Performance and Economic Evaluation of Biomass and Solar Energy System for Turmeric Processing

H. Sanchavat *, S. Kothari, D. Sharma, N. K. Jain, G. P. Sharma

ABSTRACT

India is believed to be the home of turmeric. It accounts for 78 percent of the world output and 60 percent of world exports. Indian turmeric is considered the best in the world market because of its high curcumin content. The post harvest operations for turmeric processing like boiling and drying are carried out by conventional method which are slow, tedious and labour intensive. Use of petroleum fuel or electricity for drying of agricultural produce is an expensive process at village scale. Therefore, an appropriate technology for boiling and drying of agricultural produce has been developed and its performance for the drying of turmeric rhizomes has been evaluated. The results indicate that boiling and drying intensified the colour and curcumin content. The results also revealed that the solar drying is better than direct sun drying as it achieved the desired moisture content and essential quality in 42 hour (6 days) compared to 56 hour (8 days) in sun drying, thus saving considerable time (14 hours). The economic feasibility of the biomass and solar energy system for turmeric processing was also carried out.

Keywords : Turmeric, Solar drying, Economic evaluation

INTRODUCTION

Turmeric is a spice derived from the rhizomes of *Curcuma longa*, which is a member of the ginger family Zingiberaceae. Turmeric is the most ancient medicinal spice, traditionally ubiquitous and held sacred. The history of turmeric is entwined with the history of Indian culture and also with the socio-religious practices of the country. It was popular even in Vedic times because of its unique properties of colour, flavor and also its importance as medicine in Ayurveda, besides its use as a cosmetic and significance in religious ceremonies and auspicious occasions (Jacob 1995). In Rajasthan, turmeric is cultivated in Jhadole, Dungarpur, Bichiwara, Gogunda (Udaipur Division), Chittorgarh, Kota and Bhilwara districts.

The post harvest processing of turmeric involves many unit operations such as washing, cleaning, curing, drying, polishing, size reduction and packaging. Curing is the process of boiling the raw rhizome in water for the development of attractive colour and characteristics aroma (Sharma et al. 2008). Boiling also destroys the viability of the fresh rhizomes, eliminates the raw odour, reduces the time of drying, ensures an even distribution of colour in the rhizomes and gives a better quality product by gelatinisation of the starch (Purseglove et al. 1981). Mother and finger rhizomes are boiled separately for about 40–60 minutes under slightly alkaline condition (100g of sodium bicarbonate or sodium carbonate in 100L of water). These unit operations with traditional methods require more time and energy, besides using improved processing technology, one can obtain quality hygiene product and earn more. Therefore, an appropriate technology for boiling and drying of agricultural produce has been developed and its performance for the drying of turmeric rhizomes has been evaluated. The economic evaluation of the developed systems was carried out in terms of Net present worth (NPW), Internal rate of return (IRR), Benefit cost ratio (B/C) and Payback period (Gene 2002).

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MATERIALS AND METHODS

The biomass combustor used for boiling of turmeric was designed and developed (Panwar 2008). The biomass combustor consists of gasifier reactor, grate, ash chamber, burner assembly, primary air control supply system etc. The line diagram is shown in Fig.1.

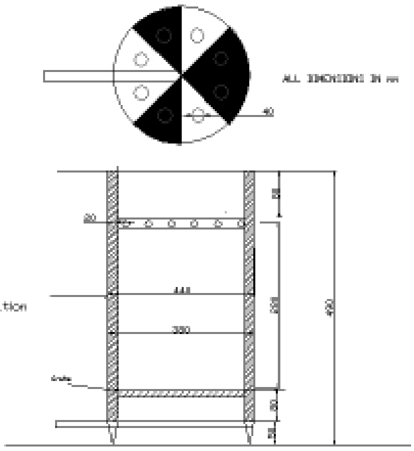

Fig. 1: Line diagram of bio mass combustor

The drying was carried out under sun and in the developed indirect natural convection solar cabinet dryer showed in Fig.2. The drying was done from 9 AM to 5 PM in the month of January 2012. Temperature and relative humidity of the ambient air and hot air inside the solar dryer and exit air were recorded in one hour interval. The sample was dried until the moisture level in the sample reduced to a safe storage level of 8 % (w.b.). The dried sample was ground to powder and the colour 'b' value that is yellowness and Curcumin content were determined.

