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Design, Construction And Comparative Analysis Of A Metal Solar Dryer With Electric Kiln Dryer And Open Air Dryer In Drying Unripe Plantain (musa paradisiaca)

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ABSTRACT

Preserving fruits, vegetables, grains, and meat has been practiced in many parts of the world for thousands of years. Methods of preservation include: canning, freezing, pickling, curing (smoking or salting), and drying. In this work, a metal solar drying system was constructed which consists of two parts - solar collector and solar drying cabinet. The Solar collector is a translucent polycarbonate panel which absorbs solar radiation. The cabinet is divided into 3 divisions separated by 3 removable shelves. Unripe plantain (*musa paradisiaca*) was dried with the metal solar drying system, electric kiln drying system and open air drying system. The moisture content of banana reduced from 539g to 233g within 3 days of drying using the metal solar drying system (56.8% moisture content loss); 539g to 352g within 2 days of drying using the electric kiln drying system (65.3% moisture content loss); and 539g to 238g within 3 days of drying using the open air drying (55.4% moisture content loss).

Keywords: electric kiln drying, metal solar drying, moisture content loss, *musa paradisiaca*, open air drying, solar collector, solar drying cabinet.

1.0 INTRODUCTION

Drying is one of the most important post-harvest operations for produce. It is mainly aimed at reducing the moisture content of the produce for preservation. For some spices such as banana, fish, maize e.t.c, drying is not only for preservation purposes but also for modifying the tastes and flavors in order to increase their market values [5]. In developing countries, natural sun drying method is commonly used for drying produce. Although negligible investment is required by this method, products being dried are usually contaminated by insects, birds and dusts. Due to rewetting of the products during drying by rain and too slow drying rate in the rainy season, toxic substances such as an alphatoxil produced by molds is often found in the dried products [1, 3]. This is one of the main problems obstructing the growth of exports of this produce in international markets. Consequently, the utilization of a solar drying technology is considered to be an alternative solution to the problem of drying agricultural products [6].
As farmers usually have a farmhouse with galvanized iron sheets as a roof for use in various agricultural activities, with a proper design it is feasible to use this roof to produce hot air for drying agricultural products. Such a drying system will provide space for the solar collectors and reduce the total investment cost [5].

Drying crops by solar energy is of great economic importance the world over, especially in Nigeria where most of the crops and grain harvests are lost to fungal and microbial attacks. These wastages could be easily prevented by proper drying. Nigeria lies within the equator and is

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blessed with abundant solar energy all the year round [1]. This solar energy can easily be harnessed by a proper design of solar dryers for crop drying. This method of drying requires the transfer of both heat and water vapour [2]. Most of our crops and grain are harvested during the peak period of rainy season and so preservation proves difficult and most of these grains and crops perish.

A solar dryer is an enclosed unit, to keep the food safe from damage, birds, insects and unexpected rainfall. Solar dryers are normally designed for use below 55^{o} C [4]. The green/unripe banana is dried using solar thermal energy in a cleaner and healthier way.

2.0 METHODOLOGY

The dryers considered in this research paper are the metal solar dryer, electric kiln dryer and open air dyer. Here in solar dryer the product is located on trays inside a drying chamber. Solar radiation is thus not incident directly on the crop. Preheated air warmed during its flow through solar energy air heater, is ducted to the drying chamber to dry the product. Because the products are not subjected to direct sunshine as in open air drying, localized heat damage does not occur [3]. The Solar energy dryer is made up of the following basic units:

(a) A drying chamber.

(b) An air-heating solar energy collector, which consists of cover plate, absorber plate and insulator.

2.1 MATERIALS

The materials used for the construction of metal solar dryer include: Steel tubing (1" square, 40'), Sheet metal (Galvanized, 16' X 3'), polycarbonate panel (Flat, 2'×8', translucent. sold for greenhouses and patio covers), dimensional lumber (1×2, 8' lengths), sheet metal screws (self-tapping), wood screws, black paint, hinges, latch and net.

