Pak. J. Sci. Ind. Res. 2009 **52** (4) 228-230

Development of a Solar Fish Dryer

Adenike Boyo[a]* and Henry Boyo[b]
[a]Physics Department, Lagos State University, Ojo, Lagos, Nigeria
[b]Physics Department, University of Lagos, Akoka, Lagos, Nigeria

(received June 11, 2008; revised March 13, 2009; accepted April 6, 2009)

Abstract. The solar fish dryer developed for particular conditions of Bishop Village, Lagos, Nigeria absorbs sunlight with a flat plate collector for its air heater. Mirrors are appended to one of the collector sides to enhance collection of solar radiations. The dryer is a passive type, tailored to solve the energy needs of the people of the area. On days of high irradiance, temperature within the solar fish dryer can be as high as 80°C with relative humidity around 10%.

Keywords: renewable energy, flat plate collector, solar fish dryer, fish drying

Introduction

Principal profession of the male population of Bishop village of Lagos, Nigeria, is catching fish whereas local females work on its drying. The chief method commonly employed for fish preservation at the Bishop village is the smoke drying whereas on a small scale, fish is dried openly in the sun. In the absence of electric power, the local population did not have access to other means of food preservation such as refrigeration, freezing or any other method that requires electricity.

Sun drying in open air exposes seafood to contamination such as dust, flies, insects, birds etc., while the smoke drying technique can roast or scorch the fish. Protein and vitamin losses become a major concern at elevated temperatures (above 90 °C) at which fish is dried. The smoke drying method depends heavily on wood as fuel, a valuable commodity that can be utilized in building huts and canoes; smoke also pollutes the environment.

The solar fish dryer presently developed is powered by solar energy and requires minimum labour. Apart from the initial investment, the maintenance cost of the solar fish dryer is negligible. Fish is kept in an enclosure during drying process and is safe from contamination; it can be dried completely in a day under optimum sunshine conditions. The women of village, by employing this technique, can produce better-dried fish of improved quality, thus bringing in its better monetary value. Principally made for drying the fish, the dryer can be used for drying vegetables and other related foods, as well.

Principle involved. Food preservation is based on the removal of moisture from foods upto the level at which it cannot support the growth of microorganisms and, hence, stops spoilage of food (Desrosier and Desrosier, 1987). In the developed solar fish dryer, solar energy is employed to heat the air that passes through the drying chamber and removes moisture from the fish along its convective path (Boyo, 2001).

Construction of solar fish dryer. Figure 1 shows essential features of the solar fish dryer. It is composed of a flat plate collector "C" (Ikejiofor, 1985; Sayigh, 1979) for air heating, a drying chamber "D" and mirrors A and B. The drying chamber is made of hard wood in the form of a stool which stands 80 cm above the ground. The base of the drying chamber is lined with blackened aluminium to absorb radiations and also to protect the wooden frame of the chamber from fish oil drippings when the dryer is in use. The outlets at the drying chamber are regulated in such a way that proper temperature for fish drying is attained (below 80° C). Mirrors 'A' and 'B' are put in place to converge sun rays towards collector plate and drying chamber "D".

The dryer can be positioned in such a way that its mirrors 'A' and 'B' face southward, so that while the sun traverses its path (east to west), it can function without human involvement. Otherwise it would be cumbersome to reorient the mirrors for receiving direct sunlight.

Collector plate "C", placed at a tilt angle of 40° relative to horizontal, allows the hot air flow into the drying chamber "D" *via* convective air drift, reducing humidity within the drying chamber (by the replacement of wet cool air through inflow of dry hotter air); it thus accelerates evaporation of moisture from surface of the fish. A fraction of heat is transferred from hot air to fish, which increases its temperature and helps in migration of moisture to the surface of fish.

