

ASSESSMENT OF THE ECONOMICS OF ROSELLE (*Hibiscus Sabdariffa* L.) CALYCES POWDER AND SEEDS PRODUCTION USING INDIRECT FORCED CIRCULATION SOLAR DRYER

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Abstract: The study investigates the economic feasibility of an indirect forced circulation solar dryer for dehydrating roselle (*Hibiscus sabdariffa* L.) fruits, aiming to provide an affordable and efficient drying solution for rural tribal communities in Gujarat, India. Traditional drying methods such as hot air tray drying, microwave drying, freeze drying, and vacuum drying are cost-prohibitive for rural populations. The proposed solar dryer, with a total construction cost of ₹.4,91,000, incorporates a 6 m² PV-thermal solar air heater, a 12 m² packed bed solar air heater, a 10 kg capacity insulated drying chamber with stainless steel trays, a 1 hp blower, and automated control systems. This technology targets small-scale cottage industries to enhance value addition and create employment opportunities, particularly for rural women. Economic viability was assessed using four indicators: net present worth, benefit-cost ratio, internal rate of return, and payback period. The study highlights the potential of roselle processing to boost local economies through export opportunities, addressing the lack of awareness and limited research on value addition in roselle farming. The findings suggest that the IFCS dryer could be a sustainable, cost-effective solution for rural communities, promoting commercialization and economic development in tribal areas.

Keywords: Economic analysis, NPW, IRR, BCR, PBP, roselle fruits and indirect forced circulation solar dryer

NUTRITIONAL AND AGRICULTURAL SIGNIFICANCE OF ROSELLE LEAVES

Roselle (*Hibiscus sabdariffa* L.), a versatile shrub of the Malvaceae family, is extensively cultivated in tropical and subtropical regions, including India (notably Bihar, Assam, Tamil Nadu, and Andhra Pradesh), the Philippines, Malaysia, and the Caribbean [11,13]. As a home garden crop, roselle yields approximately 4 t/ha of fresh calyces, which are valued for their vibrant colour and nutritional properties. The plant is primarily grown for its stem-derived bast fibers, which are used in textile production, while the residual stalks serve as a sustainable fuel source. Roselle fruits (Fig.1), both fresh and dried, are integral to culinary traditions across various regions. Fresh as well as dried calyces are eaten raw or cooked with

onions and groundnuts, green or dried, as vegetables, used in food preparation [16]. In Gujarat and Maharashtra, fruit petals are used in making juices or drinks, squashes, jellies and pies, to produce a bright red-colour, chutney (sweet and sour in taste). Fresh or dried calyces are used for herbal drinks, hot and cold beverages, ice cream, chocolates, flavouring agents, fermented drinks, wine, jam, jellied confectionaries, puddings and cakes [5,6,16,29,30,42]. The biochemical composition of roselle petals and seeds highlights their significant nutritional potential. Per 100 g, roselle petals contain 2.0 g of protein, 11.1 g of carbohydrates, and 0.1 g of fat, alongside essential vitamins including thiamine (0.05 mg), riboflavin (0.07 mg), niacin (0.06 mg), and vitamin C (17 mg), as well as minerals such as calcium (150 mg) and iron (3 mg). In contrast, roselle seeds offer a richer nutritional profile, with 28.9 g of protein, 25.5 g of carbohydrates, and 21.4 g of fat per 100 g, accompanied by higher levels of thiamine (0.1 mg), riboflavin (0.15 mg), niacin (1.5 mg), and vitamin C (9 mg), and significantly greater amounts of calcium (350 mg) and iron (9 mg) [15,40]. These attributes underscore the potential of roselle petals and seeds as valuable components in functional foods and nutraceuticals. The seeds are eaten roasted or ground into powder and used in meals, such as oily soups and sauces [43] and for their oil [4] and as a substitute for coffee [28]. These attributes make roselle petals a valuable dietary component, particularly in regions where nutrient-dense foods are essential for food security.



Fig.1: Roselle fruits and its plants

SOLAR DRYING OF ROSELLE FRUITS

Roselle calyces, harvested with high moisture content (82%, wb), require drying to reduce moisture and extend shelf life while preserving nutritional quality and antioxidant potential.

