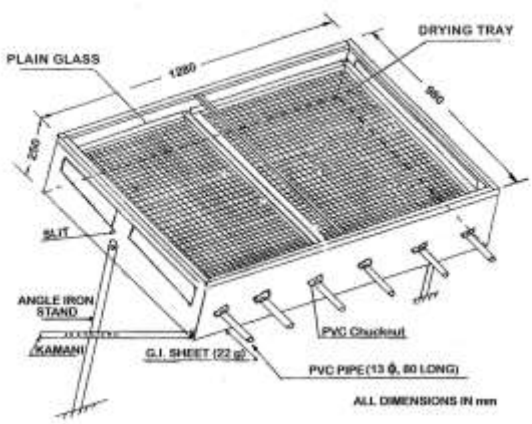

Fig-1 Schematic diagram of inclined solar dryer

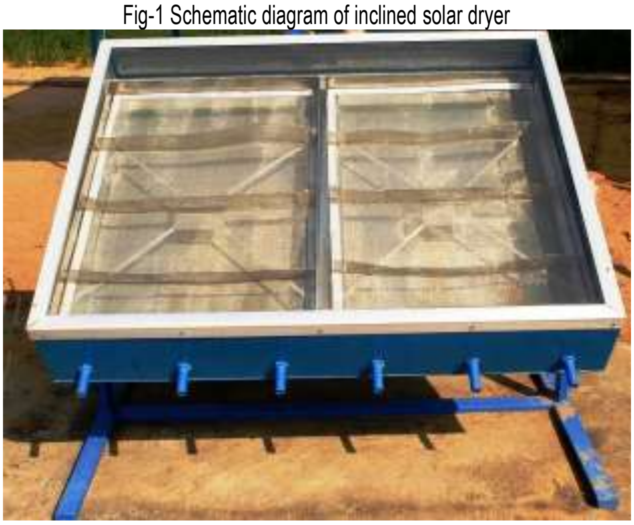

Fig-2 Inclined solar dryer installed at CAZRI solar yard

The dimension of two drying trays made of stainless-steel angle frame and stainless-steel wire mesh are (950 mm x 600 mm). The drying material can be kept on two trays and can be placed on angle iron frame in the dryer through an openable door provided on the rear side of the dryer. Five partitions are also provided in each tray so that the vegetables can be stacked even on inclined plane. Six plastic pipes are fixed in the front wall of the dryer just below the trays for fresh air at the base. Two tapered slits are made on sidewalls of dryer for escaping the hot moist air from the drying chamber. An overhang over these slits protects the material from rain and wire mesh in these slits safe guards against flies and squirrels. An adjustable iron angle stand is provided to keep the dryer at optimum tilt in accordance with latitude and season of operation. In this dryer, the material can be loaded in drying trays to a maximum depth of 5 cm. Actual installation of the optimally tilted solar dryer is shown in [Fig-2].

Experimental procedure

Tomato, spinach, carrot, ber and gonda were used for the drying experiment procured from a local market and selection was based on visual assessment of uniform colour and geometry. The initial moisture content of the fruit and vegetables were determined according to AOAC [14]. The drying experiments were conducted during the year 2017. During the drying process, the moisture loss of samples was determined by means of a digital electronic balance (Testing Instrument Pvt. Ltd., India) having an accuracy of ±0.001 g. The two drying trays were loaded with equal amount of fruit and vegetables. During the experiments, solar insolation, ambient temperature and temperature inside dryer were measured using digital thermometer. Hourly total solar radiation received on the horizontal plane was measured by pyranometer coupled with integrator.

The initial moisture content of fruit and vegetables on wet basis were calculated using the relation:

$M_i = W_i - W_f / W_i$ (2)

Where M_i is the initial moisture content of crop on wet basis expressed in %, W_i is the initial weight of crop in g and W_f is the final weight of crop in g. The recorded moisture contents for each sample were then used to plot the drying curves. The drying rate of fruit and vegetables were calculated using following equation.