2.2 CONSTRUCTION PROCEDURE

The size of the constructed metal solar dryer was 48" long by 18" wide. This was the size that could be covered with one sheet of 24"×96" polycarbonate. Three (3) lengths of square tubing 46" long and 2 lengths of 48" were cut. These are for the horizontal beams of the frame and 2 lengths 28" long and 2 lengths of 22" for the upright pieces of the frame respectively. The two 28" uprights on a level surface was marked each 3" from the bottom and 10" from the top. The 46" beam was then placed between the 2 uprights below the 3" mark and welded in place. Then another beam was placed between the 2 uprights, above the 10" mark, and welded in place. The 22" uprights were welded between the 48" beams to form a big rectangle. The beams are above and below the uprights, not between them, so that everything will come out to be 48" long. The back panel stands vertically on a level surface. For the bottom sidepieces, two 20" lengths of square tubing was cut and laid butted against the back panel, one on each side. The front panel stands vertically on top of these sidepieces forming a square; the bottom sidepieces with the uprights were arranged vertically and welded in place. Because the front is taller than the back; these 2 top sidepieces are angled at the latitude of Ikorodu. A piece of square tubing was marked and placed so that it fits in between the front and back panels. The other side was repeated. Because the panels are level and square, these top sidepieces are of the same size.

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Two 47" beams and two 19½" uprights were placed over the opening of the door panel to check for size. The door panel is to overlap the frame about ¼" on all sides. The door frame was welded together.

A piece of sheet metal measuring 47"×21" was cut and attached to the door frame using the drill and screwing in place with sheet metal screws. Before covering the frame, the tray supports were installed by cutting six (6) 21" lengths of 1×2 lumber and Marked all 3 of the uprights 4" up from the bottom bar. Using sheet metal screws, the 1×2 boards were attached inside the dryer frame between the front and back panels at each mark. A piece of sheet metal measuring 48"×18" was cut for the heat absorber. The absorber sheet sits on top of the lowest tray support boards and the bottom beam of the door panel. It was secured in place using wood screws and sheet metal screws. The absorber sheet doesn't go all the way to the back panel; with a gap of 3½". Using a box cutter to score and then slice the polycarbonate, each piece is clamped to the outside of the welded frame; one on top and one on the back panel. The frame was well covered but not tightly to prevent the polycarbonate breakage with pre-drilled holes around the perimeter of the polycarbonate; sheet metal screws were used to attach it to the metal frame. Pieces of galvanized sheet metal were cut to cover the sides. The sheet was screwed to the frame with sheet metal screws. Also, a piece of sheet metal measuring 18"×48" was used to cover the bottom. There is a 4" gap on the door panel side of the bottom plate. This gap is used as the intake vent. Then pieces of sheet metal measuring 4"×48" and 8"×48" respectively were cut and attached to the front panel below and above the door opening, respectively leaving a 2" gap at the very top for the exhaust vent.

Two (2) pieces of net 6"×48" were used to cover the intake and exhaust vents to prevent insects from entering the dryer. The sides of these nets were attached to the dryer frame using one screw on each side. The bottom net was attached with few screws on the sidebars to hold it in place. It ensured that the net was in place between the sheet metal and the frame for a secure and insect-tight fit.

The entire inside is painted black, focusing especially on the heat absorber and the sides. The trays are screwed and glued together into 4 rectangular tray frames measuring 46"×21½".

Fig. 1: Back and front view of the constructed metal solar dryer


Fig. 2: A bunch of plantain and peeled plantain before drying.

Unripe plantain fruit (green banana) bought from Ikorodu main market was used for this study. It was washed, peeled and sliced uniformly. Random samples from the chips were dried in the kiln dryer, metal solar dryer and open air dryer. The initial weight was measured using a top pan digital balance. It was then divided into three equal parts for the three dryers. The ambient and chamber temperatures throughout the duration of the process were measured using a thermometer. The weight loss during drying which was assumed to be only moisture loss was monitored periodically by weighing the samples until the weight was constant. This was used to determine moisture content loss by the product in each method of drying.