Traditional open sun drying, which takes approximately five days in Gujarat's tribal regions, is time-consuming, unhygienic due to contamination risks, and can diminish antioxidant capacity [10,20]. Alternative drying methods, such as hot air tray drying, microwave, freeze, and vacuum drying, are effective but costly and inaccessible for rural communities. Developing affordable, efficient drying techniques could foster a small-scale dehydration industry for roselle, creating employment opportunities, particularly for rural women in Gujarat, where the plant holds significant potential for value-added processing. Limited research and awareness about roselle value addition highlight the need for studies to support farmers and processors in enhancing income through dried roselle products.

Various drying methods for roselle calyces have been explored to optimize moisture reduction while preserving quality. Forced air oven drying at 60°C yielded optimal results, balancing efficiency and quality retention [5]. Similarly, a constant temperature and humidity chamber was used to dry calyces at temperatures ranging from 35°C to 65°C and relative humidity levels of 30–50%, allowing precise control over drying conditions [31]. Tunnel drying at 70°C for 4.5 hours was reported as effective for achieving desirable drying outcomes [14]. Thin layer drying in a tray dryer, conducted at 40–60°C with an air velocity of 1.5–1.6 m/s, provided consistent results [41]. Comparative studies of sun and oven drying showed that oven drying at 50°C for 24 hours significantly reduced drying time compared to sun drying over three days [3]. Hot air drying at 60°C was also identified as an effective method [26], while oven drying at a higher temperature of 105°C for 45–60 minutes was found to be efficient for rapid drying [17]. These methods highlight a range of temperature and environmental controls to enhance drying efficiency, with oven-based techniques generally offering faster and more controlled results compared to traditional sun drying.

Preservation of roselle fruits is critical to extending their shelf life and maintaining their nutritional and sensory qualities. Solar drying has emerged as a cost-effective and efficient preservation method for agricultural products, including roselle fruits. This technology leverages abundant, non-polluting solar energy, reducing reliance on grid power and enabling on-farm operations. Solar drying technology encompasses a variety of methods designed to utilize solar energy for the dehydration of agricultural products. The primary categories include open sun drying and controlled drying with solar dryers. Open sun drying relies on direct exposure to sunlight, while controlled drying with solar dryers is further divided into natural convection dryers (passive), hybrid dryers, and forced convection dryers (active). Natural convection dryers include direct systems such as greenhouse dryers and cabinet

dryers. Indirect dryers, which can operate with or without storage, include chimney-type systems (chamber type, tray type, rack type, bin type, and tunnel type) and wind-ventilated dryers. Hybrid dryers combine elements of both natural and forced convection, while forced convection dryers, operating in mixed mode, enhance drying efficiency through active airflow management. This classification provides a framework for selecting appropriate drying techniques based on specific agricultural and environmental conditions. Solar dryers are classified based on the mode of solar ray contact with the material and the type of media flow [37,18,25,32,8,38]. Among these, the indirect mode forced convection solar dryer stands out for its superior drying speed and quality [8,12,27]. Unlike open sun drying, this method minimizes exposure to dust, insects, birds, and animals, preserving the colour, flavour, and nutrient content of the fruits. It also reduces drying time, labor costs, and the required drying area, while offering potential for automation and standalone operation. The advantages of indirect forced convection solar drying include its use of a non-conventional, cost-free energy source and its ability to produce high-quality dried products. These benefits are particularly relevant for roselle fruits, which are valued for both culinary and medicinal purposes. Given the cultural and nutritional significance of roselle, this study proposes to evaluate the efficacy and economic viability of an engineered indirect forced convection solar dryer for drying locally available roselle varieties. By optimizing drying conditions, this technology could enhance the quality and accessibility of dried roselle fruits, supporting sustainable agricultural practices and improving food preservation in tropical and subtropical regions.

ECONOMIC STUDY OF RE GADGETS AND SOLAR DRYERS

Research on renewable energy technologies, such as solar dryers and biomass systems, has consistently demonstrated their economic viability for agricultural applications. Sengar *et al.* (2008, 2009) assessed the economic performance of greenhouses for rose and papaya nurseries, employing metrics such as Net Present Worth (NPW), Internal Rate of Return (IRR), Benefit-Cost Ratio (BCR), and Payback Period (PBP). Similarly, Sengar *et al.* (2013) confirmed the commercial potential of briquetting technology using carbonized cashew nut shells, evaluated through NPW, BCR, and PBP. Aiswarya and Divya (2015) investigated a solar dryer integrated with phase change material (PCM), determining a favourable PBP based on production scales and costs. Chaudhari *et al.* (2018) established the economic feasibility of a hybrid solar dryer for drying spices, fruits, and vegetables, noting a notably short PBP for ginger drying. Additionally, Kiburi *et al.* (2020) reported a PBP of less than

one year for a greenhouse dryer, significantly shorter than its four-year lifespan, underscoring the economic efficiency of these systems.

