Tatari Ali Journal,
Volume 2, Issue 1, 2024. Pp. 165 – 175
ISSN - Online: 2006-6427
https://tatarialijournal.com

Received: date: 28th March, 2024
Revised: date: 26th April, 2024
Accepted: date: 28th April, 2024
Published: date: 30th May, 2024

Performance Evaluation of a Mixed-Mode Active Solar Fish Dryer

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Abstract

The goal of the project was to create an active solar dryer with mixed modes for preserving fish. The dryer is referred to as being in mixed mode because heated air from a separate solar collector is sent to the drying chamber while direct solar radiation heats the drying cabinet through the cover. This indicates that the temperature of the surrounding air, the drying cabinet, and The temperature range of the heat absorber was 32–35 °C, 75 °C, and 90 °C, in that order. Additionally, it was noted that the mean value variation of fish samples for A, B, C, D, and E, respectively, was 245–343.

Key: Solar radiation, mixed-mode, ambient temperature, heat absorber temperature, drying cabinet temperature,

1. Introduction

The most significant power source that can be used for processing and preserving fish is solar energy. However, fish farming is now acknowledged as the greatest source of revenue for farmers, providing them with essential nutrients, vitamins, and proteins in addition to creating job opportunities. Fish has been a wholesome food supply that is frequently less expensive than meat, easy to preserve, and has lengthy shelf life. Because of this, a sizable section of the population now consumes fish, making it a staple food. As a result, campaigns to start fish production globally have been launched by both national and international organizations. However, some Nigerian species are now widely harvested, such as catfish, tilapia fish, and bonga (ethamoloso finbrits) and consumed by Nigeria experiences surplus during harvest season. The majority of commercial fish farmers lack reliable ice storage infrastructure, and another issue impeding their storage capacity is the lack of electricity. To keep it from spoiling, the daily or weekly fish is either sold fresh or smoked dried. However, the large landing of catfish and other fish captures in the commercial production during the harvest season is too much for traditional ovens and kilns with their small batch capacities and lengthy smoking and drying times. Additionally, fish produced in traditional ovens and kilns has on-even quality; they consume fuel inefficiently and can present health dangers associated to their use. Likewise, workers who rotate the fish continuously breathe in hazardous levels of smoke produced by the lack of a chimney or smoke barriers.

Around the world, there is a growing recognition that renewable energy sources can help fish farmers in developing nations become more productive (Waewsak *et al.*). One technology that is quickly gaining traction as an agricultural energy-saving measure is solar thermal technology. It is ready to use wind and other renewable energy sources. Due to its abundance, free nature, endless supply, lack of pollution, and nearly year-round availability (Akinola 1999; Akinola and Fapettu 2006). The goal of this research project is to assess the performance of a mixed mode active solar fish drier. These issues led to the construction of a mixed mode active solar dryer for fish preservation, but the dryer's effectiveness was not assessed after it was manufactured.

1. Problem statement

In general, the issues are related to the preservation of fish. Fish can be preserved in two ways: either by drying it to a safe storage moisture level or by keeping it moist in cold storage. The drying solution is the greatest option because the previous one is challenging and costly for developing nations. The drying solution has energy issues because to supply constraints for fossil fuels, smoke pollution, and worker health issues.

1.2 Goals and purposes

The issues this research aims to solve are how to dry fish in a smoke-free, dust-free atmosphere without any pollutants. and make the most of the free energy that comes from solar power sources.

1.2.1 Research purposes

This study set out to assess the effectiveness of an active, mixed-mode solar fish dyer.

1.2.2 Goals

To assess how the ambient temperature affects the active mixed mode solar fish dryer's performance.
To ascertain how a fish sample is affected by death temperature

1.4 Rational

One of the most popular methods of preservation employed by fish processors is smoke-drying. Traditionally, this kind of drying has been done in circular mud, long drum ovens, or even on galvanized iron sheets held up by planks. However, there are serious disadvantages to each of these methods. On the other hand, open sun drying has been shown to reduce the flavor and shorten the shelf life of fish products. Many obstacles in fish processing are addressed by the built-in active mixed-mode solar fish drier, including the requirement for continuous attention to manage the fire and rotate the fish to guarantee even drying, a significant risk to health and fire safety, the lack of control over the fire's temperature, and the density of smoke. uneven drying that leaves the fish's inside under-dried while scorching the outer fish. levels of air pollution brought on by inadequate ventilation.

