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Environmental and Climate Technologies doi: 10.1515/rtuect-2015-0003
2015 / 15

Life Cycle Cost of Solar Biomass Hybrid Dryer Systems for Cashew Drying of Nuts in India

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***Abstract* – Cashew nut farming in India is mostly carried out in small and marginal holdings. Energy consumption in the small scale cashew nut processing industry is very high and is mainly due to the high energy consumption of the drying process. The drying operation provides a lot of scope for energy saving and substitutions of other renewable energy sources. Renewable energy-based drying systems with loading capacity of 40 kg were proposed for application in small scale cashew nut processing industries. The main objective of this work is to perform economic feasibility of substituting solar, biomass and hybrid dryer in place of conventional steam drying for cashew drying. Four economic indicators were used to assess the feasibility of three renewable based drying technologies. The payback time was 1.58 yr. for solar, 1.32 for biomass and 1.99 for the hybrid drying system, whereas as the cost-benefit estimates were 5.23 for solar, 4.15 for biomass and 3.32 for the hybrid system. It was found that it is of paramount importance to develop solar biomass hybrid dryer for small scale processing industries.**

***Keywords* – Benefit cost ratio; conventional dryer; energy saving; pay back**

1. INTRODUCTION

India is one of the largest producers and processors of cashews in the world [1]. In 2013–14, India exported 113,620 metric tonnes of cashews which generated US$ 825.89 million in revenue [2]. Cultivation of cashew nuts promotes employment, and contributes to revenue through foreign exchange. In India, more than 70 percent of cashew area is under small and marginal farmers.

Cashew nut processing in India depends on raw materials, locations, type of technology and the availability of energy supply. The processing steps include drying of raw nuts, steaming the raw nuts, cooling, cutting to separate shell from kernel, drying the kernel, peeling, grading and packing. In cashew processing, much of the energy and time is consumed during the drying, steaming and kernel drying. The energy consumption of cashew nut processing to produce same quantity of similar products revealed wide variation in energy intensity, ranging from 4.43 to 8.66 kg of fuel wood per kilogram of kernel [3].

1.1. Literature Review

Sengar and Kothari carried out economic evaluation of greenhouse for cultivation of rose nursery. The total construction cost of a 80 m^2 arch shape greenhouse was Rs 100000/-. Suitability of the economics of greenhouse, four economic indicators such as net present worth, internal rate of return, benefit cost ratio and payback period were calculated for rose nursery.

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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 [5].

Barnwel and Tiwari analyzed the cost of a hybrid photovoltaic greenhouse dryer. A hybrid PV/T integrated greenhouse dryer has been used to dry grapes under forced mode of operation. 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 [6].

Debbarma et al designed and developed a low cost bamboo solar dryer at MANIT Bhopal, India to test its performance for crop drying. The dryer is a tent-type designed for multi-crop solar drying. The economic cost of bamboo dryer is around Rs 400/- which is very much affordable for the poor farmers. The payback period of the solar dryer could be recovered within one to two months [7].

Ahmad et al performed a techno-economic study of solar drying system in Malaysia. The solar dryer is designed for drying agricultural and marine products such as seaweed. The cost benefit analysis is performed assuming prevailing market prices of fresh seaweed (RM 0.2/kg), dried products (RM 5/kg), salary for the workers (RM 9000/year), electricity costs (RM 600/year), maintenance and insurance cost (RM 641/year), and annual operating cost of RM 15421. The results of economic analysis indicated that the double pass solar collector is best suited for drying marine products as its payback period is as low as 2.33 years [8].

Atul et al conducted a study for the estimation of energy consumption in eight unit operation of small scale cashew nut processing in India. Solar energy, electricity and fuel are the major source of energy consumed for cashew nut processing. Finally, the total energy consumption was estimated at 5321.43, 5540.14 and 6061.34 MJ for 60, 30 and 15 kg batch capacity industries [9].

Sachidanada et al analyzed the performance of biomass fired drier for copra drying. The results indicated that biomass fired took 22 hours to reduce initial moisture content from 57.4 % (Wb) to 6.8 % (Wb). The cost benefit ratio is calculated to be 1.4 and 1.19 for two drier tested for quality copra production [10].

Bala and Morshed analyzed and investigated the performance of solar tunnel dryer for drying mushrooms. The temperature in drying chamber varied from 37 to 66.5 °C. The payback period of the dryer is 3.8 years [11].