$DR = \Delta M / \Delta t$ (3)

Where, ΔM = loss of the mass of the crop (kg water/kg dry matter); Δt = interval of time (m)

Thermal efficiency (η)

The efficiency of utilization of solar energy in solar dryer (ratio of heat used in evaporation of moisture from fruit and vegetables to the total incident solar radiation on horizontal plane) has been worked out by using the following relation [3, 15-16]:

$$\eta = \frac{ML}{A \int_T^{\theta} H_T d\theta} \quad (4)$$

Where A = Absorber area (m^2); H_T = Solar radiation on horizontal plane (J m^{-2} hr^{-1}); L = Latent heat of vaporisation (J kg^{-1}); M = Mass of moisture evaporated from the product (kg); θ = Period of test (hr) and η = Efficiency of the solar dryer.

Results and Discussion

A series of experiments was conducted to study the performance of solar drying system for dehydrating tomato, spinach, carrot, ber and gonda in inclined solar dryer during the year 2017. For experimental study, dryer was kept facing due south and loaded with equal quantity of material in two drying trays. The unit was kept at optimum tilt in accordance with latitude and season of operation. Hourly air temperatures inside the dryer at the centre of the drying trays and ambient air temperature were recorded from 08:00 hr to 18:00 hr during the drying trials. Solar radiation on glass planes of dryers were also measured hourly during the drying trials. The initial and final moisture content of the product was determined by random selection of samples which were cut into small pieces if necessary, weighed by accurate scale with a degree of accuracy of 10-5 gm and then oven dried. During the experiment, all the drying trays were weighed at a regular interval of 2 or 3 hours. These experimental observations were continued until the product acquired a constant weight i.e. it attained its equilibrium moisture content. Moisture content of materials was computed from the difference in these weights. The maximum stagnation temperature observed inside the drying chamber that was 70°C and on loading 12 kg of ber fruit the maximum temperature reduced to 64°C, when the outside ambient temperature was 23°C on a clear sky condition (from 8:00 hr to 18:00 hr) in the month of January, 2017. The variation of solar insolation, ambient temperature and temperature inside the dryer, when ber fruit was loaded during the drying trails is shown in [Fig-3].

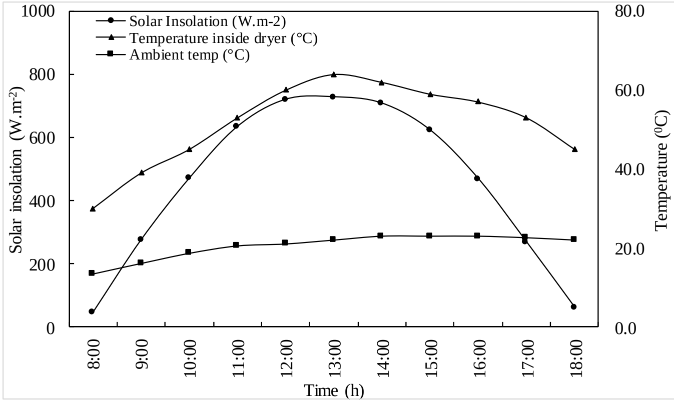

Fig-3 Temperature and solar insolation variation with time for load test (Ber)

The variation of measured moisture content (wet basis) of the ber fruits on each day of drying trials was shown in Fig. 4. It can be seen that the moisture content was reduced from about 80% to 26% within 8 days by the solar drying method and on 10th day it come 20%, however after 8 days (26% moisture content) it could be safely stored for further use. On the contrary, open sun drying tool as many as 20 days to dehydrate the same quantity ber fruits. The drying rate in the solar dryer increases sharply when the moisture content falls below 66%. The shape of the drying curve indicates a rapid moisture removal from the product at the initial stage, which later decreased with increase in drying time. Thus, the moisture ratio decreased continually with drying time. The internal mass transfer is affected by diffusion as is evident from continual reduction in moisture raio. This is in agreement with the results of study on ber [17] and in pumpkin slices [18].

