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Original Article

Qualitative performance and economic analysis of low cost solar fish driers in Sub-Saharan Africa

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Abstract

Qualitative performance and economic analysis of five low cost solar driers were evaluated at the Zoology and Physics Laboratories of the University of Ilorin, Ilorin, Nigeria. The solar driers were constructed from mosquito net, plastic, aluminum and glass with black stone inserted in it. The driers were found to be better than the other driers because they are cheap, reliable, safe to use, easy to repair, well insulated, and cost effective. The solar driers are compact, efficient with drying of fish with lowest moisture content achieved within a few days and the dried products of good quality, with long shelf life, highly acceptable to consumers. The driers save man-hour, money, use renewable energy, with no operational or maintenance costs. The driers have a long life span, with net income to fisher folks very high and the payback time for the driers very low. The adoption of the driers will contribute to the economy of rural populace in the developing countries where there is no electricity and the challenges of deforestation are becoming prominent. The improved low cost solar driers will ensure food safety and security and assist in combating climate change resulting from burning of wood and fossil fuel.

Keywords: Solar drier, fish drier, smoking kiln, electric oven, qualitative performance, Sub-Saharan Africa, economic analysis

INTRODUCTION

Low cost solar driers for fish drying and preservation has been developed, tried and in use in many developing countries of the world such as India, Bangladesh, Nepal, Zambia, Nigeria, Ghana and so on. The benefits and advantages of using these low cost solar driers for drying fish against the traditional and modern methods are numerous and have been highlighted by many workers such as Bala and Hossain (2012) and Mustapha *et al.* (2014a).

The performance and cost benefit of some of these low cost driers have also been evaluated. For example, Soda and Ram (1994) and Grupp *et al.* (1995) compared and evaluated the performance of different solar driers, while Fuller (1995), and Ekechukwu and Norton (1999) reviewed many solar driers and compared their performance and applicability in rural areas. Imre (2004) described in detail the construction principles of solar dryers along with their economics and performance evaluation. Ajang *et al.* (2010) analyzed the cost benefit of using *Chorkor* which is an improved smoking kiln and traditional smoking kilns for fish processing in Nigeria, Chavan *et al.* (2011) evaluated the cost of drying of Mackerel by solar funnel dryer, Weiss and Buchinger (2001), Crapiste and Rostein (1997), Green and Shwarz (2001) also highlighted the cost of solar fish driers in various countries of the world. Visvale (2012) showed cost for solar drying of Bombay duck in India; Sengar *et al.* (2009) compared the economic cost of low cost solar driers for fish with mechanical drying while Rahman *et al.* (2012) analyzed the benefit-cost ration of using three different low cost fish dryers in Bangladesh. Palaniappan and Subranaian (1998), Purohit and Kandpal (2005) and Purohit *et al.* (2006) evaluated the financial implications of solar drying systems. Purohit *et al.* (2006) looked at the benefit and cost of solar drying over sun drying. Kiebling (1996) listed 66 different solar driers, their configurations, capacity, products dried and cost and Kumar *et al.* (2002) proposed a detailed evaluation for testing the performance of solar food dryers.

According to Kumar *et al.* (2002), evaluating the performance of a dryer is necessary in order to provide a basis for comparison with other dryers. This will help in improving and selecting appropriate dryers for a particular food, climatic region and condition, adaptability and other factors such as highlighted in this paper.

Cost-benefit analysis of solar driers will depend on the size, materials for construction, efficiency, operation, sophistication and sustainability of the driers which vary from countries to country. Thus, it is imperative to analyze the cost-benefit of the solar driers before its adoption for use. This is in order to compare the cost and benefits with other means of drying such as open sun, smoking kiln, and electric oven in order to select the most economical one without compromising the quality and shelve life of the final product. Sreekumar (2010) opined that economic analysis on a solar dryer should also be incorporating the cost benefits.

