Development of a Solar Dryer for Drying Agricultural Products

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ABSTRACT
This paper describes a solar drying system that makes use of solar energy to heat air and dry any food substance that has been loaded into it. This system is effective in minimising agricultural product waste and aids in the preservation of agricultural products, among other things. Taking into consideration the drawbacks of natural sun drying, such as contact with direct sunlight, pest and rodent problems, lack of effective monitoring, and the increased high cost of the mechanical dryer, a solar system has been devised to address these issues. In this project, we will show you how to design and build a solar dryer system from scratch. The dryer is comprised of a solar collector (air warmer) and a solar drying chamber confining rack of three cloth (net) trays, which are both merged into a single structure. During the drying process, air is drawn into the drying chamber and heated by the solar collector. This heated air is directed through the drying chamber and used for drying purposes. The design was based on the geographical location, which was Edo State Polytechnic, the usen village in Ovia, in the south-eastern part of Edo state, and climatic data was acquired to ensure that the design specification was accurate. Wood, glass, aluminium metal sheet, copper, and net cloth for the trays were among the materials utilised in the construction, which was primarily made of locally available materials. The dryer operates at its most efficient temperature of 50.500 degrees Celsius, with an ambient temperature of 34.5^0 degrees Celsius. The solar dryer was successful in removing 43.2 percent and 40.6 percent of the moisture content from maize and plantain, respectively, as compared to 28.2 percent and 27.89 percent from maize and plantain using the sun drying method, indicating a difference of 15.0 percent and 12.71 percent, respectively. The rapid rate of drying in the dryer demonstrates its ability to dry food items reasonably quickly to a high degree of consistency, as compared to the sun drying method.

Keywords: Solar dryer, Moisture loss, Design and Construction, Maize and Plantain Solar Energy, Alternative Energy, Drier, Design and Fabrication

1.0 Introduction

Solar energy is now being utilised to dry a variety of food products, including grains, fruits, vegetables, fish, and meat, among others. On a farm, drying is one of the most energy-intensive operations to perform. The purpose of drying agricultural food is to remove moisture from it so that it can be handled safely and stored for longer periods of time without spoiling. The drying procedure increases the stability of non-timber forest products, medicinal plants, and aromatic plants, allowing for safe long-term storage. That is, storage conditions that eliminate the possibility of colour loss, the development of unwanted odours and tastes, unwanted chemical changes that degrade the product's suitability for further processing, the development of mould and microorganisms that cause the formation of toxic substances, and the development of harmful bacteria are eliminated.

1.1 Conventional solar drying

"Sun drying" is the oldest way of drying farm goods known to man, and it is as simple as laying the agricultural products out in the sun on mats or drying floors, allowing the products to dry naturally. There are several disadvantages to this method, including the fact that the farm produce is laid out in the open sky, increasing the risk of spoilage due to adverse climatic conditions such as rain, wind, moist, and dust, as well as the loss of produce to birds, insects, and rodents; being completely reliant on good weather; and having a very slow drying rate with the potential for mould growth, resulting in the deterioration and decomposition of the farm produce. The method also necessitates a vast amount of land and is quite labor-intensive.

Artificial mechanical drying became popular as a result of cultural and economic progress, however this technique is extremely energy consuming and expensive, which eventually increases the cost of the finished product. Recent efforts to improve "sun drying" have resulted in the development of "solar drying." Solar dryers are specialised machines used in solar drying that regulate the drying process and protect agricultural goods from being destroyed by insect pests, dust, and rain. While sun dryers produce higher temperatures and lower relative humidity than natural "open drying," they also produce a smaller moisture content in the product and less spoiling during the drying process. Furthermore, when compared to the artificial mechanical drying process, it takes up less space, requires less time, and is relatively inexpensive. For all of the disadvantages of natural drying as well as artificial mechanical drying, solar drying is a superior alternative approach to be considered. The solar dryer can be viewed as one of the solutions to the global food and energy problems and issues that we are currently experiencing. Most agricultural goods may be kept through drying, which can be accomplished more efficiently with the use of solar dryers. Solar dryers are becoming increasingly popular.

2.0 EXPERIMENTAL SETUP

The most commonly seen design types are of cabinet form, some types are even improved making use of cardboard boxes and transparent nylon or polythene. For the design being considered, the greenhouse effect and thermo siphon principles are the theoretical basis.

There is an air vent (or inlet) with guide ways to the solar collector where air enters and is heated up by the greenhouse effect, the hot air rises through the drying chamber passing through the trays and around the food, removing the moisture content and exits through the air vent (or outlet) near the top of the shadowed side

The hot air acts as the drying medium, it extracts and conveys the moisture from the farm product (or food) to the atmosphere under free (natural) convection, thus the system is a passive solar system and no mechanical device is required to control the intake of air into the dryer. "Here is an additional cabin for heat exchanging at the air exhaust door". "There is a lot of heat wastage at the air outlet, so to accomplish that here we have one heat exchanger and it consists of copper tubes for water heating system; there is a hole at the top side of the cabin for air outlet".