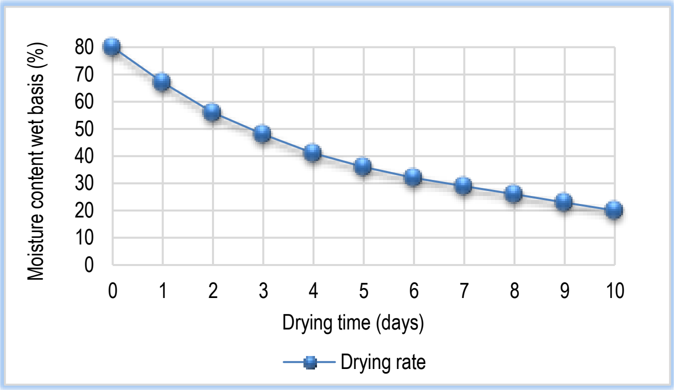

Fig-4 Variation of moisture content in ber solar drying against drying time

Different types of fresh vegetables were also dried. Vegetables were cut into pieces and loaded in optimally tilted dryer. During the drying process, moisture content of tomato was reduced from 95% (wet basis) to about 5%, in spinach 93% to 5%, in carrot 71% to 12%, and in gonda it was reduced from 85% to 10% within 2 days of exposure in solar dryer.

The overall efficiency of the drying is affected by several factors such as drying time, climatic conditions (solar insolation and temperature), the drying characteristics of the dried materials, and structure of the drying devices *etc.* The average efficiency of utilization of solar energy in the solar dryer was calculated by [Eq-4] and it was found that about 17.57% solar energy was utilized in this solar dryer. During drying process, it was observed that higher efficiency was observed at initial stage of drying, later stage this dryer efficiency was decreased due to decrease in moisture content. Moreover, the efficiency was more at a higher drying load of 12 kg might be due to highest drying time.

Table-3 *Cost estimates of inclined solar dryer*

Item with specification	Quantity	Unit cost ₹	Amount ₹
G.I. Sheet (22 gauge) 2.20 x 1.500	3.30 sqm	727/ sqm	2400
Plain glass (1.28 x 0.980 m)	1.25 sqm	480/ sqm	600
M.S. angle (37 x 37 x 6 mm)	4.65 sqm	54/ sqm	250
Kamani (25 mm wide x 3 mm thick)	1.12 m	134/ m	150
PVC chuck nut	6 Nos.	8/No.	50
PVC pipe (13 mm f) 6 x 0.800	4.8 m	26/ m	125
Insulation (pearl millet stem) 1.28 x 0.98 x 0.050	0.0627 cum		
Aluminium angle (25 mm x 25 mm)	4.52 m	28/ m	125
Wooden batten (0.025 x 0.025 x 0.980 x 2)	0.00122 cum		
Drying tray			
(i) S.S. channel (50 mm x 50 mm) – 3.1 x 2	6.2 m	234/ m	1450
(ii) Wire mesh (stainless steel) (1.10 x 0.60) x 2	1.32 sqm	2197/ sqm	2900
(iii) Hinges (100 mm long)	10 Nos.	12/No.	125
Nut bolts	250 g	2.5/g	100
Fevicol	250 g	3.1/g	80
Black board paint	1.5 lit.	100/lit.	150
Zinc Chromate Primer	1.0 lit.	200/lit.	200
Synthetic Enamel paint	1.0 lit.	240/lit.	240
Rubber gasket (25 mm x 3 mm)	4.52 m	12/m	55
Total			9000

Economic Analysis

The economic analysis of the present dryer was carried out by computing the life cycle cost (LCC) and life cycle benefit (LCB) of the dryer. In addition, five economic attributes, namely, benefit-cost ratio (BCR), net present worth (NPW), annuity (A), internal rate of return (IRR) and payback period (PBP) were also determined for judging the economic viability of the dryer technology.

