Evaluation of Solar Thermal Drying Potential Related with Fish Drying Product in Sri Lanka

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Abstract-*Sri Lanka is situated close to the equator; therefore most of the parts of the country receive an abundant solar radiation throughout the year. As estimated in the solar resource map developed by the National Renewable Energy Laboratory (NREL) of the USA, it varies from 4.0 – 4.5 kWh/m^2/day. But solar thermal energy related applications are limited in commercial forms. However, solar energy is the most popular form of energy in day to day life .The one of most common commercial applications of solar energy in Sri Lanka is fish drying process such as products of dry fish, and Maldivian fish. In general, small scale fish drying process are used open sun drying techniques for their products. But this method has several drawbacks such as poor quality, high drying time, and contaminations. Solar dryer is providing effective solution for this kind of product drying purposes. Research methodology is comparison of two technologies with field data .This paper presents the overview of solar thermal drying potential and financial viability with fish dying process in Sri Lanka.*

Keywords: *Open sun drying, solar dryer, fish drying potential*

I. INTRODUCTION

Sri Lanka is a tropical country; hence it has adequate solar energy intensity and a large number of days of sunshine Island –wide. This energy is available free for use for many purposes. However, the vast amount of solar energy available is not utilized to the maximum for the food drying industry, in the country. Solar energy is traditionally used by the food industry for drying of spices, fish, vegetables, paddy and agro based products. Generally ,the open sun drying methods is used by the food drying purposes Problems of wastage of product, low quality of dried product, large number of labour requirement ,difficulty to bulk handling, difficulty to drying on rainy days arise,Objectives of implementing this research study are to effectively preserve additional fish at the harvesting and improve their income earning activities to uplift the living standard of fisheries community in Sri Lanka. Traditional drying method is an open sun drying; but there is a considerable loss due to various reasons such as rodents, birds, insects, dust, micro-organisms, and dirt. On the other hand due to unexpected weather conditions also negatively affect for the quality of product. In addition over drying and insufficient drying, the fish product would become a bad bargain.

Recently, solar dryers were introduced by various organizations institutions and researches, to overcome problems such as destruction of nutrition when exposures sunrays .Nevertheless even today, this technology is not popular in the country. Unutilized solar thermal potential for the fish industry is available in most parts of the country throughout the year. If this potential is utilized, a successful solution can be found for the fish drying industry in Sri Lanka. Investors in the fish drying industry do not have any clear idea about how to utilize the solar thermal potential of the country. Nevertheless, attempts have been made through this research, to quantify the unutilized solar thermal drying potential and present an analysis of potential socio-economic gains for the fish drying industry.

According to this study a solar dryer technology for fish drying industry in Sri Lanka can be recommended because it has shown several salient features that required to be taken in to consideration. Mainly consideration is the location of the country where the dryer is planning to operate. The other important factor is that the target group should be used by the dryer technology for fish drying, because of financial strength and period of harvesting. Most of the small-scale dry fish producers in coastal area provide open sun dried products to local market. But open sun dried results in an inferior quality product. As a result profit of the product is lost. To avoid such kind of drawbacks solar power fish dryers have been introduced by government and private organizations. Most of projects are functioning in Puttlam,Negombo, Chilaw southern coastal area and northern and eastern part of the country. But, this technology is difficult to popular among fisheries community without proper financial support activities and technical assistant. To avoid such kind of barriers SEED's (Sarvodaya Economic Enterprise Development Services) Solar Division introduced a micro-credit scheme for solar dryer purchases. Government supplied 75 solar dryer units to the parallel with Uthuru Wasanthaya Programme. Near recently, solar dryer units have been established at the Naththandiya,Pulmudei and Nandikadal providing technical assistance and awareness about the solar dryers by Vidatha and Practical actions

Figure 1: Open sun drying

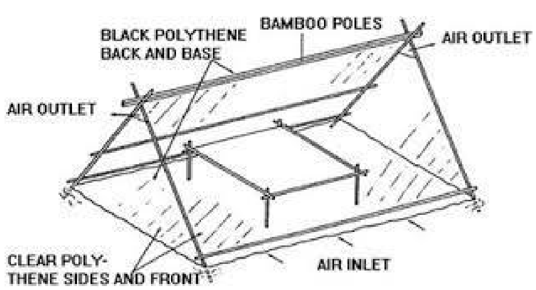

Figure2: Low cost solar tent dryer (Speirs,C.I &Coot,H.C,1986)

Figure 3: solar dryer technology

Advantages of solar dryers over heated-air mechanical dryers are their low running cost, affordable investment of capital and suitability for low capacity. All drawbacks could be addressed to if the problems of poor quality and low-priced markets are solved simultaneously. On the other hand this technology is avoided the environmental pollution as a result it can introduced as a sustainable approach of fish drying in Sri Lanka.