Sujata et al analyzed the performance of hybrid photovoltaic thermal integrated solar dryer. The experimental study has been conducted under no load and load condition. The dryer is able to dry 90 kg of maize grain from the initial moisture content of 33.3 to 20 %. Finally, it was concluded that the PV based solar dryer is a self- sustained solar dryer with the total energy payback period of 5.6 years [12]. The existing literature survey clearly indicated that so far no work has been carried out on solar biomass hybrid drying of cashew nut [13]–[18]. Thus there is a wide gap in this area of research and therefore this study is intended to fulfil the gap on economic life cycle analysis of renewable hybrid drying system for cashew processing.

1.2. Objective of the Study

The economic analysis is more important for processing industries as well as the end users to find out the cost of drying. The study was conducted using the standard economic tool with the following objectives:

- To estimate the energy cost associated with conventional small-scale cashew processing industries.
- To individually compare the economic feasibility of solar-biomass hybrid in terms of payback period, rate of return, discounted cash flow and B/C ratio.
- To study the economic feasibility of solar, biomass and hybrid system for cashew drying.

2. METHODOLOGY

Data collection: The performance study of solar biomass hybrid dryer for cashew drying has been carried out by the authors [3], [4]. The cost of material and labour charges has been used to arrive at the initial cost of solar biomass and hybrid dryer. Conventional steam drying cost was obtained from the local cashew nut processing industries in Cuddalore district, India. Several indicators are available to study the economic viability of renewable energy based drying technologies which are classified and shown in Fig. 1.

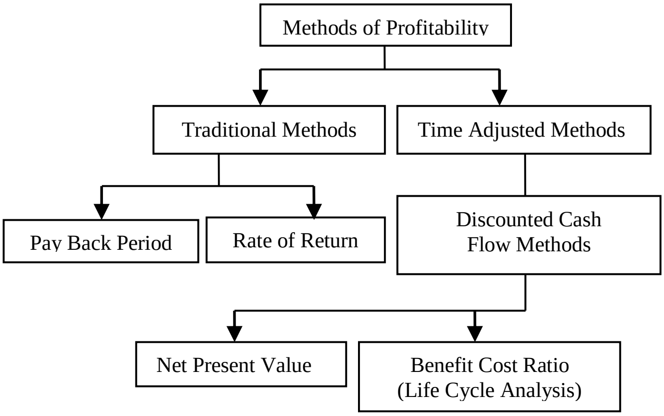


Fig. 1. Classification of profitability methods.

2.1. Simple Pay Back Period

The simple payback period is calculated by dividing the initial investment by the annual cash-flows. The formula is

$$Payback\ Period = \frac{Initial\ investment}{Annual\ cash\ benefit} \tag{1}$$

The payback method measures the time period between investment and its recovery. The returns are therefore referred to as cash benefits of revenues in excess of expenditure.

2.2. Accounting Method of Rate of Return

According to this method, the profitability is measured on the basis of accounting information derived from the financial statement. It is also known as Accounting Rate of return Method (ARR). The accounting rate of return (ARR) is calculated by dividing the average income after taxes by the average investment or average book value after depreciation.

$$ARR = \frac{Avg\ Net\ Income\ after\ Taxes}{Avg\ Investment\ over\ the\ life\ of\ the\ project} \tag{2}$$

2.3. Discounted Cash Flow Method

The discounted cash flow technique (DCF) recognizes the changing value of money and it takes into account the fact that the same amount of money received today is more valuable than the one received after a year and so on. For projects stretching over several years, one should take into account the cash-flows expected from the project over future years and discounted them back to the present in order to determine the "Net Present Worth" of the investment. The formula expression is used for discounted cash flow

$$F = P\left(\frac{(1+i)}{100}\right)^n \tag{3}$$

2.4. Net Present Value

This method under DCF attempts to compare the present value of the future benefits with the present value of the investment. An important advantage of this method is that it allows comparison of the projects having different service lives, even if the life span of the project differs. The relation for finding out the total present value of all cash inflows generated from an investment is as follows:

$$NPV = \sum_{t=1}^{n} \frac{R_t + S}{(1+i)^t} \tag{4}$$

2.5. Revenue - Dominated Cash Flow Diagram

A generalized revenue – dominated flow diagram to demonstrate the present worth method of comparison is presented in Fig. 2.

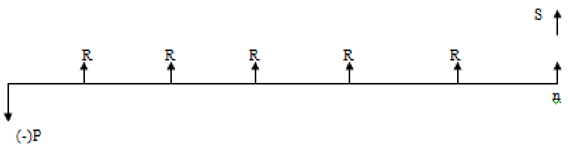


Fig. 2. Revenue - Dominated Cash Flow Diagram.