Standard test procedures for evaluating the performance of solar dryers are not available (Soda and Ram 1994). This is due to dryer design, construction materials, operating conditions, consumer preference, quality interpretations as well as economic consideration, availability and other factors highlighted in this paper.

The aim of this paper is to therefore to evaluate qualitative performance and cost-benefit of five different low cost small scale solar driers developed for drying fish and comparing them with the traditional open sun drying, smoking kiln and the electric oven used in sub-Saharan Africa. This comparison is based on qualitative assessment and evaluation of the performance, economic cost, benefits of the solar driers to low-income fisher folks and rural people and not on the quantitative or engineering evaluation of the driers. Thus, the paper is devoid of mathematical equations relating to the driers performance and cost analysis.

METHODOLOGY

The five different low cost solar fish driers were constructed at the Physics department of the University of Ilorin, Ilorin, Nigeria. The qualitative performance evaluation and cost benefit of the driers over open sun drying, smoking kiln and electric oven were also evaluated for a period of 14 days.

Description of the driers: Five different solar driers with a square size of 2x2ft were constructed from inexpensive and readily available materials and used for drying of two fish species. Inside the driers were placed a wooden stand having a dimension of 1.5x1.5x0.5ft (length, width and height), and a 1.7x1.7ft wire mesh in which the fish species were placed was put on top of the stand. The solar driers were: (1) Plastic drier: This was constructed using a thermopile plastic material; (2) Mosquito net dryer: This was constructed by using plywood for the frame (edges). The drier was subsequently covered with mosquito net all around the wooden frame; (3) Glass drier: This was made of transparent glass; (4) Aluminum drier:This was constructed from aluminum sheet. The drier was however coated both inside and outside with black paint; (5) Glass drier containing black stones: This is similar to the glass drier in every respect but with a black (igneous rock) stone placed in it; (6) A direct open sun drying: The fish species were placed on a 2x2ft steel plate. The steel plate was placed on top of a wooden stand and exposed directly to the sun. The open sun drying was not enclosed. All the solar driers including the open sun drying were placed at the top of a story building where there was no obstruction to sun rays and facing the direction of the prevailing wind.

A smoking kiln constructed from steel drum with firewood as the source of energy and an electric oven were also used in drying the fish samples in order to compare the qualitative assessment and evaluation of the performance, economic cost and benefits of the solar driers for drying fish.

Qualitative performance evaluation and cost benefit analysis of the solar driers were evaluated through the data analyses of the materials used for their construction, cost of drying 10 kg of fish samples, maintenance and operation, time of drying the samples, moisture contents and organoleptic assessment of the final dried samples (Mustapha *et al.* 2014b).

RESULTS AND DISCUSSIONS

The shape and size of the driers are compact and durable, thus giving it great mobility, reliability, stability, with ease of handling and installation. Though the size and shape of the dryers as described are small, the tray area can accommodate 20 kg of fish with ease of loading irrespective of the number of fish loaded. In addition, the size and shape of the driers could be increased and modified to accommodate higher number and weight of fish. These confer advantages over smoking kiln and electric oven which are not easily moved and installed except certain requirements like clay mold for the kiln and electricity for the oven are put in place.

The final dried products from the driers are highly acceptable to consumers (Mustapha *et al.* 2014a). Various organoleptic properties of the dried fish were used to assess the quality and shelf life of the dried fish samples and the quality and the shelve life of the dried fish products from the driers were very high (Mustapha *et al*. 2014a). The dried products are hygienic with no incidence of microbes/insect/rodent infestation. The products are protected from filtness and wetness and nutritional quality of the products are enhanced. The market value of the fish products was high. This is because the fish have very good flavor, odor, appearance, texture, palatability and shelf-life. Wood used in smoking kiln burns inefficiently and produces noxious gases that could hinder the nutrient quality of the fish and causes health hazard to the person drying the fish and consumers (Yola and Timothy 2012).