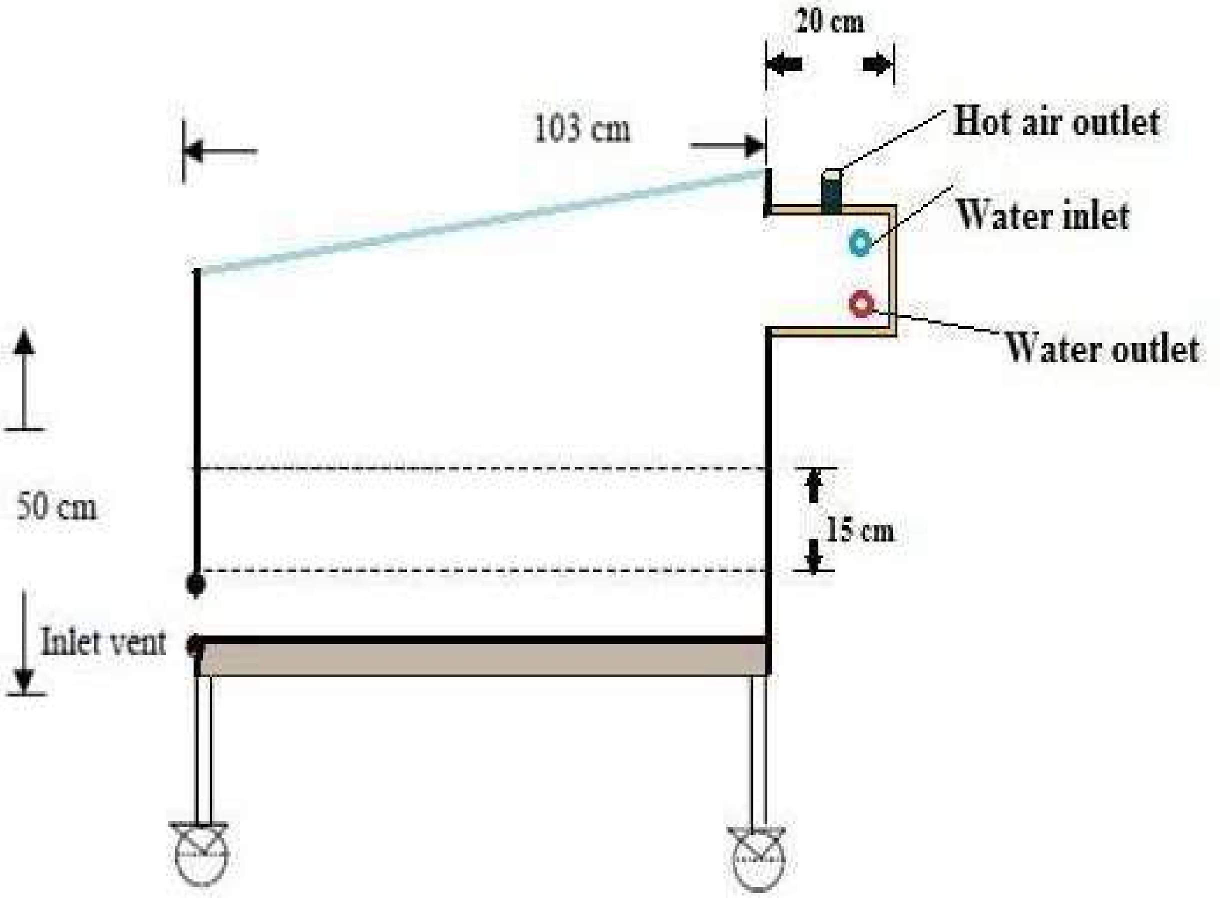
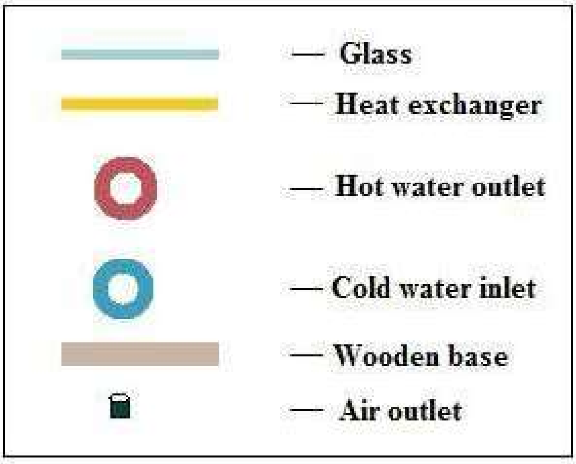