3.0 RESULTS AND DISSCUSSION

The metal solar dryer, open air dryer and kiln dryer were used for drying green / unripped banana in the month of October for three days. The drying was carried out in Lagos State Polytechnic Ikorodu campus. Ikorodu area of Lagos state, Nigeria with Latitude 6.666667°N. The solar Dryer was placed outside with the collector facing the direction of the sun. About 3.24kg of freshly harvested unpeeled banana with a total mass of sliced banana of 1.76kg was dried by arranging on the drying bed in a single layer to avoid moisture being trapped in the lower layer. The dryer chamber door was closed and seals placed in position. The results obtained for hourly reading of 6hours everyday at a maximum temperature of 45ºC are tabulated.


Fig. 3: Dried banana from metal solar dryer, electric kiln dryer and open air dryer respectively

3.1 RESULT

1.	Mass of unpeeled plantain	=	3.42kg
2.	Mass of Pot	=	0.41kg
3.	Mass of peeled plantain + Pot	=	2.31kg
4.	Mass of peeled plantain	=	2.31kg – 0.41kg = 1.9kg
5.	Mass of sliced plantain + pot	=	2.17kg
6.	Mass of sliced plantain	=	2.17kg – 0.41kg =1.76kg

7. Average thickness of sliced plantain = 2.14mm
8. Average mass of each sliced plantain = 1.1g

Table 1.0: Variation of mass and temperature with time on 28th October 2011.

	KILN DRYER		METAL SOLAR DRYER		OPEN AIR DRYING	
TIME/hr	MASS/g	TEMP/°C	MASS/g	TEMP/°C	MASS/g	TEMP/°C
11.58	539	45	539	41	539	35
12.58	448	50	488	41	481	36
13.58	369	52	465	40	437	34
14.58	301	55	442	42	419	36
15.58	238	54	391	39	363	35
16.58	215	54	352	34	323	32

Table 2.0: Variation of mass and temperature with time on 29th October 2011.

	KILN DRYER		METAL SOLAR DRYER		OPEN AIR DRYING	
TIME/hr	MASS/g	TEMP/°C	MASS/g	TEMP/°C	MASS/g	TEMP/°C
12.00	215	55	352	37	323	36
13.00	210	56	306	32	323	33
14.00	198	65	301	35	323	32
15.00	187	69	301	34	289	33
16.00	187	66	289	38	261	33
17.00	187	65	278	34	255	34

Table 3.0: Variation of mass and temperature with time on 30th October 2011.

	KILN DRYER		METAL SOLAR DRYER		OPEN AIR DRYING	
TIME/hr	MASS/g	TEMP/°C	MASS/g	TEMP/°C	MASS/g	TEMP/°C
12.00	-	-	278	44	255	38
13.00	-	-	255	40	250	33
14.00	-	-	244	45	244	38
15.00	-	-	233	44	238	36
16.00	-	-	233	44	238	36
17.00	-	-	233	42	238	34

3.3 CALCULATION OF MOISTURE CONTENT LOSS

Moisture content loss of the dried banana was calculated using the formula;

