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High Density Fibreboard as an Alternative for Polypropylene Materials in the Construction of Solar Dryer

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Abstract:- Foods are preserved by drying them out to eliminate moisture using a procedure that, depending on the food type, removes water content. In addition to extending the shelf life, this preserves the essential nutrients. Produce dried in the open sun has been shown to be unsanitary because of contaminations. This made it necessary to build a solar dryer that would be within every farmer's budget. The construction materials were purchased locally, and the sliced plantain samples were dried over three days in the sun and in a solar dryer.

With open sun drying, the sliced plantain sample, which had an initial mass of 300.00g, lost 76.25% of its moisture content, and with sunshine drying, it lost 96.64%.

The sliced plantain sample, which had an initial mass of 300.00g, was also dried simultaneously in a solar dryer manufactured of polypropylene, and it had a moisture content of 97.2%. The procedure and outcome showed that, while the solar-dryer approach is more controlled, clean, and effective with a greater drying rate, the old open-sun way of drying agricultural goods is neither efficient nor clean. Furthermore, it was established that when it comes to drying agricultural products with comparable moisture content, solar dryers made of polypropylene and high-density fibre board work better.

The cheaper high-density fibre board solar dryer cost two hundred and sixty-eight thousand naira while the imported solar dryer made of polypropylene cost two thousand five hundred dollars equivalent of one million naira as of 2021.

The above-mentioned parameters were determined by the constructed and tested solar dryer, and it was advised that farmers and individual households utilise the high density fibre board produced solar dryer for drying agricultural produce.

Keywords:- *Food, High-Density Fibre Board, Open Sun, Solar.*

I. INTRODUCTION

High Density Fiberboard can either be made from hardwood or softwood. There were no obvious rings, knots, or wood grain; it was just made up of tiny wood fibres. Fibres, glue, and heat are used in the composite's creation to provide the necessary tight bonding board.

According to Adeniyi *et al*. (2021), food may be kept by drying, by lowering its moisture content. According to their definition, drying is the process of removing less than 25% of the water content in different types of products.

They made it clear that using the open sun to dry food items is unclean and contaminated, and that a solar dryer will need to be built for use. It was determined that farmers would be able to considerably increase their revenue if solar dryers were made available for use with agricultural produce. But higher savings also improves and fortifies the food security and economic circumstances of many farmers in emerging nations, and it will also alter the nutritional landscape of these nations.

According to research conducted by Vijaya Venkata Raman et al. (2012), around 15% of people on the planet are undernourished. They revealed that the world's population is growing, which exacerbates the current imbalance between people and food. As a result, food production is necessary. Appropriate harvesting and post-harvest handling combined with effective marketing appears to be a workable solution to boost food supply and slow population growth. Efficiently reducing food losses also provides relief for small farmers in developing nations, who produce more than 80% of the food in their nations.

Traditional sun drying methods such as open sun drying had been used since ancient times to preserve food and agricultural commodities.

Traditional sun drying is a sluggish procedure that can result in significant food losses and worse product quality due to enzymatic reactions, insect infestation, microbe growth, and the creation of mycotoxin.

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This procedure has many drawbacks, including product spoiling from unfavourable weather conditions such rain, wind, moisture, and dust; material loss from animals and birds; material deterioration through decomposition; and fungal and insect development. Furthermore, this procedure needs a lot of space, a lot of labour, and time.

The necessity to accommodate cultural and industrial expansion, which might result in an energy-intensive and costly drying process, led to the invention of artificial mechanical drying.

The greatest way to overcome all the shortcomings of both artificial and natural drying is to use solar drying.

Solar drying is described by Mujumdar *et al*. (2000) as the process of converting a solid, semisolid, or liquid feedstock into a solid product by evaporating its liquid into a vapour through the application of heat from sunlight. On the other hand, Zobaa *et al*. (2011) unequivocally declared that solar drying is superior to open sun drying in terms of the quality of the dried product, post-harvest gains, and drying times.

Hartmans E. H. *et al*. (1991) emphasised, however, that 20% of the world's grain production is thought to be lost during harvesting due to handling issues and inadequate post-harvest technology adoption.

According to Erteken *et al*. (2004), drying is the process of removing moisture from a substance via mass transfer and heat transfer occurring at the same time. He reiterated that using the traditional technique of food preservation will result in a longer shelf life, less weight during transit, and less storage space.