The factors that enhance drying speed include:

1. High temperature
2. Low relative humidity

---

* Author for correspondence; E-mail: nikeboyo@yahoo.com

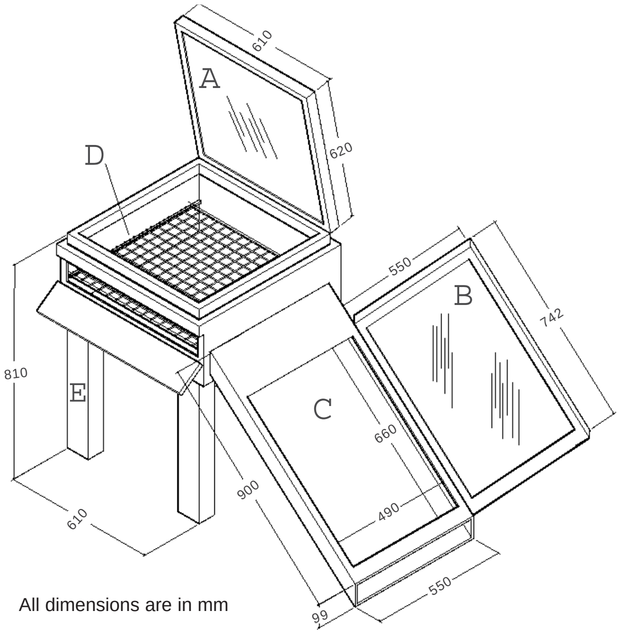

Fig. 1. Essential features of the solar fish dryer.

3. High wind speed
4. High porosity of the food
5. Large surface area to volume ratio of food

Attainable temperature analysis. The temperature inside the dryer does not increase indefinitely even when it is continuously supplied with energy by the sun at its best collector's tilt.

The energy analysis of the heating chamber is discussed herein. The heating chamber is a flat plate collector having a glass glazing and within it is a blackened aluminum sheet that serves as absorber.

Let:

Q_{rad} : be the effective solar irradiance on collector absorber plate

C_{ap} : heat capacity of the absorber plate.

T_{ap} : mean temperature of the absorber plate and

T_o : the ambient temperature.

Q_L : represents all the heat taken away from the absorber plate either by the air (it is supposed to heat) or the loss mechanisms at the collector in particular.

Q_{rad} and C_{ap} are constants.

The energy balance equation for the system takes the form:

$$Q_{rad} = C_{ap}\left(\frac{dT_{ap}}{dt}\right) + Q_L \tag{1}$$

Experimental work by Sayigh (1979) showed agreement with what was expected, that is:

Q_L generally increases with the increasing difference (T_{ap}-T_o). Q_L is taken to depend on (T_{ap}-T_o) alone and with that, the second term in the Taylor's expansion of Q_L is $k(T_{ap}$-$T_o)$ which will be taken to approximate Q_L in our case.

$Q_L = k(T_{ap}$-$T_o)$ substituted into equation (**1**), gives,

(2)

Equation (2) can be rewritten as:

$$\frac{dT_{ap}}{dt} = \frac{[Q_{rad} - k(T_{ap} - T_0)]}{C_{ap}} \tag{3}$$

The solution of equation (3) is,

$$T_{ap} = \left(\frac{Q_{rad}}{k}\right)\left[1 - \exp\left(-\frac{k}{C_{ap}}\right)\right] + T_0 \tag{4}$$

From equation (4), one can draw the conclusion that plate temperature has an upper limit, $T_{ap} = \frac{Q_{rad}}{k} + T_o$, determined by the irradiance on the plate, the energy transfer rate from the plate to the air (the rate of useful air heating) and various losses (due to imperfect insulation etc).

Higher order terms in the Taylor's expansion for Q_{rad} would only reduce the steady state temperature T_{ap}. Since the air temperature from the collector would not exceed that of the absorber plate (if this indeed is the air heater), then with proper designing one can create the heating chamber of the dryer so that the temperature does not exceed particular values.

Q_{rad}

Maximum attainable temperature for the developed dryer was set to about 80 °C as required for fish drying so as to avoid over- cooking.

Results and Discussion

The data collected for the dryer, while drying fish at the Bishop village on the 6th of May 2006, (Fig. 2) was obtained with an autolog temperature and humidity sensor (RH-02) made by Pico Technology. This was set to sample data every 3 min. From the graph, temperature within the dryer was about 40 ºC above the ambient one at about 4:30 pm. It can be seen from the graph that the environment of Bishop Village has ambient humidity of approx 70% during the day. Thus, open sun drying would occur at a comparatively much slower rate in this place.