1.5 Research gap

Numerous studies, including those using direct sun dryers, indirect dryers, and mixed mode dryers of various kinds, have been carried out at various research and educational institutions. Nevertheless, the power produced is insufficient to dry the fish quickly in the first place. Moreover, the majority of dryers created will not be suitable for commercial fish farmers.

2. Materials and method

2.1 Materials

Mature catfish that have just been harvested, the drying cabinet, an active solar collector, a thermometer, a digital weighing balance, a digital oven, and an EMF battery are among the items used to evaluate performance.

2.1.1 Cabinet drying

The drying cabinet shown in Plate 1 has two layers of drying trays. An output vent was added to the upper end of the dryer to help regulate the moisture inside the drying chamber and prevent the fish from getting wet again. The loading and unloading access door to the drying chamber is made up of two 13 cm-high detachable drawers that are lapped to retain heat while in use. Sawdust and asbestos lagged the cabinet's four opposing side walls, adding to its insulation against heat loss.

Plate 1 drying cabinet

2.1.2 The parabolic solar collector.

This contain a large reflecting surface (parabolic trough) that concentrate solar energy from a large area on to a relatively small absorbing area (heat absorber). Plate 2 below showed a complete assembled parabolic trough solar collector. The concentrating collector use only direct solar radiation and pointed towards the sun to keep the rays focused to the focal point which further sucked by DC pan to the air plenum of the drying cabinet. The parabolic trough (reflector) contained of mirror arranged in a geometric form to concentrate the sun rays on the focus which consists of heat absorber.

Plate 2: Parabolic trough solar collector with heater (absorber)

2.2 Method

2.2.1 Principle of operation

Plate 3 below shows an image of an active mixed-mode parabolic solar fish drier that has been fully built. The dryer is an active mixed mode system because heated solar energy is concentrated by a parabolic solar collector and absorbed by a black body air heater. The heated

air is then directed through a black-painted bed rock heat storage. Warm air rises, extracts moisture from the fish sample, and exits the drying chamber through the upper vent.

Plate 3: Active mixed mode parabolic trough dryer

2.2.2 Performance evaluation of active mixed- mode solar dryer.

The air temperature at the collector inlet, the drying chamber outlet, and the ambient temperature were measured using digital mercury bulb thermometers (accuracy 0.5 0C) in the laboratory at regular intervals of three hours between the hours of 8:00 am and 8:00 pm. These measurements were taken into consideration when performing the performance evaluation. Fish was placed inside the dryer, and its weight was recorded both at the beginning and every three hours after that. The weight loss was used to compute the moisture eliminated in kilograms per hour (Kg/h) while the fish dried, taking into account the beginning weight and the weight at a safe moisture content for preservation. The examination took into account the drying rate, or the amount of moisture extracted from the fish sample. The performance indicators that were pertinent were displayed below.

2.2.3 Determining the moisture content

It was done to vary the moisture content for various readings during the performance assessment. Based on the weight of water contained in the fish product, the amount of moisture in the product is expressed, typically as a percentage. Two techniques are used to identify moisture content.

Base of moisture content, wet: The mass of water in a product divided by the mass of the wet material is known as Mwb as presented in equation 1 below (Sahay and Singh, 2003).

$$M_{wb} = \frac{M_{db}(100)}{100 + \mathrm{M_{db}}} \quad (1)$$

Dry base moisture content: Mdb, which is stated as a percentage, is the mass of water in a product per unit mass of dry matter expressed mathematically in equation 2 below. The following equation in 2 describes the connection between Mdb and Mwb:

$$M_{db} = \frac{M_{wb}(100)}{100 - \mathrm{M_{wb}}} \quad (2)$$

The following formula in 3 was used to determine the initial moisture content (Ranganna 1986):

$$IMC,\ \%\ (d.b.) = \frac{W_2 - W_3}{W_3} \times 100 \qquad (3)$$

Where, IMC, % (db) = percentage initial moisture content dry basis, W_2 = Weight of fish sample before drying and W_3 = Weight of dried fish sample.

