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Comparative Drying Efficiency Of Open Air And Passive Solar Cabinet Dryers For Plantain (*Musa Paradisiaca*) And Sweet Potato (*Ipomoea Batatas*) South Eastern Nigeria

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Abstract
A successful comparative studies on the adequate techniques for the drying fresh plantains (Musa paradisiaca) and sweet potatoes (Ipomoea batatas) were carried out in Awka, Anambra State Nigeria. Though there are many methods of drying but, we choose to study and compare solar dryer (cabinet option) and open air dryer (direct sun) drying methods. The solar dryer (cabinet option) designed and constructed is passive integral type, such that its heating source depends solely on solar energy. The cabinet dryer has a box-like drying chamber with dimension $1.5x2.0x0.6$ *meter supported midway by wooden shelve-like structures along the walls of the drying chamber, with a volume of* 1.080m^3 *and its specific volume is* $1.020m^3$. *The transparent material which was tilted at an angle about* $12^0 - 15^0$ *facing south for optimum solar radiation. While the open air drying method was carried out using clean dried mats, placed on an open free air space on the earth. It was observed that the open air dryer was faster in losing moisture from the plantain than the solar cabinet drying option, which implies that the open air dryer is faster in drying (losing moisture) than the cabinet solar drying option.*

Keywords: *solar dryer, cabinet option, open air dryer, tilted angle*

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I. Introduction

Millions of dollar worth of gross National food product are lost through spoilage. Reasons include; ignorance about preservation of crops, lack of knowledge on the construction of adequate drying technique, and geographical location; this implies that parts of the globe receive more solar energy (radiation) than others, example is the tropic regions, which receives, more solar energy than the cooler countries. .The increase at which farmer's losses their farm product is disheartening and alarming. Fresh unripe plantains (*Musa paradisiaca)* and sweet potatoes (*Ipomoea batatas*) are both perishable farm products that are nutritious and very expensive. Most times both of these farm products easily gets spoilt if they are not properly preserved, thereby causing the farmers to lose much money. As a result of this, a sustainable and efficient methods of preserving agricultural products has to be in place in order to eliminate such challenge (Hao *et al.,* 2021, and Villagran *et al*., 2021). Drying is one of oldest and suitable means of preserving the farm products (Elzubeir 2014). Drying is simply known as the process of water removal, usually driven by heat, from solid and liquid products resulting in solid-dried products (Fernandes and Tavares 2024). When farm or agricultural product are properly preserved and secured, it will put to an end the great losses of farm and agricultural products. In a country where there are too many waste of farm products; hunger, unemployment and poverty are always in place.

There are several methods or techniques of drying, including open-air, mechanical, and solar drying (Edwin 2024). Open air drying, also known as natural drying; this method of drying is easy, simple and more economical method, it's completely dependent on climatic conditions, though in most cases, the products are attacked by birds, human beings, insects and mostly not been hygienic and can lead to inconsistent product quality (Kumar *et al*., 2016).

On the other hand, mechanical drying systems, while offering improved control and higher operational efficiency, it require substantial capital investment in infrastructure as well as considerable energy input (Prakash *et al*., 2013). Mechanical solar dryers (active solar dryers) enhance natural solar drying by using mechanical components like fans or blowers, powered by electricity or solar PV panels, to force airflow and speed up dehydration. They operate at temperatures up to 65°C and often include humidity controllers to ensure consistent, high-quality drying while protecting products from insects and contaminants (Radhakrishnan *et al*., 2024). In contrast, solar dryers offer a balanced solution by harnessing abundant and freely available solar energy - particularly in regions with high solar irradiance - to achieve efficient and cost-effective dehydration of agricultural products (Kumar *et al.,* 2021, Firfiris *et al.,* 2022, Delgado-Plaza *et al.,* 2019, Barbosa *et al*., 2023).

Among the various techniques for drying agricultural products, solar drying has demonstrated several advantages compared to alternative methods.

Solar drying is distinct from open sun drying in that it employs engineered systems to capture and utilize solar radiation for controlled dehydration processes. In many Southeast Asian countries, agricultural commodities such as spices, crops, and herbs are routinely preserved through drying techniques (Gajendra *et al* 2024). However, traditional sun drying is often constrained by climatic variability, particularly unexpected rainfall, which can lead to rehydration and subsequent spoilage.

Moreover, prolonged direct exposure to intense solar radiation may induce case hardening, a phenomenon in which a hardened layer forms on the surface of the product, trapping internal moisture and accelerating deterioration (Kumar and Tiwari, 2006). In addition, open sun drying typically requires extensive land area, depends heavily on weather conditions, and exposes products to contamination from dust, insects, birds, and rodents.