Fig: 2.0 Side view of the constructed solar dryer



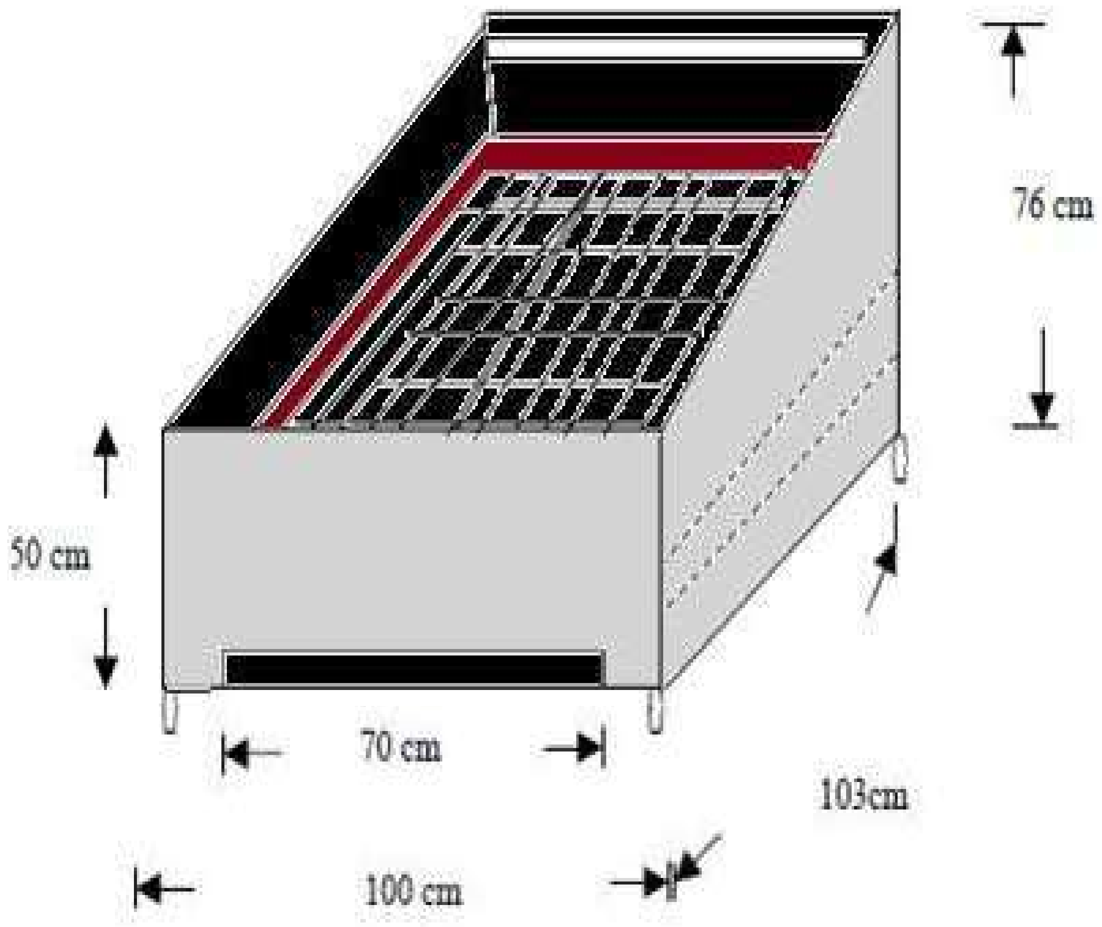


Fig: 2.1 Isometric view of the constructed solar dryer

3.0 Materials Used for fabrication of solar dryer: The following materials were used for the construction of the efficient solar dryer:

- Wood
- Glass
- *Galvanized* steel (GS).
- Nails and glue
- Hinges and handle
- Paint (black and grey)
- Copper tubes
- Mesh wire

 Wheels.

Fig: 3.1 Wood works

Fig: 3.2, Tray work

Fig: 3.3 Tray after painting

4.0 MATERIALS AND METHODOLOGY

Factors considered in selecting the engineering materials for the fabrication of the equipment were:

i. Cost of the fabrication.
ii. Mechanical properties of materials (e.g. stress, fatigue etc.).
iii. Corrosion resistance.
iv. Ease of fabrication (e.g. forming, nailing, bending, cutting etc.)
v. Service requirement.

Considerations were also given to the most economical materials that satisfy both Process and mechanical requirements, over the working life of the solar dryer, allowing for easy loosening, maintenance and replacement. Finally the selected materials to be used were ensured of having sufficient strength and easily worked with.