TECHNICAL DESCRIPTION OF IFCS DRYER FOR ROSELLE LEAVES

Indirect forced circulation solar (IFCS) dryer consisted of PV-thermal as well as packed bed solar air heaters, drying chamber, ducting, SS trays, automation, safety and measuring sensors. IFCS dryer was installed in Energy Park of Department of Renewable Energy Engineering, College of Agricultural Engineering and Technology, Dediapada, Dist. Narmada, Gujarat as shown in Fig.2. Solar energy produced from the sun was used for air heating through PV-thermal and packed bed solar collector. This hot air was circulated through air blower which was placed between collector and drying chamber. Ambient air was circulated at constant flow rate of 4.1 to 4.4 m/s using air blower to absorb heat from the hot air flowing through absorber plate and to dissipate this absorbed heat inside drying chamber for drying of roselle fruits at constant temperature as well as variable temperature. The system was also provided with electrical heater to optimize in such a way that constant temperature was maintained throughout drying process. Technical specifications of the IFCS dryer are mentioned below in Table 1.



Fig.2: PV-thermal and packed bed collectors with drying chamber, control panel, ducting and blower

Table 1. Technical specifications of IFCS dryer

Particulars	Details
PV-Thermal solar collector (3 Nos.)	Poly crystalline solar cells of 335W stitched on the inner side of the glazing; Approximate 2 m ² ; Air flow between solar cells and absorber sheet
Packed bed solar collector (6 Nos.)	Black painted Al spiral rings as packing material; Approximate 2 m ² ; Air flow through packing material and over the absorber sheet
Collector stand	MS angle and MS base plate
Cabinet type tray dryer	Loading capacity: 15 kg fruits of fresh roselle; Approximate 0.72 m ³ ; PUFF insulation; Air flow arrangement through the product
Perforated tray (10 Nos.)	Dimensions: 630 × 730 × 25 mm
Air Blower	Centrifugal blower of 2000 m ³ /h air flow rate; 1 HP AC power of 220V, 100 mm of water column
Ducting	26 SWG GI sheet with protective paint with 150 × 150 mm square having 25 mm PUFF insulation
Automation for weighing of material, flow arrangement, hot air recirculation, constant temperature drying	

MATERIALS AND METHODS

An economic evaluation of the developed solar drying system was conducted to assess its financial viability for drying roselle fruits. Determining the economic feasibility of a novel technology is critical for its successful promotion and commercialization. To this end, the study analyzed the economic performance of the solar drying system, with costs calculated based on the system's loading capacity and drying duration per batch. To evaluate the economic viability and suitability of the IFCS dryer, four key economic indicators were calculated for roselle fruits drying: Net Present Worth (NPW), Benefit-Cost Ratio (B/C Ratio), Internal Rate of Return (IRR), and Payback Period (PBP).

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 the form of yearly net cash inflows. The payback period of the system indicates the time required to recover the invested amount. It is calculated as [35]: $P = \frac{I}{E}$

Where, P represents the payback period of the system (in years), I denotes the total investment in the system (in ₹), and E signifies the annual net cash revenue or profit (in ₹).

Capital cost

The capital cost (C) was found out by determining the cost involved during the fabrication of the IFCS dryer which included the cost of solar air heaters, drying chamber with trays, automations and measuring instruments/devices & control panel.

Fixed Cost

The fixed cost of a solar drying system comprises depreciation, interest, housing, insurance, and taxes.

Depreciation (D): Depreciation represents the annual reduction in the value of the solar drying system. It is calculated using the formula [23]: $D = \frac{C - J}{L}$

Interest (I): Interest is calculated based on the average investment in the solar drying system, considering its value in the first and final years. The annual interest is determined as follows

$$[23]: I = \frac{i \times (C + J)}{2 \times 100}$$

Insurance and taxes (IT): Insurance and tax costs are estimated at 2% of the capital cost per year and calculated using the formula [23]: $IT = \frac{2 \times C}{100}$

Total fixed cost: The total fixed cost is the sum of depreciation, interest, and insurance and taxes, expressed as: Total fixed cost, ₹/yr = D + I + IT

Depreciation (D) is measured in ₹/yr, representing the annual depreciation of the solar drying system. The capital cost (C), in ₹, is the initial cost of the solar drying system. Salvage value (J) is 10% of the capital cost. The life of the solar drying system (L) is expressed in years. Interest per year (I) refers to the annual interest amount in ₹, while the rate of interest per year (i) is the annual interest rate. Insurance and taxes (IT) are measured in ₹/yr, covering the annual costs for insurance and taxes.