Fig. 2: Solar Cabinet Dryer

For the success and commercialization of any new technology, it is essential to know that the technology developed is economically viable or not. Therefore, an attempt has been made for estimation of economics of the developed solar and biomass energy systems. The capital cost, variable cost, fixed cost, total cost, revenue and net profit are the basic components for an economic analysis of any business. The following assumptions/ considerations were made for carrying out economic analysis of integrated biomass and solar energy system for turmeric drying.

i. The cost of fabrication and installation of biomass combustor and solar cabinet dryer was Rs 3,400/- and Rs 25,400/-, respectively.
ii. The useful life of biomass combustor and solar cabinet dryer is 10 years.
iii. The combustor is operating on wood logs and consumed 5 kg batch^{-1}. The cost of wood Rs 5 kg^{-1}.
iv. The cost of raw turmeric is Rs 9kg^{-1}.
v. Labour requirement for curing operation is 1 man-h batch^{-1} and 6 man-h batch^{-1} for drying
vi. The cost of labour is Rs.120 day^{-1} (8 h).
vii. Discounting rate is assumed to be 10 per cent as compared to bank lending rate of interest.
viii. The annual repair and maintenance cost is 2% of the initial investment.
ix. The sale price of turmeric is Rs 120 kg^{-1}.
x. Turmeric is available for 160 days only however, economic evaluation considers that dryer was used for other product. The solar cabinet drying system can be operated 300 days in a year.

Different economic indicators were used for economic analysis of solar and biomass system under this study.

Net present worth

The present values of the future returns calculated through the use of discounting. Discounting was essentially 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 mathematical statement for net present worth can be written as:

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

Where, C_t = Cost in each year, B_t = Benefit in each year, t = 1, 2, 3................n, i = discount rate

Benefit cost ratio

This B/C ratio was obtained when the present worth of the benefit stream was divided by the present worth of the cost stream. The formal selection criterion for the benefit-cost ratio for measurement of project worth was to accept projects for a benefit-cost ratio of 1 or greater. The mathematical benefit-cost ratio can be expressed as:

$$\text{Benefit Cost ratio} = \frac{\sum_{t=1}^{t=n} B_t}{\sum_{t=1}^{t=n} C_t}$$

where, C_t = Cost in each year, B_t = Benefit in each year, t = 1, 2, 3................n.

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 economic analysis of integrated biomass and solar drying system for turmeric processing was calculated.