Equilibrium moisture content

When the weight constant changed, the final moisture content was regarded as the equilibrium moisture content (Pande et al., 2000, Jain et al., 2000, Olayanju 2014, and Adekunle et al., 2018).

Rate of drying

The average drying rate was calculated using the formula indicated in equation 4 below derived and evaluated by Tonui *et al.*, 20014, Mansehsh 2020.

$$D_r = \frac{M_w}{t_d} \qquad (4)$$

Where Dr is the drying rate, Mw is the mass of water removed from the material in kilograms, and t_d is the drying time in hour.

Drying efficiency

Drying efficiency is calculated as the product of the drying over fire multiplied by 100 and the dried fish sample obtained using an active mixed-mode solar fish dryer (Mesa 2020). The drying efficiency was assessed mathematically using the formula 5 below, which reads

$$DEf = \frac{Sdv}{Dof} \times 100 \qquad (5)$$

Where Dof is the drying over fire values, Sdv is the solar dryer value, and Def is the solar drying efficiency.

3. Result and discussions

3.1 Average temperature of the drying cabinet, heat absorber and surrounding air. Figure 3.1 below shows the average value of the drying cabinet, heat absorber, and ambient temperature. The results showed that at the 2:00 pm drying interval, the highest temperatures for the ambient, heat absorber, and drying cabinet were 42.^{0}C, 87.^{0}C, and 96.^{0}C. Although the minimum mean temperature during the 8:00 pm drying time was, respectively, 30 ^{0}C, 34 ^{0}C, and 49 0C, these values are consistent with the findings of Akinola (2005).

For the majority of the daylight hours, the temperature within the drying cabinet and heat absorber was significantly higher than the surrounding air. Figure 3.1 shows that for almost three hours right after 11:00 am, the temperature inside the drying cabinet rose by 54 ^{0}C, which suggests that this method may perform better than open-air solar drying.

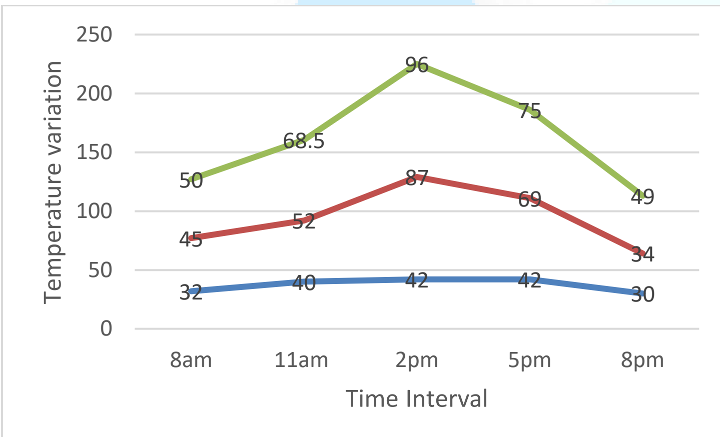
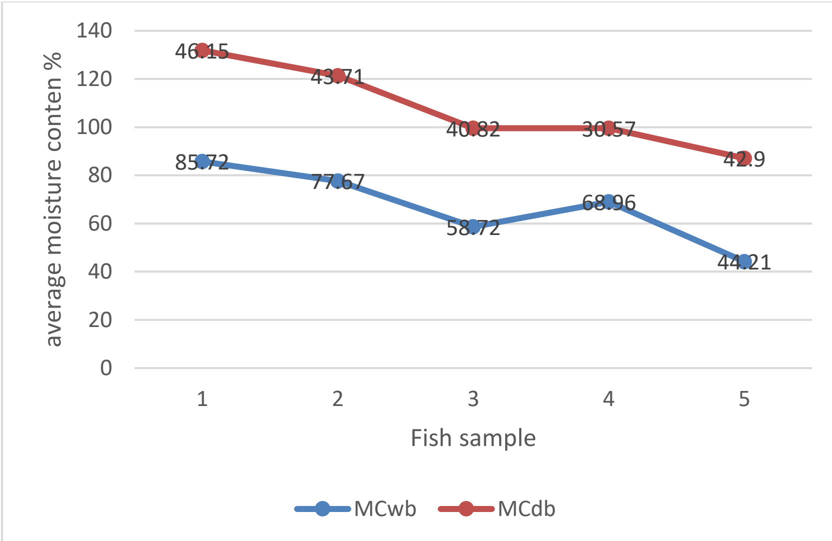


Figure 3.1 Average temperature of the drying cabinet, heat absorber, and surrounding air.