The solar driers were found to be efficient in the drying of fish species with significant moisture reduction in *Clarias gariepinus* (a fatty fish) and *Oreochromis niloticus* (a lean fish) (Mustapha *et al.* 2014a). There is a natural regulation of the temperatures in the driers which unlike the smoking kiln there is no control over the temperature of the fire smoke and also labor intensive. The efficiency of the driers was high and compared well with smoking kiln and electric oven which require non-renewable energy sources. The solar driers use solar energy, does not pollute the environment or increase greenhouse gas emissions and constitute environmental hazards, thus it is environmental friendly, unlike smoking kiln.

The driers save man-hour, energy and money. Labor required during drying is very low and there is no socio-economic impact of the drying or the driers on the people and the community. No operational cost is involved since the driers use solar energy which is available free, renewable and highly abundant especially in sub-Sahara Africa. Unlike smoking kiln and electric oven, no technical know-how or operational skill is required to operate the solar driers. The driers are safe to use without the fear of being electrocuted or burnt.

Although the time of drying of fish using the dryer is relatively longer compared to smoking kiln and electric oven (Mustapha *et al.* 2014b), but when other parameters highlighted in Table 3 for evaluating the performance of the driers are taken into consideration, it will be seen that time taken for drying is insignificant thereby making the drier better than the smoking kiln and electric oven. The higher drying temperatures of electric oven and smoking kiln which dry faster, might also damage the organoleptic properties of fish. A high drying temperature has been reported to result in more heat loss leading to reduction in system efficiency (Kumar *et al.* 2002).

The efficiency of a solar dryer is a measure of how effectively the solar radiation to the system is used to dry the product and evaluate its performance (Mastekbayewa *et al.* 1998, Rakwichian *et al.* 1998). The driers except mosquito have very low radiation and heat losses and well insulated, but smoking kiln produced the highest radiation and heat losses and not insulated.

Construction and maintenance cost for the solar driers are very low (Table 1) and the life span is estimated to range between 8-10 years depending on the frequency of use, materials used for construction and maintenance. The driers are also easy to repair in case of damage unlike electric oven. Use of the driers does not involve technical know-how or operational difficulty. The driers can be used by anybody unlike smoking kiln and electric oven which require skills, technical knowledge and literacy to operate.

Table 1: Fixed cost of the solar driers, smoking kiln and electric oven; materials and cost of production

Serial	*Dryer type and components*	*Cost (₦)*
1.	**Open sun drying**	
	Steel plate (1mm)	400
	Wood stand	200
	Labor for construction	200
	Total	*800*
2.	**Mosquito net dryer**	
	Plywood	600
	Mosquito net	100
	Hinges (pair)	100
	Glue and nails	200
	Labor for construction	500
	Wooden stand	200
	Wire mesh (fish tray)	100
	Total	*1800*
3.	**Plastic drier**	
	Thermoplastic	1000
	Silicone gum	200
	Labor for construction	800
	Wooden stand	200
	Wire mesh (fish tray)	100
	Total	*2300*
4.	**Aluminum drier**	
	Aluminum sheet	1200
	Silicone adhesives	200
	Black paint (1 liter)	200
	Wood stand	200
	Wire mesh (fish tray)	100
	Labor for construction	800
	Total	*2700*

Table 1: Continued.

Serial	*Dryer type and components*	*Cost (₦)*
5.	**Glass drier**	
	Transparent glass (4mm) thick	1500
	Silicone gum sealant	500
	Wood stand	200
	Wire mesh	100
	Labor for construction	1000
	Total	*3300*
6.	**Glass drier with black stone**	
	Transparent glass (4mm) thick	1500
	Silicone gum	500
	Wood stand	200
	Black igneous rocks	100
	Wire mesh (fish tray)	100
	Labor for construction	1000
	Total	*3400*
7.	**Smoking Kiln**	
	Metal drum of galvanized iron sheet	4000
	Wire mesh (fish tray)	500
	Labor for construction	1500
	Total	*6000*
8.	**Electric Oven**	
	Price of the oven	20, 000