To address these limitations, solar dryers that harness freely available solar energy in a controlled environment have been developed. These systems not only improve drying efficiency but also enhance the quality and safety of the final product (Badgujar *et al*., 2019, Amir et al 2024). Consequently, significant research efforts have been directed toward optimizing solar drying technologies for agricultural applications (Norton *et al*., 1987, Leon *et al*., 2022].

Solar dryers are generally classified into four main categories: direct solar dryers, indirect solar dryers, mixed-mode dryers, and hybrid solar dryers (Ong, 1999). Direct solar dryers: A solar cabinet dryer is a controlled-environment dehydrator that uses a specialized box-like structure to harness solar energy for drying agricultural and food products. The product is placed directly in a cabinet or enclosure with a transparent cover (glass or plastic). Sunlight passes through the cover, heating the product and air inside simultaneously. Unlike traditional open-air sun drying, these devices protect materials from dust, rain, and pests while significantly reducing drying time by raising internal temperatures between 40°C and 80°.

Indirect Solar Dryers: The product is housed in a separate, opaque drying chamber. Air is heated in a separate solar collector (often a flat-plate collector) and then transported—either naturally or with a fan—into the drying chamber, protecting the product from direct UV radiation.

Mixed-Mode Dryers: These combine the features of both direct and indirect types. The product is placed in a chamber that receives direct sunlight, while also receiving heated air from a separate collector.

Hybrid Solar Dryers: These integrate a solar collector with another energy source (such as biomass, electricity, or fossil fuel) to ensure continuous, reliable, and faster drying during cloudy days or at night.

II. Materials And Methods

The materials used in this study are as follows; woods, insulated cabinet, perforated metallic trays for absorbing solar radiation and holding the crops within the box, glazing material (transparent cover), dried clean mats, Fresh unripe plantains (*Musa paradisiaca)*, sweet potatoes (*Ipomoea batatas*) kitchen knife, hand gloves, nose mask, clean water, long spoon.

Methodology

The fresh unripe plantains (*Musa paradisiaca)* and sweet potatoes (*Ipomoea batatas*), were harvested from the farm, washed, peeled and sliced into pieces. All the sliced plantains (*Musa paradisiaca)* and sweet potatoes (*Ipomoea batatas*), were measured using a scale, in order to obtain their accurate weights. Prior to the experiment, the solar dryer had been fully constructed and prepared for operation. The sliced plantains and sweet potatoes were separately loaded into the dryer and uniformly distributed within the drying chamber. An equivalent quantity of each sample was simultaneously spread in a thin layer on a clean, dry mat of comparable dimensions to that of the cabinet solar dryer for open-air drying under identical conditions.

Both the open-air drying setup and the solar cabinet dryer were exposed to sunlight for a specified period, as presented in the tables below. At the end of each drying day, samples of plantains and sweet potatoes were collected and weighed separately to determine moisture loss.

Throughout the drying period, it was consistently observed that samples subjected to direct sun exposure (open-air drying) exhibited a higher rate of moisture loss compared to those dried within the solar cabinet dryer. Furthermore, the relatively slower drying rate within the cabinet dryer created conditions that favored mould growth in some samples.

Based on these observations, open-air solar drying demonstrated higher drying efficiency under the conditions studied. This method also contributed to better preservation of certain agricultural products, thereby reducing post-harvest losses. Consequently, improved drying practices of this nature have the potential to enhance food security and support economic development by minimizing waste and contributing to reductions in unemployment, hunger, and poverty associated with agricultural losses.

Table 1: Drying of unripe plantain using open air solar dryer,

s/n	Time (10 hrs.) per day	Weight before sun shine day (kg)	Weight after sun shine (kg)	Weight lost per day
1	7:00am – 5:00pm	4.00	3.20	0.8
2	7:00am – 5:00pm	3.20	2.40	0.8
3	7:00am – 5:00pm	2.40	1.70	0.7
4	7:00am – 5:00pm	1.70	1.65	0.05
5	7:00am – 5:00pm	1.65	1.65	0.00
6	7:00am – 5:00pm	1.65	1.65	0.00

Table 2: Drying of unripe plantain using solar cabinet dryer.