3.2 Average moisture content values on wet and dry basis of samples

Figure 3.2 presented the average moisture content wet dry basis values of five fish samples at a particular drying intervals. From the result, it indicated that for wet basis, sample a has the corresponding values of 85.72 %, 77.62 %, 68.72 %, 68.72 % and 44.20 % for samples ABCD and E respectively. While dry basis result respectively 46 %, 43 %, 40 %, 30 % and 42 % for five fish samples ABCD and E. This agrees with work of Adekunle 2018.



3.3 Average drying rate value

For days one, two, and three, the drying rates were determined to be 11.048 g/h, 5.033 g/h, and 1.1 g/h, respectively. The drying rate was shown to increase in response to temperature between 11:00 am and 2:00 pm, but to decrease after that. This indicates that the fish's moisture content was removed earlier and more quickly, which is consistent with the findings of Sengar *et al.*, (2009).

The three drying days yielded an average drying temperature of 71 ^{0}C, compared to the recommended 90–105 ^{0}C for drying fish for human consumption. The average mean drying temperature for each day was 69.1, 69.8, and 74.5.

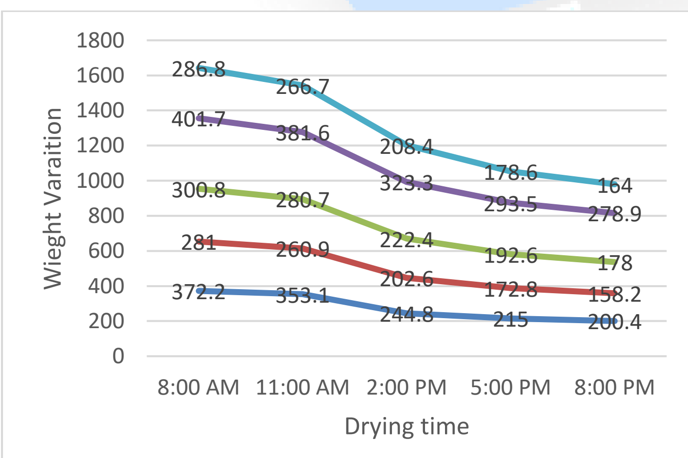


Figure 3.2 Result average drying rate value

3.3 Fish sample effects of drying cabinet temperature and drying rate

The results of the analysis of variance are shown in figure 3.1 below. The hypothesis testing the effect of drying interval (time) was successful, and there is strong evidence that the drying intervals had distinct effects on the fish samples, as indicated by the F value 118.58 being greater than the 3.01. According to Adekunle *et al.,* (2018), the results of the test conducted to determine the impact of the dryer on the fish sample also showed that there was no indication of a significant difference between any of the five fish samples. This is because 3.01 is more than 0.8367.

Table 3.1 Analysis of variance result on the effect of drying cabinet on temperature, drying rate on fish sample

Source of variation	Degree of freedom	Sum of squares	Mean squares	F-value calculated	F-value tabulated at 0.05
Treatment	4	69744.36	17436.09	118.58NS	3.01
Block	4	50801.96	12700.49	08637 **	
Error	16	2352.64	147.04		
Total	24				

NS is not significant, ** Highly significant

4. Conclusion and recommendation.

4.1 Conclusion

The performance of active mixed-mode parabolic solar fish dryer was evaluated. The equipment is suitable for small scale farmers to use for fish drying because it possesses sufficient heat to dry fish rapidly. The temperature inside the cabinet and air heat were much higher than the ambient temperature during most of the hours of the daylight. The temperature inside the drying as solar.

4.2 Recommendations

It is recommended that additional research be done in order to modify the solar panel and inverter to store solar energy for drying even at night when there is no solar retardation. Additionally, since these items are not readily available in the local market, durable reflective material and thermostats for temperature regulation should be sought out.

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