₦ = Nigerian Naira; ₦160 = $1

The cost of drying 10 kg of fish with the solar driers was found to be cheaper than smoking kiln and electric oven (Table 2). This is so because many factors that interplay in drying with electric oven and smoking are absent in solar drying. Due to cheaper cost of drying, the net income arising from drying 10 kg of fish in the driers was higher than oven and smoking kiln. This is coupled with the high market value of the solar dried fish. Thus, the issue of payback which is the measure of time (days/months/years) it will take to pay back the cost (fixed cost) of getting the driers may not necessary be a problem to the fisher folks considering the high net income within their life span in spite of their frequent usage, simplicity, affordability and low-cost of these solar driers. According to Sreekumar (2010), economic analysis on a solar dryer should also be incorporating the cost benefits. Because of the simplicity, affordability and low-cost of these solar driers, the issue of payback period for farmers is very low or sometimes may not be necessary as an average fisherman will be able to afford the solar driers. The low cost solar driers described in this paper are better than the traditional open sun drying, smoking kiln and electric oven on the account of being cheap and cost effective and posses many of the good attributes of an effective solar drier as highlighted in Table 3. It should however be noted that no single solar dryer could meet 100% all the evaluation procedures.

Table 2: Cost estimate of drying 10kg of fish species using the solar driers, open sun drying, smoking kiln and electric oven.

Cost Variables	**Open**	**Mosquito**	**Plastic**	**Aluminum**	**Glass**	**Glass + stone**	**Smoking kiln**	**Electric oven**
No of fish dried	15	15	15	15	15	15	15	15
Weight of fish dried (Kg)	10	10	10	10	10	10	10	10
Cost of fish (CF) (₦)	7500	7500	7500	7500	7500	7500	7500	7500
Labor cost of drying (LC) (₦)	0	0	0	0	0	0	1000	0
Operational cost of drying (OC) (solar/wood/electricity) (₦)	0	0	0	0	0	0	1000	3000
Market value of dried fish (MV) (₦)	10500	12000	13500	15000	15000	15000	16500	17500
Net income from drying = MV-CF-LC-OC (₦)	3000	4500	6000	7500	7500	7500	7000	70000
Cost benefit ratio	3:1	2.5:1	3.3:1	4.1:1	4.4:1	4.5:1	2.1:1	1.5:1

These solar driers are easy to construct, affordable (very low fixed cost) to the low income people, efficient, viable, economical and the materials used for the construction are made from simple, inexpensive, non-corrosive, toxic, flammable, rusty, and shock-proof, recyclable and degradable (after a long shelve life), locally available and affordable materials with the driers adaptable to the local conditions. The driers are light weight, occupy less space, can be used everywhere (home and on the farms), easy to maintain and operated, long lasting, saves man hour in terms of operation and does not require any special skill to operate, use renewable energy thereby impacting positively on the environment by reducing deforestation, greenhouse gas emission, air and water pollution, climate change and biodiversity decimation.

CONCLUSION

The driers dry quickly with the products very hygienic, showed no negative effects on the nutritional qualities, showed no detrimental socio, economic and environmental effects as well as health risks on the products and end users highly acceptable to consumers and the net income of drying is high. The adoption of the driers will contribute significantly to the economy of rural populace in the developing countries of sub-Saharan Africa where there is no electricity and the challenges of deforestation are becoming prominent. The use of these improved low cost solar driers will not only ensure food safety and security for a population that is faced with hunger, but also assist in combating climate change on the account of global warming resulting from burning of wood and fossil fuel.