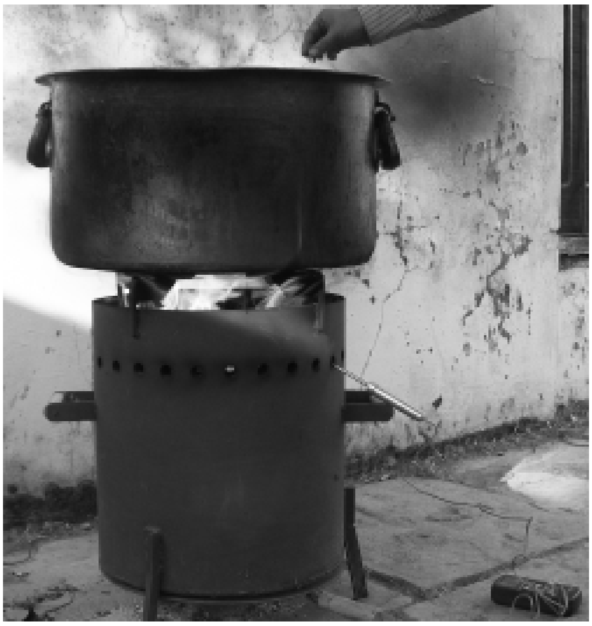

Fig. 3: Turmeric Curing with Biomass combustor

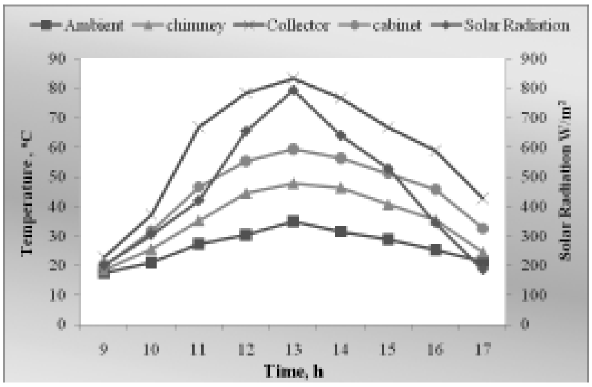

Fig. 4: Variation in temperature during full load test in solar cabinet dryer

RESULTS AND DISCUSSION

Performance of biomass combustor and solar dryer

The thermal efficiency of biomass combustor was calculated as 35%. The biomass combustor was used for boiling of 50 kg/batch of turmeric rhizomes as shown in Fig. 3 and it worked satisfactory. The maximum temperature obtained inside the drying chamber was 59.4°C at 01.00 hour in the month of January corresponding to ambient temperature of 34.8°C and solar intensity of 792 W/m^2. The average air temperature raised inside drying chamber over ambient temperature was 15-25°C during the full load condition. It was observed that the drying chamber outlet temperature was lower than that of drying chamber inlet temperature. The hourly temperature and solar intensity variation inside drying chamber observed is graphically presented in Fig. 4.

The relative humidity of drying chamber outlet was more than drying chamber inlet. This was due to addition of water vapours into heated air. It was observed from Fig. 5 that, the relative humidity inside the solar cabinet dryer varies 52 to 24 percent and corresponding ambient humidity varies 64 to 35 percent. The average relative humidity inside the solar dryer was found to be 33.44 percent as compared to 49 percent of ambient air and exit air average relative humidity 37.55 percent. The result of moisture content with time is shown in Fig. 6. The initial moisture content of turmeric was 82 percent (wb). It was observed that at the end of sixth day moisture content reduced to 8 percent (wb). It was observed that solar cabinet dryer take 42 h as compared to open sun drying which required 56 h.

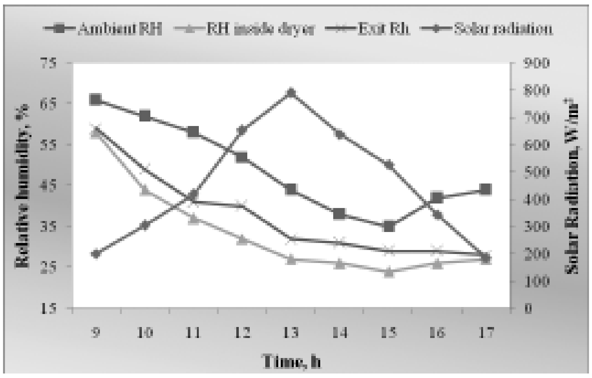

Fig. 5: Variation of relative humidity during full load test in solar cabinet dryer

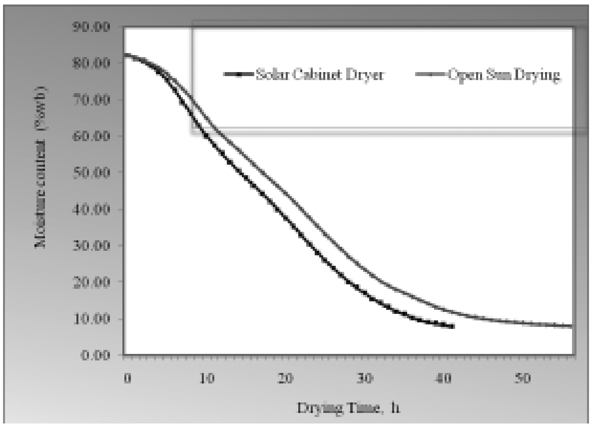

Fig. 6: Variation of moisture content for turmeric drying

The colour value (b value) of solar cabinet dried turmeric varied from 45.18 to 49.45 whereas, in commercial sample it varied from 26.5-39.7 and in open dried turmeric it varied from 32.30 to 37.98. The curcumin content of solar cabinet dried turmeric ranged between 5.14 to 5.50 percent while that of open sun dried sample varied from 4.35 to 4.58 percent and of commercial sample 3.75 to 4.33 percent. It was observed that curcumin and yellow colur value in solar cabinet dried sample was significantly better than open dried and commercial samples which was in agreement with the finding of Jose and Joy (2009).