Operating cost: Operating cost includes cost of fresh roselle fruits, repair, maintenance, labour cost and other miscellaneous costs. The repair and maintenance cost are a product of system's capital cost [23]. RM = 4 % of annual purchase price or capital investment

Total cost of operation: It is a summation of total fixed cost and total operating cost.

Total cost of operation per year = Total fixed cost + Total operating cost

Net Present Worth (NPW)

Net Present Worth (NPW) represents the difference between the present value of all future returns and the initial investment cost. It is a key discounted cash flow metric used to evaluate the financial viability of a project. Future benefits and costs are converted to their present worth through discounting, using the interest rate as the discount rate. For a project

yielding consistent annual benefits, NPW determines the justifiable investment amount by calculating the present value of the future income stream.

The NPW is calculated by subtracting the total discounted present worth of the cost stream from that of the benefit stream. Alternatively, incremental net benefits are obtained by subtracting gross costs from gross benefits or investment costs from net benefits. The

mathematical expression for NPW, as outlined by [35]:
$$NPW = \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t}$$

Where, C_t = Cost in each year; B_t = Benefit in each year; $t = 1, 2, 3, \dots, n$; i = Discount rate, %; n = Project life, years; The investment is considered worthwhile if $NPW > 0$, not worthwhile if $NPW < 0$, and neutral if $NPW = 0$.

Benefit Cost Ratio (BCR)

The Benefit-Cost Ratio (BCR) is a financial metric used to assess project viability by dividing the present worth of the benefit stream by the present worth of the cost stream. A project is deemed acceptable if the BCR is one or greater. In practice, the BCR is often calculated by comparing the present worth of net benefits (gross benefits minus associated costs) to the present worth of total project costs, which include installation, operation, maintenance, and replacement costs. Associated costs refer to the value of additional goods and services, beyond project costs, required to make the project's immediate products or services available for use or sale. The mathematical expression for the BCR [35]:

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

A BCR greater than 1 indicates a worthwhile investment, a BCR less than 1 suggests the investment is not viable, and a BCR equal to 1 represents a neutral case.

Internal Rate of Return (IRR)

IRR is a financial metric used to evaluate project viability by determining the discount rate at which the NPW of the incremental net benefit stream or incremental cash flow equals zero. The IRR represents the maximum interest rate a project can afford to pay for resources while recovering its investment and operating costs, effectively breaking even. It reflects the rate of return on capital invested in the project over its duration, making it a valuable measure of project worth. The IRR is calculated through a trial-and-error process to identify the discount rate (i) that satisfies the following equation, as outlined by [35]:

$$\sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} = 0$$

IRR is compared to the project's discount rate (*i*) to assess investment viability: **IRR is greater than (*i*)**: The investment is viable, as the project's return exceeds the cost of capital.

IRR is less than (*i*): The investment is not viable, as the project's return is below the cost of capital.

IRR is equal to (*i*): The investment is neutral, indicating a break-even point where the project's return equals the cost of capital.

RESULTS AND DISCUSSIONS

The economic evaluation of the IFCS dryer for roselle leaves was accessed after analysing various economic parameters. The estimated cost break-up of the developed solar drying system are shown in Table 2. The calculation of payback period for developed solar drying system for drying of roselle leaves are shown in Table 3. Total cost of the developed system was ₹ 4,91,000/- including the 12 % GST and 15 % profit.

Table 2. Cost break-up of the developed solar dryer

Item	Cost (₹)
PV-Thermal solar air heaters (3 nos.)	63090
Packed bed solar air heaters (6 nos.)	68220
Stand and locking arrangement (18 nos.) for solar air heaters	31500
Insulated drying chamber with 10 Nos. of SS tray and online load cell and MS stand	110000
Blower with motor (1 hp)	21000
Ducting and insulation	20000
Control panel with sensors automation and electric heater	51000
Motorized damper with control limit switch (3 nos.)	12630
Foundation for stand of solar air heaters, control panel, blower and drying chamber (48 nos.)	7200
Total cost including GST and Profit	4,88,493
Electrical grinding machine	2,507
Total system cost	4,91,000