According to Can *et al*. (2000), there are two steps to the drying process. While the second stage happens with a decreasing/falling drying rate, the first stage occurs on the surface of the drying material and has a constant drying rate, which is the same as the vaporisation of water at ambient. The characteristics of the substance being dried dictate the state of the second stage.

According to Pangavhane *et al*. (2002), agricultural items such as grains, fruits, and vegetables are frequently preserved in poor nations by open sun drying. The drying process is conducted in an unregulated, hostile environment, which causes significant losses in the dried product.

According to Yaldiz et al. (2001), the introduction of solar dryers reduces food product losses by improving the quality of the dried product when compared to traditional drying methods like sun or shade drying. This is because solar dryers prevent contamination of food products by dirt, dust, and insects, rodents, and animals.

Sun or Natural Dryers, Direct Solar Dryers, Indirect Solar Dryers, and Mixed-Type Solar Dryers are the four categories Furlan G *et al*. (1983) used to group dryers according to their mechanisms.

In their conclusion, El-Sebaii *et al*. (2012) identified sun drying of agricultural goods as one of the most significant prospective uses of solar energy that, when compared to traditional methods, helps to avoid fruit and vegetable losses during drying in underdeveloped nations. This resulted from an attractive, well-designed sun drying system that significantly decreased the postharvest losses of agricultural goods in the rural areas.

Garcia (2005) pointed out that post-manufacture heat-treatment improved surface which roughens the exterior MDF panels when treated at 225°C for 30 min. Instead of having any physical effect, firm contact between the panel and the press platens does not exist when commercially manufactured medium density fiberboard (MDF) panels are exposed to heat-treatment during manufacturing at various temperatures and durations of hot press.

The chemical modifications of heat-treated wood reveal a slight structural change that could be attributed to either carbon-carbon double bond formation or adsorbed water, as explained by Petrissan *et al*. (2003). Wood with the chemical composition of heat-treated wood is wetted in advancing contact angles of a water drop and they are systematically higher compared to untreated wood.

Hakkou *et al*. (2005) found that the hydrophobic properties of wood are caused by the behaviour of higher temperatures in terms of chemical modifications and molecular organisation of wood biopolymers. Specifically, the hydrophobic properties of wood can only be significantly increased in a temperature range between 130 and 160 °C contact angles under the measurement by Wilelhmy technique using beech heat treatment by mild pyrolysis under inert atmosphere.

The bonding ability of individual wood used is improved, according to Aydin Ismail (2004), when chemical pre-treatments are applied to the various wood surfaces. Sernek *et al*. (2004) studied the surface inactivation of two wood species, southern pine (Pinus taeda) and yellow poplar (Liriodendron tulipifera), when exposed to high temperature drying. The surface analysis involved X-ray

According to Wellons (1977), wood from these new sources is created by adhering tiny wood pieces together to create products of the required size. In reaction to the expanding population that is straining our wood supplies to the point that they are becoming limited, it keeps gaining market share.

According to Christiansen (1990), over-drying (or over-drying) renders wood surfaces unusable for bonding, particularly when phenolic adhesives are used.

According to Podgorski (2000), strain from stained coatings causes dimensional variation in wood, which reduces the lifetime of an outdoor wood-coating system.

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According to Follrich *et al*. (2006), mechanical testing on both thermally and non-thermally changed samples showed a significant improvement in the adhesion that developed between polyethylene and the modified wood surface.

In Unsal *et al*.'s experiment to ascertain the effects of heat treatment on compression strength parallel to the grain, the air-dry density and surface roughness [average roughness (Ra)] of wood from the river red gum tree (Eucalyptus camaldulensis Dehn.) planted revealed that there were no strength values lost when Eucalyptus wood was used and appropriate heat treatment techniques were applied.

In their study, Korkut and Guller (2008) described how heat treatment improved the dimensional stability of red-bud maple (Acer trautvetteri Medw.) wood and how its physical characteristics and surface roughness were affected. They found that as treatment times and temperatures increased, so did the wood's values of density, swelling, and surface roughness.

➢ *Justification*

Today's world uses nanotechnology in numerous food businesses' packaging. In order to strengthen novel food and food contact materials (FCMs) and enhance their antimicrobial activity, oxygen scavenging potential, moisture and gas barrier, biosensing ability, changed colour and texture, and thermal stability, nanoparticles (NPs) are added (Handford et al. 2014).