This Figure represents an initial investment and R_j the net revenue at the end of j^{th} year. The interest rate is i, compounded annually. S is the average value at the end of the n^{th} year. To find the present worth of the above cash flow diagram for a given interest rate, the formula is

$$PW_{(i)} = -P + R_1 \cdot \frac{1}{(1+i)^1} + R_2 \cdot \frac{1}{(1+i)^2} + \cdots + R_j \cdot \frac{1}{(1+i)^j} + R_n \cdot \frac{1}{(1+i)^n} + S \cdot \frac{1}{(1+i)^n} \tag{5}$$

In this formula, the expenditure is assigned a negative sign and revenues are assigned a positive sign.

2.6. Benefit/Cost Ratio Analysis:

Cost-benefit analysis is a systematic process for calculating and comparing benefits and costs of a project. It has two purposes:

1. To determine if it is a sound investment/decision (justification/feasibility).
2. To provide a basis for comparing projects. It involves comparing the total expected cost of each option against the total expected benefits, to see whether the benefits outweigh the costs, and by how much.

2.7. Life Cycle Cost Analysis:

Life Cycle Cost analysis is the systematic, analytical process of evaluating alternative courses of action early on in a project, with the objective of choosing the best alternative to employ scarce resources. It is:

Annual Cash Flow (CF) = Savings from RE based dryer or cost of electricity in conventional dryer.

Annualized uniform cost, unacost (R), is defined as the product of the net present value of the system and capital recovery factor (CRF).
Annualized uniform cost/unacost (R) = $P_{NPV} \cdot CRF$

$$R = \frac{P_{NPV} \cdot i(1+i)^n}{(1+i)^n - 1} \tag{6}$$

Annualized salvage value (R′)

$$R' = \frac{S}{(1+i)^n - 1} \tag{7}$$

Annualized Cost of Dried cashew kernel (Rs) = R–R′. Cost of drying is Cg (Rs/kg):

$$Cg = (R/dried\ product\ per\ year) \tag{8}$$

Total Benefits

$$B = CF - (R - R') \tag{9}$$

2.8. Assumptions

The following assumptions were made to assess the economic feasibility of solar biomass hybrid dryer for cashew drying.

1. The useful life of the solar dryer, biomass dryer and hybrid dryer solar are taken as 20, 10 and 15 years, respectively.
2. Dryer processing capacity is 40 kg/batch/day.
3. The discount rate is 8 percent.
4. The dryer can be operated 200 days in a year.
5. The annual maintenance cost of the solar dryer, biomass dryer and hybrid dryer solar are taken as 1 %, 2 % and 3 %, respectively.

The economic indicators like payback period, cost-benefit and life cycle cost were used to perform the economic analysis of solar biomass hybrid dryer.

3. RESULTS AND DISCUSSION

3.1. Cost Analysis of Cashew Kernel Drying by Conventional System (Steam Drying)

TABLE 1. ENERGY COST OF CONVENTIONAL DRYING

S. No.	Factor	Existing Conventional System
1	Dryer capacity (kg)	180 kg
2	Energy / batch (MJ)	575.64 MJ
3	Energy/day/batch (kWh)	159.9 kWh
4	Energy per kg (kWh/kg)	0.888 kWh
5	Energy consumption for 40 kg	35.52 kWh
6	Annual Total Energy consumption @200 days (kWh)	7104 kWh
7	Annual Energy Cost (Rs) @ Rs 5.6 per unit	Rs 39787
8	Specific cost (Rs/kg)	Rs 4.97/kg

The total energy consumption and energy cost associated with drying of 40 kg of cashew kernel can be observed in Table 1.

The energy consumption was 7104 kWh and it can be noticed that the specific cost of drying per kg of cashew kernel is around Rs 5/kg. The total amount of electrical energy used in the conventional dryer can be reduced substantially by adapting renewable energy based dryer. The energy consumption required to achieve the moisture reduction from 10 % to 5 % can be achieved using renewable energy based drying systems.

3.2. Analysis of Initial Cost of Renewable Energy Based Dryer

The economic feasibility of the hybrid dryer for drying of cashews was calculated by considering the initial investment of the dryer, repair and maintenance cost, cost of raw material. The cost calculations of different raw materials used for fabrication of the system are summarized in Table 2.