Economy of biomass and solar energy system for turmeric processing

The economic feasibility of the integrated biomass solar cabinet dryer for the drying of the turmeric was calculated by considering the initial investment for the dryer, average repair and maintenance cost, cost of raw material and selling price of the material. The economics of the integrated biomass solar cabinet dryer for the drying of the turmeric are summarized in Table 1. Processing cost of turmeric in the developed system was found to be Rs. 3.78/kg which increases its value to Rs. 8.82/kg, an increase by 2.3 times. B/C ratio of the system was 1.69 and payback period was found 1.31 years which indicates that within this short period the investment amount can be recovered. Cash inflow, outflow and net present worth of integrated biomass and solar drying system for turmeric drying has been presented in Table 2. It shows the annual profit after each year and in the 10^{th} year of the system, there will be a net profit of Rs. 73501.

Table 1: Economic analysis of biomass and solar drying system for turmeric drying

Particulars	Value
Production Capacity (Kg/day)	1.5
Operating days per year	300
Raw Turmeric dried (Kg/year)	2500
Dry Turmeric output (kg/year)	450
(A) Biomass Combustor initial cost (Rs.)	3400
(B) Solar Cabinet Dryer initial cost (Rs.)	25400
(C) Total annual investment Cost (Rs.) = A+B	28800
(D) Annual Manpower @ Rs. 15 /h for one labour	4500
(E) Annual Cost of wood @ Rs. 5 kg^{-1}	1500
(F) Annual Maintenance @ 2 % of (A)	576
(G) Discount rate (@10 % for plant)	2880
(H) Cost of raw material (@Rs. 9 /kg of turmeric)	22500
(I) Cost of processing = D+E+F+G	9456
(J) Total input or cost of production = H+I	31956
Processing cost per kg turmeric (Rs.)	3.78
(K) Sell price of turmeric @Rs 120 kg^{-1}	54,000
(L) Net Benefit (Rs.) = (K-J)	22044
Value addition by processing of turmeric (Rs.kg^{-1})	8.82
Benefit Cost ratio = K/J	1.69
Payback Period (Year) = A/D	1.31

CONCLUSIONS

The developed system is suitable for curing and drying of 50 kg of turmeric in one batch. The results indicate that solar cabinet drier took lesser time than open drying system. The turmeric sample had higher colour value and higher Curcumin content indicating better quality product. The present net worth of developed system for turmeric processing was found to be Rs. 28800. The system payback

Table 2: Cash inflow, outflow and net present worth of integrated biomass and solar drying system for turmeric drying

Yr	Cash outflow, Rs.	PW of Cash outflow, Rs.	Cash inflow, Rs .	PW of Cash inflow, Rs.	NPW
1	2	3	4	5	(5)-(3)
0	62756	62756	0		-62756
1	33956	30866	54000	49086	18220
2	33956	28047.7	54000	44604	16556.3
3	33956	25501	54000	40554	15053
4	33956	23191.9	54000	36882	13690.1
5	33956	21086.7	54000	33534	12447.3
6	33956	19151.2	54000	30456	11304.8
7	33956	17419.4	54000	27702	10282.6
8	33956	15857.5	54000	25218	9360.55
9	33956	14397.3	54000	22896	8498.66
10	0	0	54000	20844	20844
TOTAL		258275		331776	73501.4

period was 1.31 years and benefit cost ratio was found as 1.69. The system was found to be economical for turmeric processing. The system could be good household appliance for processing of turmeric and revenue generation.

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REFERENCES

Gene O (2002). Best practices guide: economic & financial evaluation of renewable energy projects. U.S. Agency for International Development Office of Energy, Environment & Technology, Global Bureau Environment Center, Washington DC, 20523: 1810

Jacob B (1995). Turmeric quality requirements of importing countries. In: Quality improvement of turmeric, Ed. C.R. Sivadasan and N.A. Devananda Shenoy, Spices Board (Govt. of lndia), Kochi, pp 25-36

Jose KP, Joy CM (2009). Solar tunnel drying of turmeric (*Curcuma longa* linn. syn. *C. domestica* val.) for quality improvement. J Food Proc Preserv 33(15): 121-135

Panwar NL, Rathore NS (2008). Design and performance evaluation of a 5 kW producer gas stove. Biomass Bioenerg 32: 1349-1352

Purseglove JM, Brown EG, Green CL, Robbin SRJ (1981). Spices, Vol.2, Longman group ltd., London, New York

Sharma PD, Sinha MK, Kumar V (2008). Curing Characteristics and Quality Evaluation of Turmeric Finger. J Agric Eng 45(2): 58-61