Table 1: Selected fish types for drying

Commercial group	English Name (Common Name)	Scientific Name	Sinhala Name
Shore Seine	Smoothbelly Sardinells	*Amblygaster clupeoides*	Keeramin
Shore Seine	Anchovy	*Stolephorus* sp.	Halmessa
Balaya	Skipjack tuna	*Katsuwonus pelamis*	Balaya
Kelawalla	yellowfin tuna	*Thunnus albacares*	Kelawalla

Source: <www.fisheries.gov.lk>

II. THEORY OF SOLAR FISH DRYING

A. Moisture content

The percentage moisture content was determined by using the following formula, (Ranganna, 1986).
Moisture Content (WB)=$(w_1-w_2)/w_1*100\%$
Moisture Content (DB)= $(w_1-w_2)/w_2*100\%$
Where, W_1= Weight of sample before drying (kg)
W_2= Weight of dried sample (kg)
WB-Wet base DB-Dry base
Drying rate (D.R.)= $\Delta W/\Delta T$

Where,

ΔW - Weight loss in selected sample (kg)

ΔT- Difference in time reading (hr)

The drying was carried out by loading the weighted fish in dryer from morning 8:00hrs to 17:00 hrs. The Fish were dried up to the final moisture content of (Malviya and Gupta, 1985) 16% (w.b.).Similar procedure was adopted for drying of fish sample in open sun drying. The drying time required for drying the fish sample from IMC to 19% (wb) in solar dryer and under open sun drying condition.

B. Moisture ratio

The Moisture ratio of product can compute by using the initial moisture content (IMC) and equilibrium moisture content (EMC)

Moisture Ratio $=(M-M_e)/(M_o-M_e)$

Where, M = Moisture content (DB.), %

M_e = EMC, (d.b), % M_0 = IMC, (d.b), %

The EMC for fish was considered as 16% (w.b.)

Profit and market margin analysis was used to determine the profitability of dry fish marketing in selected areas.

C .Operation and Maintenance

Operation and maintenance of solar driers are very simple. Operation merely involves loading layers of pre-processed fish (cleaned and salted) on to the drying platforms (trays), turning the fish at the end each day and finally unloading the dried fish when they are fully dried. The maximum drying time would be 3½-4 days for Skipjack Tuna(“Balaya”) and yellow fin tuna(“Kellawalla”).For Smooth belly sardnells(“Keeramin”) ,Anchovy (“Halmessa”)or other smaller fish 1-1½ days would be sufficient. However drying time depends on several factors (Prakash,J. & Garge,H.P,1998)Maintenance is only a matter replacing the polythene cover. This needs to be done every year. It is the only item that needs replacing and amounts to approximately Rs. 25,000 per replacement annually. However replacement time depends on environmental conditions of the location. However this cost needs to be weighed against the benefits. The benefit in terms of higher quantity and price premium for quality covers this cost several times more. The double sided adhesive tapes facilitate easy removal and replacement. If the cover is pre-prepared, the replacement should take less than a couple of hours. Both operation and maintenance can be handled by an unskilled worker.

III. METHODOLOGY

D.Site Selection

The solar powered fish dryer in the Mudukatuwa fisheries village in Naththandiya, Pulmudei and Nandikadal has been established by the Technology, Research and Atomic Energy Ministry under its Vidatha programme. Naththandiya Vidatha centre implemented the project to encourage the public to produce new value added products using endemic resources. This is the first solar power fish dryer established by the ministry with technical assistance granted by the Practical Action Institute. After establishing the solar power system as an effective measure to preserve fish for the fisheries community in Mudukatuwa village, it has been successfully functioning since 2013 .However even today, open sun drying method is also used for fish drying purposes. Therefore Naththandiya area was selected as a site for data collection in this research.

Table 2: Dryer dimensions

Location	Dimensions(Inches)		
	L	W	H
Natthandiya	156	132	72
Pulmudai	156	132	72
Nandikadal	180	180	72

Figure 4: Stationery solar dryer at Naththandiya

E. Data collection

Required data was collected for different technologies as follows.