TABLE 2. INITIAL COST OF COMPONENTS OF RENEWABLE ENERGY BASED DRYER

Item	**Specification**	**Quantity**	**Rate (Rs)**	**Total (Rs)**
		Solar Air collector		
Glazing	4 mm thick (21.12 ft^2)	2 glass	90/sq. feet	3802.00
Aluminium L-Angle	¾ x ¾ inch x 2 mm	5 length	270/length	1350
GI Sheet	8’ x 4’ x 1.6 mm	3 sheet	2550/sheet	7650
Aluminium absorber plate	8’ x 4’ x 2 mm	1 sheet	5880	5880
Step Angle	1/2 “	5 length	250/length	1250
Rivet	1“	200	1/unit	200
Glass Wool Insulation	–	10 Kg	40/kg	400
Labour cost				3500
	Total			**24032.00**
		Drying Chamber		
GI Sheet	8’ x 4’ x 1.6 mm	4 sheet	2550/sheet	10200
Aluminium L-Angle	¾ x ¾ inch x 2 mm	5 length	270/length	1350
Perforated aluminium sheet	8’ x 4’ x 1.5 mm	2 sheet	3350/sheet	6700
Square Pipe	¼’ x ¼’ x 1.6 mm	5 length	500/length	2500
Glass Wool Insulation	–	10 kg	40/kg	400
Rivet	1“	200	1/unit	200
Labour cost				3000
	Total			**24350.00**
		Blower		
Blower	0.37 kW, 0–2800 rpm, 440 V(AC)	1	10000	10000
Connecting Pipe	3” MS pipe	1 length	2500/length	2500
Connecting Pipe	1.5” MS Pipe	1 length	850/length	850
	Total			13350
Biomass heater				
GI Sheet	8’ x 4’ x 1.6 mm	1 sheet	2550/sheet	2550
MS Sheet	6mm (1.25 m x 2.5 m)	1 sheet	4100/sheet	4100
Glass Wool Insulation	–	8 kg	40/kg	320
Chimney Pipe	6” x 1 m	1m	1320/m	1320

Stand	20” dia x 10 mm	1 piece	300	300
Stand Pipe	1½ “ x 1”	3 pipe	200/pipe	600
Rivet	1“	50	1/unit	50
Labour cost				2000
	Total			**11240**

TABLE 3. INITIAL COST OF RENEWABLE ENERGY BASED DRYERS

No.	Component details	Solar dryer	Biomass dryer	Hybrid dryer
1	Solar air collector	+	–	+
2	Drying chamber	+	+	+
3	Blower	+	+	+
4	Biomass Heater	–	+	+
	Total cost			

+Applicable
–Not Applicable

The initial investment for the three cases of dryer with solar, biomass and hybrid dryer are Rs Rs 61, 732, Rs 48, 940 and Rs 72, 972, respectively. It is arrived at by adding the materials cost of the components of the dryer (Table 3).

3.3. Economic Analysis of Solar Biomass Hybrid (Renewable Energy Based Dryer for Cashew Processing)

Table 4 comprises the data about the Factors like the Initial Investment, Salvage value, Annual Savings from conventional energy cost, operating and maintenance cost, expected economic life of asset, time value of money and annual cash benefit for all the three types of renewable energy based dryers.

TABLE 4. INITIAL INVESTMENT AND ANNUAL CASH FLOW DATA

No.	Factor	Solar dryer	Biomass dryer	Hybrid dryer
1	Initial Investment (P) in Rupees	61732	48940	72972
2	Salvage Value (S) (@10 % of P) in Rupees	6173	4894	7297
3	Annual Savings (Conventional Energy Cost) in Rupees	39787	39787	39787
4	Annual Operating Cost (Annual Fuel Consumption and Cost) in Rupees	0	For 8 hours operation: 4 kg/batch/day Cost = 4·200·Rs 2 = Rs 1600	For 8 hours operation: 2.5 kg/batch/day Cost = 2.5·200·Rs 2 = Rs 1000
5	Annual Cash Flow (3)–(4)	39787	38187	38787
6	Maintenance Cost	@1 % of P=617	@2 % of P=980	@3 % of P=2190
7	Total Cost (4)+(6)	617	2580	3190
8	Expected Economic Life	20 years	10 years	15 years
9	Time value of money (Annual Interest Rate in %)	8 %	8 %	8 %
10	Annual Cash Benefit (3)–(7)	39170	37207	36597