Table 3: Qualitative performance evaluation and cost benefits of the solar driers, open sun drying, smoking kiln and electric oven

Performance evaluation	***Open***	***Mosquito***	***Plastic***	***Aluminum***	***Glass***	***Glass + stone***	***Smoking kiln***	***Electric oven***
Moisture reduction in fish sample (%)	69.46	69.48	69.51	70.69	69.98	71.25	69.54	75.20
Drying rate/efficiency	Low	High	High	High	High	Very high	High	Very high
Maximum capacity (kg)	50	20	20	20	20	20	40	30
Drying time for 10kg of fish	12 days	9 days	10 days	7 days	7 days	6 days	1 day	3 hours
Quality of dried products	Low	High	High	High	High	High	High	High
Radiation losses	Very high	High	Low	Low	Low	Very low	High	Very low
Heat losses	Very high	High	Low	Low	Low	Very low	High	Very low
Environmental pollution	None	None	None	None	None	None	High	None
Shelve life of dried fish	Short	Long	Long	Very long	Long	Very long	Long	Very long
Life span (years)	5	8	8	10	10	10	5	15
Safety	Very safe	Very safe	Very safe	Very safe	Very safe	Very safe	Not very safe	Not very safe
Installation cost	0	0	0	0	0	0	0	3000
Maintenance cost	Low	Low	Low	Low	Low	Low	High	Very high
Installation	Easy	Easy	Easy	Easy	Easy	Easy	Not so easy	Not so easy
Insulation	Bad	Good	Good	Good	Good	Good	Bad	Good
Repair	Easy	Easy	Easy	Easy	Easy	Easy	Not so easy	Not so easy
Technicality/operability	None	None	None	None	None	None	Yes	Yes
Durability/handling	Not durable but easy	Very durable and easy	Very durable and easy	Very durable and easy	Very durable and easy	Very durable and easy	Not durable and easy	Very durable and easy
Hygiene of products	Not hygienic	Very hygienic	Very hygienic	Very hygienic	Very hygienic	Very hygienic	Very hygienic	Very hygienic
Energy source	Solar	Solar	Solar	Solar	Solar	Solar	Wood	Electricity
Availability/local adaptability	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Affordability	Very high	High	High	High	High	High	High	Low
Reliability	Low	Not high	High	High	High	High	Not high	Low
Space	Less	Less	Less	Less	Less	Less	More	Less
Fixed cost of driers (₦)	1800	800	2300	2700	3300	3400	6000	20000
Operational cost of drying 10 kg of fish (₦)	0	0	0	0	0	0	1000	3000
Market value of dried fish (₦)	10500	12000	13500	15000	15000	15000	16500	17500
Net income (₦)	3000	4500	6000	7500	7500	7500	7000	7000
Pay back (month/s)	1	3	3	3	3	3	12	36
Cost benefit ratio	3:1	2.5:1	3.3:1	4.1:1	4.4:1	4.5:1	2.1:1	1.5:1

REFERENCES

Ajang RO, Ndome CB and Ingwe RU (2010) Cost-Benefit Analysis of Chorkor and Traditional Smoking Kilns for Fish Processing. Iranica Journal of Energy & Environment 1 (4): 339-346.

Bala BK and Hossain MA (2012) Solar drying of fishery products. In: Hii CL, Ong SP, Jangam SV and Mujumdar AS (eds.) Solar drying: fundamentals, applications and innovations. ISBN - 978-981-07-3336-0, National University of Singapore Press, Published in Singapore. pp. 95-110.

Crapiste GH and Rotstein E (1997) Design and performance evaluation of dryers. In: Valentas Kenneth J, Rotstein Enrique, Singh Paul, editors. Handbook of food engineering practice. New York: CRC Press. pp. 132-173.

Chavan B, Yakupitiyage RA and Kumar S (2011) Drying performance, quality characteristics, and financial evaluation of Indian Mackerel (*Rastrilliger kangurta*) dried by a solar tunnel dryer. Thammasat International Journal of Science and Technology 16: 11-25.

Ekechukwu OV and Norton B (1999) Review of solar-energy drying systems II: an overview of solar drying technology. Energy Conversion and Management 40: 615-655.

Fuller RJ (1995) A Review of Solar Drying of Fruit, Vegetables and Other Food Crops. Victorian Department of Agriculture Research Report Series, No 121, 49 pp.