Table 3. Assumptions for calculation of payback period

Initial cost of developed solar drying system (C) ₹ 4,91,000/-				
Assumptions [1,39]				
Salvage value of developed solar drying system		(J)	10 % of capital cost	
Useful life of developed solar drying system		(L)	10 years	
Annual working hours		(H)	8 h/d × 300 d/year = 2400 h/year	
Annual rate of interest		(I)	10 %	
Annual rate of insurance and taxes		(IT)	2 % of initial cost	
Operating cost				
1.	Cost of fresh roselle fruits	Rate of fruits = ₹ 30/kg	Mass flow rate = 4500 kg/year	₹1,35,000/year
2.	Labour cost (1 labour)	Rate = ₹ 350/labour/day	300 days in a year	₹ 1,05,000/year
3.	Total energy cost 1 hp blower was operated with the help of DC power generated from the 1005 Wp PV-Thermal solar air heaters through inverter and battery bank.	Used energy = 250 kWh/year	Rate = ₹ 8/kWh	₹ 2,000/year
4.	Maintenance cost	Repair and maintenance cost @ 4 per cent of capital cost per annum		₹ 19,640/year
Total operating cost [A = 1 + 2 + 3 + 4]				₹ 2,61,640/year ₹ 58.14/kg
Fixed cost				
6.	Depreciation (D)			₹ 44,190/year
7.	Interest on capital (I)			₹ 27,005/year
8.	Insurance and taxes (IT)			₹ 09,820/year
Total Fixed cost [B = 6 + 7 + 8]				₹ 81,015/year ₹ 18.00/kg
Total cost of operation [A + B]				₹ 3,42,655/year ₹ 76.14/kg

Selling cost of dried product

The recovery (%) in terms of whole seeds, dried pods and roselle calyx fine powder after sieving were 10.3, 4.1 and 8.0 respectively. The market rate of dried roselle calyx fine powder was ₹ 1800 per kg (<https://www.tarunaturals.com/product-page/roselle-powder>), whereas dried seed was ₹ 150 per kg. The selling price of the dried products used for economic assessment of the developed system is always higher than the market rate of dried

products. The selling rate of dried roselle calyx fine powder was ₹ 1800 per kg, whereas dried seed was ₹ 150 per kg. Thus total cost of dried roselle calyx powder and dried seeds (₹/year) is ₹ 7,17,525/-.

Table 4. Estimated total cost of system dried roselle fruits

1	Weight of dried roselle fruits available from each batch of 15 kg fresh roselle fruits	3.4 kg (22.7 % of fresh roselle fruits)
2	Weight of dried roselle calyx available from each batch of 15 kg fresh roselle fruits	1.26 kg (8.4 % of fresh roselle fruits)
3	Weight of good quality dried roselle calyx powder available from each batch of 15 kg fresh roselle fruits (fine powder after sieving)	1.2 kg (8.0 % of fresh roselle fruits)
4	Total weight of dried roselle calyx powder produced in a year (300 days drying for roselle fruits in a year)	360 kg/year
5	Total price of system dried roselle calyx powder produced in a year (@ Rs.1800 per kg)	₹ 6,48,000/year
6	Weight of dried roselle seed available from each batch of 15 kg fresh roselle fruits	1.54 kg (10.3 % of fresh roselle fruits)
7	Total weight of dried roselle seed produced in a year (300 days drying for roselle fruits in a year)	462 kg/year
8	Total price of system dried roselle seeds produced in a year (@ Rs.150 per kg)	₹ 69,525/year
9	Weight of dried roselle capsules as seed cover available from each batch of 15 kg fresh roselle fruits	0.61 kg (4.1 % of fresh roselle fruits)
10	Total price of system dried roselle fruits having calyces, seeds and pods (Row 5 + Row 8)	₹ 7,17,525/year

Benefit: The benefit is a difference between total cost of dried product and total cost of operation, (₹/year). Benefit (₹/year) = Total selling cost of dried product - Total cost of operation = 7,17,525 – 3,42,655 = ₹ 3,74,870 per year

Net Present Worth (NPW): The net present worth for the system is ₹ 18,12,414/-. The NPW is calculated for the next ten years and tabulated in Table 5.