Life cycle cost (LCC)

Life cycle cost (LCC) of the inclined solar dryer is the sum of all the costs associated with a solar drying system over its lifetime in terms of money value at the present instant of time and takes into account the time value of money [19]. The initial investment (P) in dryer unit is ₹ 9000 as shown in [Table-3]. The annual cost of operation and maintenance (O&M) including labour are taken as ` 4000. The salvage value is taken as 10% of initial investment.

Economic attributes

BCR: The ratio of discounted benefits to the discounted values of all costs given as LCB/LCC

NPW: It is the sum of all discounted net benefits throughout the project given as LCB-LCC

Annuity (A): The annuity (A) of the project indicates the average net annual returns given as,

$$(Annuity) = \frac{NPW}{\sum_{t=1\ to\ 10}\left(\frac{1+e}{1+i}\right)}n + \frac{NPW\left(\frac{1+e}{1+i}-1\right)}{\left(\frac{1+e}{1+i}\right)\left[\left(\frac{1+e}{1+i}\right)^n - 1\right]}$$

PBP: It is the length of time from the beginning of the project before the net benefits return the cost of capital investments (value n for LCB - LCC = 0)

IRR: It is that rate of interest which makes life cycle benefits and life cycle cost equal (LCB - LCC = 0)

Determination of (LCC)

Economics of inclined solar dryer was calculated through life cycle cost (LCC) analysis. Let P_i is initial investment (₹), P_w is operational and maintenance expenses including replacement costs for damaged components (₹), n is life of the dryer (Year), P_w (SV) is salvage value of the dryer at the end of the life (₹). The procedure of life cycle cost estimation as adopted by [1, 16 and 20], the LCC is given as,

(i) LCC (Unit) = Initial cost of unit (P_i) + P_w (O & M Costs including labour) – P_w (SV) (5)

$$= P_w + P_i\,\frac{X\,(1-X^n)}{1-X} - SV\,(1+i)^{-n}$$

$$= 9000 + 4000\,\frac{X\,(1-X^n)}{1-X} - 900\,(1+i)^{-n}$$

$$= 9000 + 4000\,\frac{0.945\,(1-0.945^{10})}{1-0.945} - 900\,(1+0.1)^{-10}$$

= 38349

Where $X = \frac{1+e}{1+i} + \frac{1+0.04}{1+0.1}$

Where, e = annual escalation in cost (in fraction); i = interest or discount rate (in fraction)

Life cycle benefits (LCB)

The values of R (annual benefit) is obtained by using the dryer 10 trials each for ber, seed less lasoda/gonda. The quantity of ber dried was about 120 kg costing about ₹2400. The dried ber was about 40 kg, which accrued about ₹6000/- @ 150 ₹/ kg. The ensuring benefit of ₹3600/-. Similarly, thirty trials of seed less lasoda/gonda dried about 120 kg gonda which ensured ₹30/- kg benefit on raw seed less gonda amount to about ₹ 3600/- and remaining six month drying trials of tomato, spinach and carrot about 360 kg @ 10 ₹/ kg. The ensuring benefit of ₹ 3600/-. Thus, total annual benefit from dried product was about ₹ 10800/-.

The LCB can be given as,

$LCB = R\,\frac{X\,(1-X^n)}{1-X}$ (5)

Where R = annual benefit (₹) and $X = \frac{1+e}{1+i}$

Determination of economic attributes

(i) BCR: The ratio of discounted benefits to the discounted values of all costs can be expressed as:

Benefit cost ratio (BCR) = Life cycle benefit of inclined solar dryer / Life cycle cost of inclined solar dryer

$$BCR = \frac{R\,\frac{X\,(1-X^n)}{1-X}}{P_i + P_w - P_w(SV)} = \frac{LCB}{LCC} = \frac{80179}{38349} = 2.09$$

(ii) NPW = LCB – LCC = 41830

(iii) The annuity (A) of the project indicates the average net annual returns. This term can be given as,

$A\,(Annuity) = \frac{NPW}{\sum_{t=1\ to\ 10}(X)^n} = 5635$ (6)