Table3: Collected data for open sun drying technology

	Tuna(Dry Fish)	Modives fish (Tuna)	Keeramin	Halmassa
Drying period(days)	5	7	3	1.5
Required Labour days per month(days)	30	30	30	30
Batches per months	6	4	10	20
Average Cost of raw material(kg)	100	100	90	80
Average Price of final product(Rs/kg)	500	1000	350	325
Average quantity per batch(kg)	150	150	225	350
Average through put per batch(kg)	47	42	75	115

Table 4: Collected data for dryer technology

	Tuna(Dry Fish)	Modives fish	Keeramin	Halmessa
Dryinng period(days)	3.5	5	1.5	1
Labour days per month	10	6	20	30
Batches per months	9	6	20	30
Cost of raw material(Rs/kg)	100	100	90	80
Wholesale Price of final product(Rs/kg)	500	1000	350	325
Quantity per batch(kg)	150	150	225	350
Through put per batch(kg)	49.5	30.0	75	115

F. Procedure of Analysis

In this research, two different technologies were selected, open sun drying and solar dryer technology. The necessary information was collected and measured related to two technologies. Four different products such as Dry fish (large medium and small sizes) and moldavian fish were selected. Subsequently the measured data was used for calculating the required energy and cost of production with respect to each fish products. The collected data and information were tabulated for different products in Table 2&3.Fish drying data was collected from "Naththandiya" area.

Temperature of dryer was measured and it was 42^0 C and average ambient temperature was 30^0C.This differences is matching with analysis of Narong,Chamchalow in 1998. The total energy consumption of both technologies was calculated for each product. Then energy differences of the two technologies were obtained for each product. To calculate the total energy all relevant products were converted to energy form. For example laboure force was converted to energy form. If the same product, the same environmental conditions and the same drying area were considered the reason for the large energy differences for drying the same quantity necessitated calculation of the product.

This is the energy present in solar radiation and this quantity of solar energy cannot be captured in the absence of an appropriate technology. Dryer technology is used to capture that unutilized potential. However, there may be other technologies to capture this potential. According to practical data for different products, these solar thermal potential values were calculated separately for each. After, this the commercial value for each selected fish item in the fish drying industry was evaluated. Further, the commercial value of that energy was calculated for different products and land area is saved by the unutilized solar potential. Each calculation was based on the production of one kilogram and one month time period were considered. The annual production was not considered for calculation because fish drying is done in the harvest period only. Otherwise, if the annual product is considered, the rain factor effect must also be included.

III. EXPERIMENTAL RESULTS

The collection of data on four different fish drying products was analysis. It was found that the, consumption of total energy requirement to make a product using open sun drying technology and solar dryer technology respectively, varied. This energy difference is due to the unutilized solar thermal potential in the fish drying process in selected area.It was found through calculation that the quantity varied, for example according to the product Dry fish (Tuna), the total energy consumption under two technologies was 62.1MJ/kg and 55.9MJ/kg respectively. However, the numerical value depends on a number of factors like environmental condition, characteristics of fish, technology of capturing energy. Actually, the theoretical potential might be higher than the figures calculated above. But, the amount of energy that could be practically captured was calculated. Anyone using or trying to capture this unutilized energy for drying purposes will achieve substantial benefits. Actually, unutilized solar thermal potential was subject to study where all other external factors remained constant and only the drying technologies were varied. However environmental factors such as relative humidity speed of wind and ambient temperature variations are uncontrolled factors.

Table 5: Calculated Result of open sun drying

	Dry fish (Tuna)	Modives fish	Dry fish(small)keer aminn	Halmassa
Total energy requirement Per month(MJ)	17,517	12,339	42,072	131,160
Labour cost per month(Rs)	39,000	39,000	39,000	39,000
Total expenditure per month(Rs)	129,000	99,000	241,500	599,000
Total income per month(Rs)	173,100	168,000	262,500	747,500
net Profit per months	44,100	69,000	21,000	148,500
Throughput per month(kg)	282	168	750	2300

Table 6: Calculated Result of Dryer technology

	Dry fish(Tuna)	Modives fish	Dry fish (Small)	Halmessa
Total energy requirement Per month(MJ)	25,160	16,766	37,792	59,193
Labour cost per month(Rs)	13,000	7800	26,000	39,000
Total expenditure per month(Rs)	148,000	97,800	431,000	879,000
Total income per month(Rs)	232,650	252,000	525,000	1,121,250
net Profit per months	84,650	154,200	94,000	242,250
Throughput per month(kg)	450	300	1500	3450