s/n	Time (10 hrs.) per day	Weight before sun shine day (kg)	Weight after sun shine (kg)	Weight lost per day
1	7:00am – 5:00pm	4.00	3.85	0.15
2	7:00am – 5:00pm	3.85	3.57	0.28
3	7:00am – 5:00pm	3.57	3.07	0.50
4	7:00am – 5:00pm	3.07	2.57	0.50
5	7:00am – 5:00pm	2.57	2.10	0.47
6	7:00am – 5:00pm	2.10	1.70	0.4
7	7:00am – 5:00pm	1.70	1.65	0.05
8	7:00am – 5:00pm	1.65	1.65	00
9	7:00am – 5:00pm			

Table 3: A comparative study of open air and solar cabinet dryer for unripe plantain

day	Time (duration) am-pm	Open air dryer	Solar cabinet dryer (weight kg)
0	7am – 5pm	4.00	4.00
1	7am – 5pm	3.20	3.85
2	7am – 5pm	2.40	3.57
3	7am – 5pm	1.70	3.07
4	7am – 5pm	1.65	2.57
5	7am – 5pm -	1.65	2.10
6	7am – 5pm	1.65	1.70
7	7am -5pm	1.65	1.65
8	7am - 5pm	1.65	1.65

Table 4: Drying of sweet potatoes using open air solar dryer,

s/n	Time (10 hrs.) per day	Weight before sun shine day (kg)	Weight after sun shine (kg)	Weight lost per day
1	7:00am – 5:00pm	4.00	3.10	0.9
2	7:00am – 5:00pm	3.10	2.60	0.5
3	7:00am – 5:00pm	2.60	1.75	0.85
4	7:00am – 5:00pm	1.75	1.69	0.06
5	7:00am – 5:00pm	1.69	1.65	0.04
6	7:00am – 5:00pm	1.65	1.65	0.00

Table 5: Drying of sweet potatoes solar cabinet dryer.

Day	Time (10 hrs.) per day	Weight before sun shine day (kg)	Weight after sun shine (kg)	Weight lost per day
1	7:00am – 5:00pm	4.00	3.65	0.35
2	7:00am – 5:00pm	3.65	3.52	0.13
3	7:00am – 5:00pm	3.52	3.00	0.52
4	7:00am – 5:00pm	3.00	2.64	0.36
5	7:00am – 5:00pm	2.64	2.15	0.49
6	7:00am – 5:00pm	2.15	1.70	0.45
7	7:00am – 5:00pm	1.70	1.68	0.02
8	7:00am – 5:00pm	1.66	1.65	0.01
9	7:00am – 5:00pm	1.65	1.65	00

Table 6: A comparative study of open air and solar cabinet dryer for sweet potatoes

Days	Time (duration) am-pm	Open air dryer	Solar cabinet dryer (weight kg)
0	7am – 5pm	4.00	4.00
1	7am – 5pm	3.65	3.65
2	7am – 5pm	3.52	3.52
4	7am – 5pm	3.00	3.00
5	7am – 5pm	2.64	2.64

5	7am – 5pm -	1.70	2.15
6	7am – 5pm	1.66	1.70
7	7am -5pm	1.65	1.66
8	7am - 5pm	1.65	1.65

III. Results And Analysis

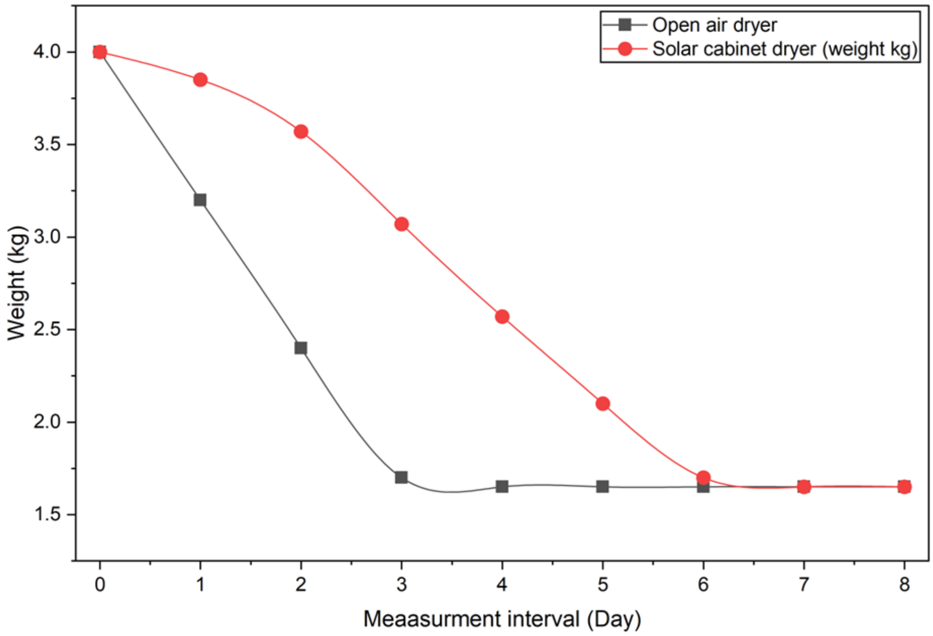

Figure 1: A comparative graph for open air and solar cabinet drying methods for unripe plantain.