3.4. Economic Analysis Using Simple Payback Period Method

TABLE 5. SIMPLE PAYBACK PERIOD

No.	Factor	Solar	Biomass	Hybrid
1	Initial Investment (P)	61732	48940	72972
2	Annual Cash Benefit	39170	37207	36597
3	Pay-Back Period in Years (1) / (2)	1.58	1.32	1.99

Based on the estimated Initial and annual operating costs of the drying system for drying of cashew kernel (Table 5), the payback period of the solar, biomass and hybrid drying system for this product is estimated and this is found to vary between 1.3 to 2 years. The payback period of the biomass dryer is even less (1.34 years) than solar and hybrid dryers. The amount invested in a hybrid dryer can be recovered within 2 years. Both of these systems solar and biomass dryer have almost the same payback period, but a considerable increase in initial cost and number of components made the hybrid system payback period higher than the other two systems.

TABLE 6. ACCOUNTING RATE OF RETURN

No.	Factor	Solar	Biomass	Hybrid
1	Annual Cash Benefit	39170	37207	36597
2	Initial Investment (P)	61732	48940	72972
3	Salvage Value (S)	6173	4894	7297
4	Net Investment (2)–(3)	55559	44046	65675
5	Expected Life of the Project	20 years	10 years	15 years
6	Average Net Investment (4)/(5)	2778	4410	4378
7	Average Net Income (1)–(6)	36392	32797	32219
8	Accounting Rate of Return	65.5 %	74.5 %	49.1 %

TABLE 7. NET PRESENT VALUE (NPV)

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
P/F	0.9259	0.8573	0.7937	0.7353	0.6897	0.6289	0.5834	0.5405	0.5	0.463	0.4292	0.3698	0.3676	0.3491	0.3155	0.2915	0.2703	0.25	0.2315	0.2146

3.5. Economic Analysis Using Accounting Rate of Return Method:

From Table 6, it can be inferred that, out of these three renewable energy based dryers, the biomass dryer gives the highest Rate of Return (75 %) when compared to the other two dryers. The hybrid dryer gives the lowest return, nearly 50 % whereas solar dryer gives 65 % rate of return

From the above Table 7,

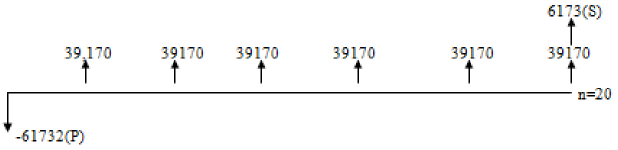
$\sum (1 / 1.08^{20}) = 9.8068$ (for 20 years)

$\sum (1 / 1.08^{10}) = 6.7177$ (for 10 years)

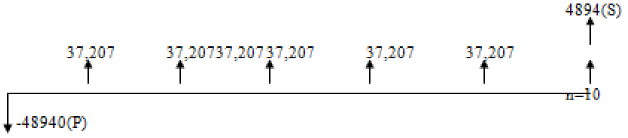
$\sum (1 / 1.08^{15}) = 8.5489$ (for 15 years)

For Salvage value:

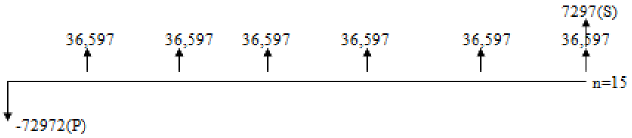
$(1 / 1.08^{20}) = 0.2146$ (for 20 years)
$(1 / 1.08^{10}) = 0.4632$ (for 10 years)
$(1 / 1.08^{15}) = 0.3152$ (for 15 years)
Present Value of the Future Benefits, Solar Dryer:



Net worth = –61732 + 39170·9.8068 + 6173·0.2146 = Rs 3,23,725



Net worth = –48940 + 37207·6.7177 + 4894·0.4632 = Rs 2,03,339



Net worth = –72972 + 36597·8.5489 + 7297·0.3152 = Rs 2,42,192

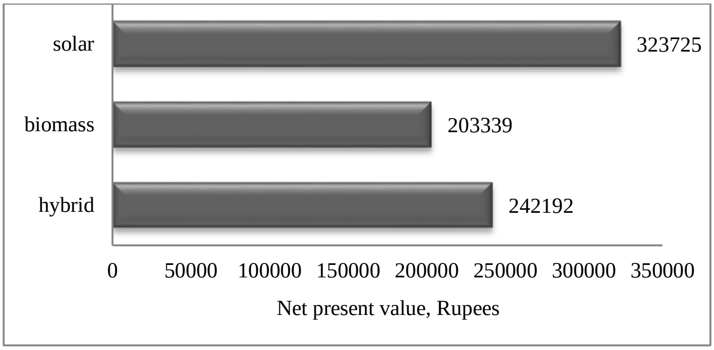


Fig. 3. Project benefit using net present value.