The average humidity inside the dryer between 12:30 pm and 5:30 pm was around 25%, which shows a relatively well-improved environment for drying compared to its surroundings.

It was observed that 50 ºC temperature was good enough for the initial drying of fish which was then gradually increased to 80 ºC to avoid cake-layer formation of the outer tissues.

At about 3:20 p.m., the dryer was momentarily opened (for about 3 min to check the dryness of the fish) causing the humidity to jump to about 54%. It is suggested that in the design of dryer, some arrangement for energy storage like coal or granite stones may be provided to preserve the heat inside the chamber especially during cloud cover (Boyo, 2003).

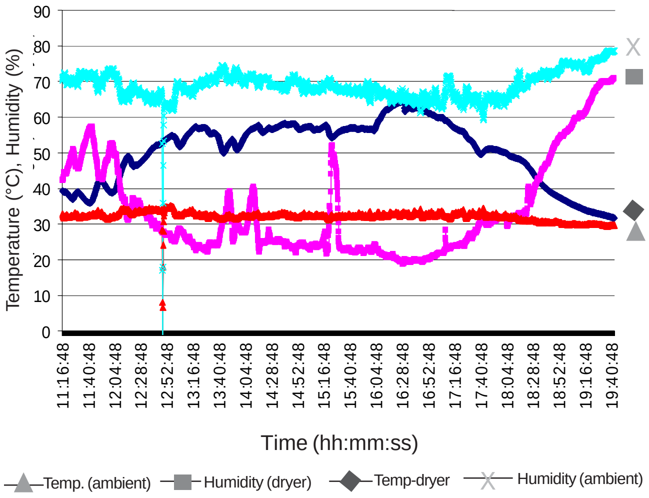

Fig. 2. Temperature and humidity profile inside and outside dryer during fairly clear sky on 6th June 2006.

The drying time required to dry any type of fish depends on the extent of dryness to be achieved. On a reasonably sunny day, when the dryer operates close to 80 ºC with humidity within 10%–30%, moisture content of thin slices of 2 kg of fish may be reduced by 76%. For thick slices, the problem of case hardening may occur which sets in when food is dried too rapidly. For the solution of this problem, common practice is to salt the fish so as to build up osmotic pressure that will encourage the diffusion of water onto the surface. A solar photovoltaic powered micro-controller will be incorporated in future design to regulate the temperature and humidity inside the dryer to suit specific products (Anyanwu, 2006).

Conclusion

The solar fish dryer, developed herein, provides optimum drying conditions for fish between 50 ºC to 80 ºC and humidity range of 10% to 30%. Under these conditions, the moisture content of about 2 kg of sliced fish was reduced by about 76% over a period of seven hours.

The solar fish dryer provides a convenient and hygienic way of drying the fish and is useful particularly for use in the Bishop Village, Nigeria. The wood (or coal) that would have been used for drying can now be spared for better utilization.

References

Anyanwu, A. 2006. Design and Construction of a User Friendly Universal Solar Food Dryer Using Programmable System on Chip. B. Sc. Thesis, Department of Physics. pp. 11-17, University of Lagos, Nigeria.

Boyo, A. O. 2003. Comparative efficiencies of different storage materials for solar collectors and their applications in solar drying. *Journal of Engineering Applications* **3:** 19-24.

Boyo, A.O. 2001. Solar radiation on inclined surfaces in Lagos, Nigeria. *The Nigerian Journal of Research And Review In Science*. **2:** 60-65.

Desrosier, N.W., Desrosier, J.N. 1987. *The Technology of Food Preservation*, 4th edition, CBS Publishers and Distributors, New Delhi, India.

Ikejiofor, I.D. 1985. Passive solar cabinet dryer for drying agricultural products. In: *Proceedings of the Workshop of the Physics and Technology of Solar Energy Conversion*. pp. 157-165, African Union of Physics, University of Ibadan, Nigeria.

Sayigh, A.A.M. 1979. The technology of flat plate collectors. In: *Solar Energy Conversion, An Introductory Course* 5th, pp. 101-124, University of Waterloo, Ontario, Canada August 6-19, 1978, Selected Lectures (A80-42435, 18-44) Pergamon Press, Toronto, Canada and New York, USA.