The process by which a material shifts from one medium to another is known as migration. According to observations made on nanocomposite packaging, the nanoparticles diffuse through the walls of the packaging to the surface, where they are transported by matrix degradation and desorb, dissolve, or otherwise enter the food items (Duncan 2011). Because of the quantity of nanoparticles in the food that is fit for eating, this degree of migration harms human health and controls food product quality. Because of this, regulatory bodies place a lot of weight on migration levels, which is why they are a crucial element influencing the absorption of nanoparticles in food packaging (Chaudhry et al. 2008).

According to Joseph Christopher Hannon *et al*. (2015), polyethylene materials should not be used for solar dryers because they are unsafe for use as food materials. Instead, wood is a better and more sustainable alternative, and this will help prevent migration that has been observed during microwave heating, which has been found to be significantly higher than oven heating for similar temperatures (100 °C) under identical exposure times (2 min). It was found that scanning electron microscopy (SEM) was used to confirm the presence of nanoparticles (NPs) in the packaging materials and food simulants during testing.

➢ *Objectives*

- To construct a solar dryer that has its drying chamber made of high-density fibre board instead of polypropylene material.
- To use a locally available material that is affordable, repairable, and dependable for drying our food products.
- To do performance evaluation of the high-density fibre board constructed dryer.

II. MATERIALS AND METHODS

➢ *This Solar Dryer was Constructed at National Horticultural Research Institute Jericho, Ibadan, Nigeria.*

Plate 1 Showing the Constructed HDF Solar Dryer and the Polyethylene Solar Dryer

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- *Component Parts:*
  These include the drying chamber/box, the sun radiation collector, the fan and the solar panel.

Plate 2 Showing the Layers of the Seven Trays in Drying Chamber

➢ *Factor Considered in Construction and Description*

The drying chamber was made of a high-density fiberboard box joined to shape. The material was chosen because wood and its composites are poor conductor of heat, and it has a finished smooth polished surface in which heat loss by radiation was minimized. The heat loss by radiation was further reduced to avoid moisture absorption by the wood hence the inside was lagged and painted black.

The inside was constructed to accommodate seven (7) trays made of 2mm stainless wire mesh design in 60 cm x 60cm with an interval of 1ft between trays. Moreover, 60 cm x 60cm of net was placed on the wire mesh to accommodate food materials of smaller particles for drying.

➢ *Sun Radiation Collector*

The collector was constructed from ordinary metal plate of 900cmt x 150cm x 60cm. It was bended in such a way to collect sun radiation at reflection. The base was painted black to enable it to retain the radiation as hot air ready to be blown into the drying chamber. The left and right edges of the metal plate were tapered and bended such that it will clip the nylon material used to cover the top. The nylon enables the penetration of the sun radiation by refraction.

➢ *Fan*

A chosen centrifugal fan was attached to the solar dryer at the tail – end enclosure made of high-density fibre board so that the rotation of the fan will blow the collected hot air in the collector into the drying chamber being powered by a connected solar panel thereby fitting into the design of the construction.

➢ *Theory of Drying*

Most agricultural products, be it fruits, vegetables, cereals, or grains are dried either as solid or coarse material as piles or layers. The solid pile is blown through by preheated air for drying to occur, and subsequent energy needed for evaporation is in the same vein provided for the materials. Heated air introduced to the food products undergoing drying removes the evaporating water from the surface of the food products. The mass and heat transfer that occurs during drying helps in the science of a complex mathematical description based on approximation. Thus, semi empirical methods based on experimental data is applied. Moisture was removed because of the difference in vapour pressure between the surface and its surroundings and this brought about the migration of moisture to the surface under the effect of the moisture gradient that was formed in the drying zone. This process of drying continues until equilibrium was attained between the surface and the inner part and between the surface and the ambient. Temperature remains a decisive factor in drying. It ensures that both the concentration gradient and the diffusion coefficient increase with temperature, thus making the amount of water removed to also increase. For a temperature above 70°C, the partial pressure of water vapour increases in the food products such that it may exceed the external and further reduce both the quality and the nutritional contents of the product.

- Efficiency of the dryer is otherwise called **Collector Efficiency (EF)**

- Collector efficiency is represented as:

$$\eta = \rho V C_P \, \Delta T A I C \quad (1)$$

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Where ρ is the density of air (kg/m^3), IC is the sun intensity (maximum of 25MJ/m2 in Nigeria) on the collector, ΔT is the temperature elevation, Cp is the specific heat capacity of air at constant pressure (J/kgk), V is the volumetric flow rate (m^3/s), and A is the effective area of the collector facing the sun to trap the sun radiation.