Where $X = \frac{1+e}{1+i}$

Payback period

Pay-back period can be determined as following: -LCC + LCB = 0

$$9000 + 4000 \times \frac{0.945\,(1-0.945^{10})}{1-0.945} = 10800\frac{0.945\,(1-0.945^{10})}{1-0.945}$$

$$9000 = 4800\frac{0.945\,(1-0.945^{10})}{1-0.945}$$

$$(1-0.945^{n}) = \frac{9000\,(0.055)}{4800\ \times 0.945}$$

$$(0.945^{n}) = 1 - \frac{9000\,(0.055)}{4800\ \times 0.945} = 0.923$$

Or *n log 0.945 = log 0.923*

n = *log 0.923/ log 0.945*

n = 1.42 year

Or Pay-back period (PBP) = 1.42 year

Internal rate of return (IRR)

The values of NPW at varying discount rates are given in [Table-3]. From [Table-3] it may be inferred that at 10% interest rate the NPW is Rs 41830/- respectively. At 60% rate of interest the NPW is Rs 3516.44. However, the NPW is negative at 90% interest rate (*i.e.* NPW = Rs –804.93/-). The IRR can determine using data presented in [Table-4] and the following relationship:

IRR= Lower discount rate + (Difference of discount rate x NPW at lower discount rate) / (NPW at lower discount rate-NPW at higher discount rate)

IRR = 60 + 30 x 3516.44 / 3516.44+804.93 = 84.4%

The internal rate of return (IRR) which comes to 84.4% in the present case, which is very high for a project to be economically viable.

Table-4 *Values of NPW for different rates of discount/interest (i)*

NPW (Rs.)	41830.2	3516.44	-804.93
Interest rate *i* (%)	10	60	90

The values of five economic attributes, namely, benefit-cost ratio (BCR), net present worth (NPW), annuity (A), internal rate of return (IRR) and payback period (PBP) was presented in [Table-5].

Table-5 *Values of economic attributes*

Attributes economics	Values
BCR	2.09
NPW	41830 `
A	5635 `
IRR (per cent)	84.40%
PBP (years)	1.42 years

Conclusion

An optimally tilted type solar dryer can be used for dehydration of fruits and vegetables. The initial moisture content of tomato was reduced from 95% (wet basis) to about 5%, in spinach 93% to 5%, in carrot 71% to 12%, in ber 80% to 20% and in lasoda/gonda it was reduced from 85% to 10% within 2 days in solar dryer for tomato, spinach, carrot and gonda and 10 days for ber. The efficiency of the inclined solar dryer was 17.57%, respectively. The farmers can dehydrate vegetables when these are available in plenty and at low cost. Dehydrated vegetables can be sold in the off season when prices of vegetables are high and farmers can generate more income. The economic evaluation of the inclined solar dryer unit revealed that high value of IRR (84.4%) and low value of payback period (1.42 Years) make the unit is very cost efficient. The use of inclined solar dryer considerably reduced the drying time, energy consumption and improves the quality of dried products. The use of inclined dryer at remote locations/rural areas can go a long way in reducing post-harvest losses as well as carbon emission and will be a great boon for farmers in the developing countries.

Application of research: Solar drying of fruit and vegetables by reducing its moisture content to a safe level. It has been provided different tilt angles for different months of the year. It is observed that fruit and vegetables are sold at throw away prices when there is a glut in the market. In the light of perishable nature of fruit and vegetables they can be dried and stored and used for longer periods. This practice considerably reduces the post-harvest losses as well as reduces CO_2 emission and supplements conventional energy sources.

Research Category: Renewable energy

Acknowledgement / Funding: Authors are thankful to ICAR-Central Arid Zone and Research Institute, Jodhpur, 342 003, Rajasthan, India

***Principal Investigator or Chairperson of research: Dr Surendra Poonia**
Institute: ICAR-Central Arid Zone and Research Institute, Jodhpur, 342 003
Research project name or number: Research station trials

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: ICAR-Central Arid Zone and Research Institute, Jodhpur, 342 003

Cultivar / Variety / Breed name: Nil

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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