Green MG and Schwarz D (2001) Solar drying technology for food preservation. GTZ publication Eschborn, Germany. 8 pp.

Grupp M, Hannelore B, Owen-Jones M and Gerd S (1995) Comparative tests of solar dryers. Technology Demonstration Center (TDC) Serial Report 2/95, Plataforma Solar de Almeria (PSA), Spain. 22 pp.

Imre L (2004) Solar drying, In: Mujumdar, A.S., (Ed.), Handbook of Industrial Drying, vol. 1. second edition, pp. 373-451.

Kiebling J (1996) Solare Trochner-Eine Tabellarische Ubersicht (in German), Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH, OE 402.2, Information and Advisory Service for Appropriate Technology (ISAT), Project Number: 88.2000.3-03-100.

Kumar S, Leon MA and Bhattacharya SC (2002) A comprehensive procedure for performance evaluation of solar food dryers. Renewable and Sustainable Energy Reviews 6: 367-393

Mastekbayeva GA, Leon MA and Kumar S (1998) Performance evaluation of a solar tunnel dryer for chilli drying. Paper presented at the Asean Seminar and Workshop on Solar Drying Technology, 3-5 June, Phitsanulok, Thailand, pp. 15-26.

Mustapha MK, Ajibola TB, Salako AF and Ademola SK (2014a) Solar drying and organoleptic characteristics of two tropical African fish species using improved low-cost solar driers. Food Science and Nutrition 2(3): 1-7. DOI: 10.1002/fsn3.101

Mustapha MK, Ajibola TB, Salako AF and Ademola SK (2014b) Proximate analysis of fish dried with solar driers. Italian Journal of Food Sciences 26(2): 1-5.

Palaniappan C, Subramanian SV (1998) Economics of solar air pre-heating in south Indian tea factories: a case study. Solar Energy 63: 31-37.

Purohit P and Kandpal TC (2005) Solar crop dryer for saving commercial fuels: a techno-economic evaluation. International Journal of Ambient Energy 26: 3-12.

Purohit P, Kumar A, and Kandpal CT (2006) Solar drying vs. open sun drying: A framework for financial evaluation. Solar Energy 80: 1568-1579. 10.1016/j.solener.2005.12.009

Rahman MJ, Karim E, Shahab Uddin M Zaher M and Haque MA (2012) Development of low-cost emergency fish dryer in Bangladesh to use in absence of sunlight. Bangladesh Research Publication Journal 7: 267-276.

Rakwichian W, Thadnium V, and Wiengmoon B (1998) Introduction to a solar dryer for the vegetable drying industry. Paper presented at the Asean Seminar and Workshop on Solar Drying Technology, 3–5 June, Phitsanulok, Thailand, pp 113-118.

Sengar SH, Khandetod YP and Mohod AG (2009) Low Cost Solar Drier for Fish. African Journal of Environmental Science and Technology 3(9): 265-271.

Soda MS and Ram C (1994) Solar drying systems and their testing procedures: a review. Energy Conversion and Management 35(3): 219-67.

Sreekumar A (2010) Techno-economic analysis of a roof-integrated solar air heating system for drying fruit and vegetables, Energy Conversion and Management 51: 2230-2238.

Visavale GL (2012) Principles, Classification and Selection of Solar Dryers. In Solar drying: Fundamentals, Applications and Innovations, Ed. Hii, C.L., Ong, S.P., Jangam, S.V. and Mujumdar, A.S., Published in Singapore, pp. 1-50.

Weiss W and Buchinger J (2012) Solar Drying. AEE INTEC Publication, A-8200 Gleisdorf, Feldgasse 19, Austria. 110 pp.

Yola IA and Timothy O (2012) Proximate composition and consumer acceptability of African mudfish *Clarias gariepinus* smoked with two energy sources. Bayero Journal of Pure and Applied Sciences 5(2): 115-118.