Benefit Cost Ratio (B/C Ratio): The present worth of the benefit stream after ten years was ₹. 44,08,880/-, whereas the present worth of the cost stream after ten years was ₹. 25,96,467/- . Both the value is calculated for the next ten years and tabulated in Table 5.

$$\frac{\text{Benefit (₹/10 years)}}{\text{Cost (₹/10 years)}} = \frac{4408880}{2596467} = 1.70$$

The benefit-cost ratio of the IFCS dryer is found to be 1.70

Table 5. Calculation of cost with cash outflow and cash inflow for IFCS dryer for roselle fruits

Year	Cash Outflow (₹)	PW of Cash Outflow (₹)	Cash Inflow(₹)	PW of Cash Inflow (₹)	NPW (₹)
(1)	(2)	(3)	(4)	(5)	(5) – (3)
0.0	491000	491000.0	0	0	-491000.0
1.0	491000	311504.5	717525	652295.5	340790.9
2.0	342655	283186.0	717525	592995.9	309809.9
3.0	342655	257441.8	717525	539087.2	281645.4
4.0	342655	234038.0	717525	490079.2	256041.3
5.0	342655	212761.8	717525	445526.6	232764.8
6.0	342655	193419.8	717525	405024.2	211604.3
7.0	342655	175836.2	717525	368203.8	192367.6
8.0	342655	159851.1	717525	334730.7	174879.6
9.0	342655	145319.2	717525	304300.6	158981.5
10.0	342655	132108.3	717525	276636.9	144528.6
Total		2596466.6		4408880.5	1812413.9
				NPW	1812413.9
				B/C Ratio	1.70

Internal Rate of Return (IRR)

The internal rate of return was found to be 76.08 % for ten years, which indicate that the developed solar drying system was cost efficient technology. The higher the percentage of internal rate of return indicated the good commercial return of the investment. Janjai and Tung (2005) calculated the IRR of a solar dryer for drying 200 kg of roselle using hot air from roof integrated solar collectors was found to be 70.30 %.

Payback period

$$\text{Payback period (years)} = \frac{\text{Initial Investment (₹)}}{\text{Net Annual Cash Inflow (₹)}} = \frac{4,91,000}{3,74,870}$$

$$= 1.31 \text{ yr or } 15.72 \text{ months}$$

The IFCS dryer's payback period was estimated by adding the net cash flow to the project until the cumulative net cash flow was equal to the initial investment. It was clear from the above calculation that the IFCS dryer has a payback period of 15.72 months. It was Kareem *et al.* (2016) reflected the value of a payback period of 2.14 years for forced convection multi-pass solar air heating collector system for drying of roselle. Yahya *et al.* (2018)

evaluated the payback period of a solar heat pump fluid bed dryer integrated with a biomass furnace for rice drying was estimated at 1.6 years. Kareem *et al.* (2017) investigated the performance evaluation of solar collector unit with drying cabinet loaded with screw-pine and the economic analysis of the system has indicated with a payback period of 0.75 year. Janjai and Tung (2005) calculated the PBP of a solar dryer for drying 200 kg of roselle using hot air from roof integrated solar collectors was found to be 3.9 years.

The cost economics of developed indirect forced circulation solar dryer is shown in Table 6. The developed system with automation was found as a cost-efficient drying technology.

Table 6. Cost economics of IFCS dryer

Details	Value
Total system cost (₹)	4,91,000
Fixed cost (₹/year)	81,015
Variable cost (₹/year)	2,61,640
Total cost of operation (₹/year)	3,42,655
Selling cost of calyces powder and dried seeds (₹/year)	7,17,525
Benefit (₹/year)	3,74,870
Benefit cost ratio (B/C Ratio)	1.70
Payback period (Years)	1.31
Internal rate of return (IRR) (%)	76.08
Net Present Worth (NPW) for ten years	18,12,414

CONCLUSION

It was estimated that the total cost of IFCS dryer for roselle leaves drying was approximately ₹ 4,91,000/-. The fixed cost, operating cost, total cost of operation, selling cost of dried product and benefit of indirect forced circulation solar dryer were calculated and observed as 81,015/- (₹/yr), 2,61,640/- (₹/yr), 3,42,655/- (₹/yr), 7,17,525/- (₹/yr) and 3,74,870/- (₹/yr) respectively. The estimated benefit cost ratio, net present worth of investment made on dryer and internal rate of return for the indirect forced circulation solar dryer for roselle fruits drying were about 1.70, ₹ 18,12,414/- and 76.08 % respectively. The indirect forced circulation solar dryer is an effective solution to roselle grower who would be able to recover his investment on solar dryer within a period of 1.31 years by drying only roselle leaves. This type of processing gives more income with less effort. It means the indirect forced circulation

solar dryer is very useful technology in tribal region of Gujarat for the economic development of farmers.

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