- *Dryer Efficiency*

Thie compartment at which drying takes place is expressed as:

$$\eta d= MLIcAt \quad (2)$$

Where: L is the latent heat of vaporization in the drying chamber, M is the mass of product before drying and t is period at which the drying time is completed.

- *Rate of Heat Flow into the Dryer*

Quantity of heat channeled into the dryer is refer to as the sum of the convective heat, conductive heat, and radiative heat transfers and is expressed as

$$q= qv+ qd+ qr \quad (3)$$

$$qA = Ta-Td\ 1ha/+ \Delta xk/+ 1hd/ + (Ta-Td) \quad (4)$$

Where qA is the heat transfer per unit area, ha is the heat transfer coefficient for the ambient, hd is the heat transfer coefficient for the dryer chamber, Ta is the ambient temperature, Td is the drying chamber temperature, σ is the Stefan-Boltzman constant, Δx is the thickness of the glass cover, and ε is the emissivity and k is the thermal conductivity [Aderemi *et al.*, 2021].

- *Heat Energy (Q) Needed for Food Product*

The heat energy required to dry a food product is a function of the mass and latent heat of vaporization and it is expressed mathematically as:

$$Q=MiL \quad (5)$$

Where Mi is the mass of the food products before drying and L is the latent heat of vaporization [Aderemi *et al.*, 2021].

- *Mass of Air Needed for Drying:*

This is calculated by using the equation given as below:

$$\dot{m}=[wf-wi] \quad (6)$$

Where:

mw is the amount of moisture to be removed, kg.

wf and wi are the final humidity ratio, respectively, kg H2O/kg dry air and

td is the total drying time, hrs.

- *Moisture Content (MC)*

The moisture content of food samples is given as:

$$(\%)= (Mi-Mf/Mi) \times 100\%;\ \text{Wet basis} \quad (7)$$

Where;

Mi is the mass of sample before drying and

Mf is the mass of sample after drying.

- *Moisture Loss (ML)*

The moisture loss (g) is given as:

$$ML=Mi-Mf \quad (8)$$

- *Average Drying Rate (Rd)*

$$Rd= (Mi-Mf) \quad (9)$$

- *The Health Benefits of Unripe Plantain*

Plantains are high in antioxidants that aid in the body's defence against free radicals that may lead to oxidative damage and illnesses including diabetes, cancer, and heart disease. Subsequent research also found that flavonoids and polyphenols, two significant antioxidants, are present in the peels and flesh of plantains. Boiling unripe plantains results in a low glycemic index (GI) of 45 due to their high resistant starch content. One kind of carbohydrate called resistant starch moves from the small intestine, where it breaks down into sugar, into the large intestine, where fermentation takes place. Furthermore, resistant starch is a great diet for diabetics since it does not elevate blood glucose levels and is not digested in the small intestine, allowing for fermentation in the large intestine.

Additionally, by encouraging the development of "good" gut bacteria, fermentation in the large intestine enhances glycemic management. Potassium is a crucial element that aids in the regulation of blood pressure and is abundant in plantains. You may obtain around 44% of your daily required potassium intake from 1 big green plantain. Plantains are a low-sodium meal that can help with a hypertension diet. Plantains' resistant starch and fibre both support normal digestion.

Because of its high fibre content, food passes through the digestive system more readily, reducing the risk of colon cancer and constipation. In addition, the high resistant starch concentration encourages the development of good bacteria in the stomach. Plantains are a fantastic source of iron and folate (folic acid). Iron helps prevent anaemia, while folate is necessary to prevent foetal abnormalities like spina bifida during pregnancy. In addition, plantains are a great source of calcium, phosphorus, magnesium, vitamin B-6, and vitamin C, all of which support a baby's healthy growth and development.

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➢ *Method*

Plantain samples were cut into defined masses and dried within a dryer constructed of high-density fiberboard, where the amount of hot air injected is regulated. Comparable samples were also dried outside for many days, at least three hours per day. Following the drying times, the sample is weighed using a sensitive scale to calculate the weight (moisture) loss, and a digital thermometer suspended within the dryer is used to assess the sample's temperature. The tests' outcomes are listed in the tables below.