From Figure 3 it can be inferred that the solar dryer can be considered as the best choice on the basis of highest future worth (Rs 323725) followed by hybrid dryer (Rs 242192) and biomass dryer (Rs 203339).

3.6. Benefit-Cost Ratio

TABLE 8. BENEFIT-COST RATIO

No.	Factor	Solar Dryer	Biomass Dryer	Hybrid Dryer
1	Initial Investment (P) in Rupees	61732	48940	72972
2	Salvage Value (S) (@10 % of P) in Rupees	6173	4894	7297
3	Annual Savings (Conventional Energy Cost) in Rupees	39787	39787	39787
4	Annual Operating Cost	0	1600	1000
5	Annual Cash Flow (3)–(4)	39787	38187	38787
6	Maintenance Cost	@1 % of P = 617	@2 % of P = 980	@3 % of P = 2190
7	Total Cost (4)+(6)	617	2580	3190
8	Expected Economic Life	20 years	10 years	15 years
9	Time value of money (Annual Interest Rate in %)	8 %	8 %	8 %
10	Annual Cash Benefit (3)–(7)	39170	37207	36597
11	Capital Recovery Factor=$\frac{i(1+i)^n}{(1+i)^n-1}$	0.102	0.149	0.117
12	Annualized Uniform cost $R = \frac{P_{NPV} \cdot i(1+i)^n}{(1+i)^n-1}$	(Rs 61732·0.102) Rs.6289	(Rs 48940·0.149) Rs 7293	(Rs 72972·0.117) Rs 8526
13	$\acute{R} = \frac{S}{(1+i)^n-1}$	Rs 134.86	Rs 338	Rs 269
14	Annualized Cost of Drier = R–Ṙ	Rs 6154	Rs 6955	Rs 8257
15	Cost of Drying C = (R/dried product per year)	(6289/8000) Rs 0.786	(7293/8000) Rs 0.912	(8526/8000) 1.066
16	Total Benefits B = CF–(R–Ṙ)	(Rs 39170–6154) Rs 33,016	(Rs 37207–6955) Rs 30,252	(Rs 36597–8257) Rs 28,340
17	Benefit-Cost Ratio (16÷12) = B/R	5.23	4.15	3.32

Costs of the processing of cashew kernels in the different renewable energy based dryers are shown in Table 8. It was found that cost of drying is as low as Rs 1/kg in all the three systems. The cost-benefit ratio was also as high as 5 which shows the potential of using solar dryers in place of conventional dryers. The B/C ratio of solar dryer was highest among all the dryers because of lower operating cost and nil fuel cost. The next system worth considered is biomass dryer with B/C ratio 4.15 followed by Hybrid dryer. The slight reduction in B/C ratio is due to: higher initial cost, fuel cost and operating cost of biomass and hybrid dryers. Solar, biomass and hybrid are all more economically viable than conventional drying system in terms of environmental benefits associated with adoption of this technology.

4. CONCLUSION

Renewable energy-based drying systems with loading capacity of 40/kg were proposed for application in small scale cashew nut processing industries. A techno-economic analysis of solar dryer for drying cashew kernels was carried out and compared with biomass dryers and hybrid dryers. The following conclusions could be drawn from the study:

- The cost of drying of cashew kernel is lowest for solar dryer with initial investment of Rs 61732 as Rs 0.8/kg.
- The estimated payback period of the hybrid dryer is about 1.99 years. The initial investment of biomass dryer (Rs 48,940) gives the lowest payback period of about 1.32 years which is much less than the expected life of the dryer.
- Biomass dryer gives the highest Rate of Return (75 %) whereas the hybrid dryer gives the lowest Return nearly 50 %.
- Solar dryer is the best option based on the cash discounted future worth of Rs 3,23,725 when compared to the other two types of dryers.
- Benefit cost ratio was also highest for solar dryer which was found to be 5.23.
- The developed system was found to be economically suitable for processing of 40 kg /batch of cashew kernel.
- Due to its economic effectiveness, this type of dryer can play a vital role in bringing sustainable energy to small scale cashew farmers in the rural communities of India.

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