4.1 Method

Construction of the solar dryer

The materials used for the construction of the solar dryer are cheap and easily obtainable in the local market. The solar dryer consists of the solar collector (air heater), the drying cabinet and drying trays.

Solar Dryer Components

Drying Chamber: The drying chambers is a highly polished plywood box held in place by angle iron, the material has been chosen since wood is a poor conductor of heat and its smooth surface finish, heat loss by radiation is minimized.

Cover plate: This is a transparent sheet used to cover the absorber, thereby preventing dust and rain from coming in contact with the absorber, it also retards heat from escaping, common materials used for cover plates is a glass.

Absorber plate: This is a metal painted black and placed below the cover to absorb the incident solar radiation transmitted by cover, thereby heating the air between it and the cover; here aluminum is chosen because of its quick response in the absorption of solar radiation.

Insulation: This is used to minimize heat loss from the system, it is under the absorber plate, the insulator must be able to withstand stagnation temperature, it should be fire resistant and not subject to out-going gassing and should not be damageable by moisture or insect.

The Orientation of the Solar Collector:

The flat-plate solar collector is always tilted and oriented in such a way that it receives maximum solar radiation during the desired season of used. The best stationary orientation is due South in the northern hemisphere and due north in Southern hemisphere. Therefore, solar collector in this work is oriented facing south and tilted at 17.110 to the horizontal. This is approximately 100 more than the local geographical latitude (Usen community a location in Nigeria, 7.110N), which according to Adegoke and Bolaji (2000), is the best recommended orientation for stationary absorbers. This inclination is also to allow easy run off of water and enhance air circulation.

4.2 Design consideration:

1. Temperature

The minimum temperature for drying food is 30°C and the maximum temperature is 60°C, therefore. 45°C and above is considered average and normal for drying vegetables, fruits, roots and tuber crop chips, crop seeds and some other crops .

2. Design

The design was made for the optimum temperature for the dryer. T_0 of 60°C and the air inlet temperature or the ambient temperature T_1 = 30°C (approximately outdoor temperature).

3. Air gap

It is suggested that for hot climate passive solar dryers, a gap of 5 cm should be created as air vent (inlet) and air passage.

4. Glass or flat plate collector

It suggested that the glass covering should be 4m - 5 m thickness. In this work, 4mm thick transparent glass was used. It's also suggested that the metal sheet thickness should be of 0.8m – 1.0 m thickness; here a Galvanized steel of 1.0mm thickness was used. The glass used as cover for the collector was 103 × 100cm^2.

5. Dimension

It is recommended that a constant exchange of air and a roomy drying chamber should be attained in solar food dryer design, thus the design of the drying chamber was made as spacious as possible of average dimension of 100 ×103 × 76 cm^3 with air passage (air vent) out of the cabinet of 90 × 10cm^2. The drying chamber was roofed with glass of 100 × 103 cm^2. This is to keep the temperature within the drying chamber fairly constant due to the greenhouse effect of the glass.

6. Dryer Trays

$1cm^2$ Net was selected as the dryer screen or trays to aid air circulation within the drying chamber. Two trays were made having wooden edges. The tray dimension is 96 × 98 cm of 2.5cm × 2.5cm wooden sticks used as frame. The design of the dry chamber making use of GS sheet wall sides and a glass top (tilted) protects the food to be placed on the trays from direct sunlight since this is undesirable and tends to bleach colour, removes flavor and causes the food to dry unevenly.

DISCUSSION

An hourly variation of the temperatures in the solar collector and the drying cabinet compared to the ambient temperature. The dryer is hottest about mid-day when the sun is usually overhead. The temperatures inside the dryer and the solar collector were much higher than the ambient temperature during most hours of the daylight. The temperature rises inside drying cabinet for about three hours immediately after 12.00h (noon). This indicates prospect for better performance than open-air sun drying.

CONCLUSION

From the test carried out, the following conclusions were made. The solar dryer can raise the ambient air temperature to a considerable high value for increasing the drying rate of agricultural crops. The product inside the dryer requires less attentions, like attack of the product by rain or pest (both human and animals), compared with those in the open sun drying. Although the dryer was used to dry maize and plantain, it can be used to dry other crops like yams, cassava etc. There is ease in monitoring when compared to the natural sun drying technique. The capital cost involved in the construction of a solar dryer is much lower to that of a mechanical dryer. The collector and dryer efficiencies are very reasonable.

RECOMMENDATION

The performance of existing solar food dryers can still be improved upon especially in the aspect of reducing the drying time, and probably storage of heat energy within the system by increasing the size of the solar collector. Also, meteorological data should be readily available to users of solar products to ensure maximum efficiency and effectiveness of the system. Such information will probably guide a local farmer on when to dry his agricultural produce and when not to dry them.

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