$$M_L = \frac{M_i - M_f}{M_i} x\ 100\%$$

Where: M_L = Moisture Loss
M_i = Initial Mass
M_f = Final Mass

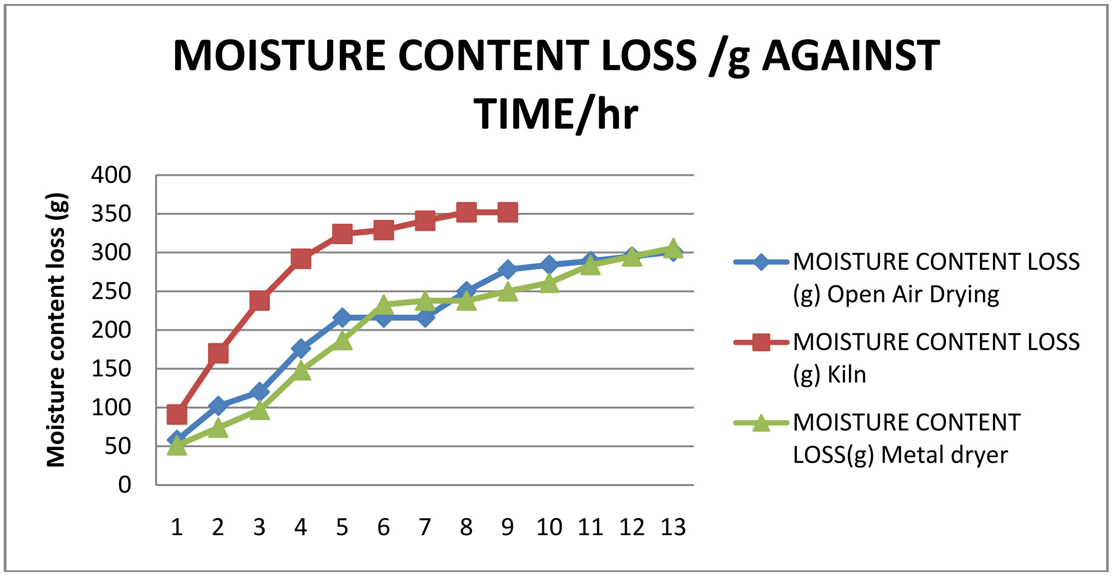

Figure 4.3: A graph of Moisture content loss/g against time/hr of the 3 dryers

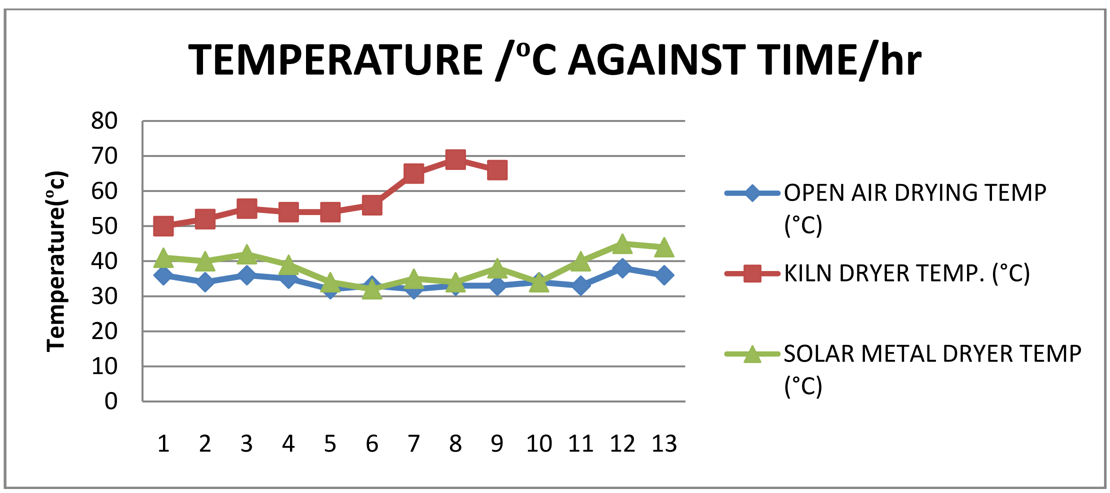

Figure 4.4: A graph of Temperature /°c against time/hr of the 3 dryers

4.0 DISSCUSSION

The kiln dryer utilizes electricity in its mode of operation with the aid of an electrical heater to produce heat. It had better and faster rate of drying banana that weighed 539g for 8hours removing about 65.3% of moisture from the sliced banana at a maximum temperature of 69ºC while the metal solar dryer harnesses the energy of the sun with the aid of a translucent polycarbonate sheet that traps the energy and preventing direct ultraviolet light to drain the nutrient of the produce it dried banana of mass 539g for 13hours removing 56.8% of moisture at a maximum temperature of 45 ºC. Open air drying is a traditional way of drying produces by spreading it to direct ultraviolet light which drains the nutrient in the produce it is used to dry sliced banana weighing 539g for 13hours removing 55.8% of moisture at a maximum temperature of 38 ºC.

5.0 RECOMMENDATION

In order to make good use of the solar dryer for drying different produce a thermostat, fan and humidity sensor could be incorporated in the solar dryer to ensure that drying is done under prescribed conditions.

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