Table 7: Result comparison of two technologies

	Dry fish	Modiven fish	Keeramin	Halmassa
Percentage of Energy decrease (%)	10	24	55	70
Percentage of increase Through put(%)	59.5	78.5	100	50
Percentage of time reduction (%)	30	38.5	50	33.3
Percentage of production cost decrease (%)	28.1	44.7	10.8	2.2
Percentage of Profit Increase (%)	20.3	25.2	123.6	8.8
Payback period(months)	2	2	1	1

V. DISCUSSION

Sri Lanka, being a tropical country, is host to massive quantity of solar energy annually. The unutilized solar thermal energy with respect to the selected product is between 6.1MJ/kg to 39.9MJ/kg. The reduction of production cost varies from 2.2% to 44.7% per month and detail shown in table 4.As a result average monthly profit increase 8.8% to 123.6% for selected items. In this achievement of the benefits above, the payback period on an investment, Rs 2, 75,000 on a solar dryer range from 1 month to 2 months for the selected product.

A further computed benefit of this process studies in the increase in the quantity of product rising in the range of 50% to 100% per month. Outcome of this project was the control of wastage in fish during harvest and the maximization of fish drying potential during the season. Another benefit of this process is saving in land area. In addition following comparative advantages can identified

Specific advantages of solar dryer

- Cost of energy is zero.
- Can be involve as a part time job
- Attention time is comparatively less
- Uniform drying no shrinkage

- Additional income and time saving
- Benefiting as apart time job and additional income
- Installation cost is low as most of the material can be easily sourced locally.
- Contamination levels of the dried fish are minimal
- The maintenance cost is minimal and it allows for faster drying compared to the conventional drying methods.
- The simple design
- Easy construction of the dryer using local workers
- Faster and easier adoption of the dryer
- Easy replication
- Material required can be easily sourced locally in almost any rural area.
- High durability- about 80% of the material used can last up to ten years.
- Can be replicated in diverse fisher community contexts.
- Installation cost is minimal.
- Maintenance cost is minimal.
- Drying time less than conventional method.
- Ensures a high quality hygienic product.
- Minimum labour requirement for construction and maintenance.
- Could easily be scaled up or down to suit individual needs.
- High consumer preference for dry fish processed using the dryer.
- No unpleasant flavours, tangs or offensive odours.
- Could potentially be used for dryer dehydrating fruits, vegetables.
- Less environmental impact.

VI. CONCLUSIONS AND RECOMMENDATIONS

The conclusion that can be arrived at, based on the utilization of solar thermal drying potential in Sri Lanka is, that utilized solar energy is not utilized for purposes of the fish drying industry in Sri Lanka. If this solar energy had been applied to the fish drying industry, it would be possible to derive economic benefits for similar industries running at a loss at present in this country. Cost invested (payback period) on solar dryer Rs.2,75,000/- could be recovered within two month .On the other hand, there is also the potential of increasing the volume of profit on industries running as viable concerns at present. According to the findings of this research, it can be seen that selected type of fish product which can be dried at profitable level.

A suitable technology must be used to capture available drying potential for the fish drying industry. However, in order to obtain the facility of drying technology, financial investment is necessary. The other very important barrier is lack of knowledge about this technology. The disadvantage of open sun drying methods are ,drying time is long, drying rate cannot controlled, and drying temperature cannot be controlled susceptibility to case hardening and nutritional change. In addition to contamination by dust and insect attack as a result, the quality of the product is not predictable. The objective of dryer technology has been to find good solution to the constraints above. But the facts remain is that most other drying technologies involved energy inputs. As such, cost of production had to rise. On the other hand, solar energy is available free, almost throughout the year. Therefore, solar drying technology was developed with the objective of minimizing fuel use and improves the product quality. One such technology is a solar dryer.

Solar driers, as well as the mechanized ones, help to increase the quality and output of dried fish. However, in developing countries like Sri Lanka, where fish drying is essentially an activity related to small-scale fisheries, mechanization is linked to ready availability of engine fuel or electrical energy, which small scale fisheries community difficult to afford such technologies without financial support of credit disbursement institute. The extension of solar drying technology is very important for the fish drying industry. This extension however is difficult in the absence of proper evaluation of engineering technology. Suggestions for extension are as follows

- Proper evaluation and experimentation of drying industries
- Front line worker well trained
- To fill the gap between fisheries community and extension agent
- Financial support to adopt new technology
- Create new market for quality drying product
- Attitude changing and awareness of target group.

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