III. RESULTS AND DISCUSSION

Table 1 Plantain Slices Inside the Solar Dryer and in the Open Sun

Days	**1st Day (5 hours)**	**1st Day (5 hours)**	**2nd Day (5 hours)**	**2nd Day (5 hours)**	**3rd Day (2 hours)**	**3rd Day (2 hours)**
Trays	Solar Dryer	Open Sun	Solar Dryer	Open Sun	Solar Dryer	Open Sun
1	300.00	300.00	99.74	161.37	10.07	71.26
2	300.00	300.00	90.67	161.37	10.09	71.26
3	300.00	300.00	91.54	161.37	10.09	71.26
4	300.00	300.00	91.71	161.37	10.08	71.26
5	300.00	300.00	91.92	161.37	10.11	71.26
6	300.00	300.00	92.05	161.37	10.10	71.26
7	300.00	300.00	92.28	161.37	10.11	71.26

As shown in table 1, the initial mass of the plantain slices to be dried was 300g both for the open sun drying and the solar dryer.

On day one, the weight of the plantain slices samples reduced from 300g to 99.74, 90.67, 91.54, 91.71, 91.92, 92.05 and 92.28 respectively on trays 1, 2, 3, 4, 5, 6 and 7 inside the drying chamber while the weight of sliced plantain samples also reduced from 300g to 161.37g in the sun drying. The rate at which drying occur in the chamber slightly varied initially from those trays closer to the entrance passage of the collected hot air until it eventually circulated evenly in the drying chamber. It was discovered that on the third day drying process was completed in the drying chamber having approximate final mass of 10.1g in each tray while the final mass of the sun method was 71.26g as at that time. Open Sun Method require another 3 hours to complete its drying.

The moisture content of crops samples is given mathematically as: (%) = $(Mi{-}Mf/Mi)$ × 100%; where Mi the mass of plantain slices sample before drying is 300g and Mf is the mass of plantain slices sample after drying is 10.1g (% Moisture Content) = (300 – 10.1/ 300) × 100%. = 96.63%

For Open Sun Drying,

(%) = $(Mi{-}Mf/Mi)$ × 100%.

Mi the mass of plantain slices sample before drying is 300g and

Mf is the mass of plantain slices sample after drying is 10.1g

(% Moisture Content) = (300 – 71.26/ 300) × 100% = 76.25%

The results showed that only 76.25% moisture content was removed in the sun drying while that of the solar dryer was 96.63%, which shows that the solar dryer is more efficient, faster and neater compared with the open sun drying method.

Table 2 Plantain Slices Inside the Polypropylene Solar Dryer and in the Open Sun

Days	**1st (5 hours)**	**1st (5 hours)**	**2nd (5 hours)**	**2nd (5 hours)**	**3rd (2 hours)**	**3rd (2 hours)**
Trays	Solar Dryer	Open Sun	Solar Dryer	Open Sun	Solar Dryer	Open Sun
1	300.00	300.00	87.47	161.37	8.37	71.26
2	300.00	300.00	85.62	161.37	8.44	71.26
3	300.00	300.00	87.12	161.37	8.41	71.26
4	300.00	300.00	86.59	161.37	8.43	71.26
5	300.00	300.00	86.96	161.37	8.41	71.26
6	300.00	300.00	86.88	161.37	8.39	71.26
7	300.00	300.00	86.23	161.37	10.11	71.26

As shown in table2, the initial mass of the plantain slices to be dried was 300g both for the sun drying and the solar dryer.

The moisture content of crops samples is given mathematically as:

(%) = $(Mi{-}Mf/Mi)$ × 100%;

Mi the mass of plantain slices sample before drying is 300g and

Mf is the mass of plantain slices sample after drying is 10.1g

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(% Moisture Content) = (300 – 8.41/ 300) × 100%. = 97.12%

The result indicated 97.12% of moisture was removed from the dried sample. This reveals that the approximate value of 97% moisture was removed from both polypropylenes made and high-density made fibre board solar dryer.

IV. CONCLUSION AND RECOMMENDATION

With an approximate value of 97% for both sun dryers compared with 76.25% of open dry surface, the moisture removed from the samples of sliced plantains placed in both the High-Density Fibreboard-made dryer and the Polypropylene-made solar dryer was 96.63% and 97.1%, respectively.

In that it is nearly as light as polypropylene materials and can contain enough heat to start and finish sun drying, high density fiberboard is a viable substitute for polypropylene materials.

Because solar drying preserves the nutritional content of the food being processed and increases sanitation, it decreases contamination caused by dirt, fungus, insects, animals, and human interference. This study supports this by showing that the drying process may be carried out in certain wood-framed enclosures and that it will function as best it can.

The dryer is built using straightforward innovative technology and is reasonably priced. Because of this, small-scale farmers and households should consider it.

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