Figure 1 displayed a comparative analysis of dried unripe plantain (*Musa paradisiaca*) processed using open-air and solar cabinet drying methods. Under open-air conditions, the sample revealed a rapid initial reduction in mass, decreasing to 1.70 kg. From Day 4 onward, the mass stabilized at approximately 1.65 kg, indicating attainment of equilibrium moisture content under ambient conditions, with no further measurable moisture loss despite continued exposure. While the solar cabinet dryer exhibited a more gradual yet consistent drying pattern during the first seven days. The sample mass decreased steadily from 4.00 kg on Day 1 to 1.70 kg by Day 7, followed by a further reduction to 1.65 kg on Day 8, ultimately converging with the final mass recorded for the open-air method.

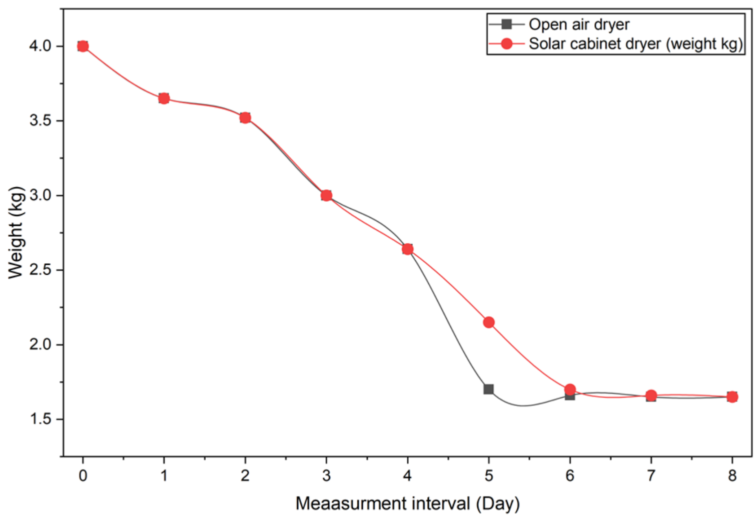

Figure 2: A comparative graph of drying for open air and solar cabinet drying methods for sweet potatoes.

Figure 2 illustrates a comparative evaluation of drying systems applied to sweet potato (*Ipomoea batatas*) using an open-air solar method and a cabinet solar dryer. During the first five-day period, both systems displayed nearly identical reductions in mass. A noticeable decline was observed in the open-air system around Day 4, with the sample mass decreasing from 2.64 kg to 1.70 kg. By Day 6, the open-air method showed a more accelerated moisture reduction, likely influenced by favorable environmental conditions such as high solar radiation, increased airflow, and low relative humidity. In contrast, the cabinet dryer recorded a mass of 2.15 kg on the same day, indicating a comparatively slower drying rate at that stage. Beyond Day 6, both drying approaches exhibited a gradual decline in mass, reaching approximately 1.65 kg by Day 8. In general, each method achieved a similar total moisture reduction of about 59% relative to the initial mass. The trend suggests that, while the open-air method facilitates more rapid moisture removal under optimal conditions, both systems ultimately attain comparable drying efficiency.

The application of open-air drying techniques offers a practical means of minimizing post-harvest losses in crops. This approach has the potential to enhance food preservation, strengthen food security, and contribute positively to economic stability at the regional level.

IV. Conclusion

A comparative evaluation of different methods for drying agricultural products was successfully conducted. The findings indicate that open-air solar drying achieved a higher drying rate than the solar cabinet dryer throughout the drying period. Although both methods exhibited similar drying trends, the open-air system consistently demonstrated faster moisture removal, likely due to enhanced exposure to natural air circulation and relatively stable elevated temperatures. This contributes to its overall efficiency in the drying of farm produce.

However, while open-air drying proved more effective in terms of drying speed, concerns remain regarding hygiene and potential contamination due to direct exposure to environmental factors. Nevertheless, it offers a practical advantage in reducing post-harvest losses by minimizing the risk of spoilage associated with mould growth in inadequately dried products.

References

[1]. Hao, W.; Zhang, H.; Liu, S.; Lai, Y. Design And Prediction Method Of Dual Working Medium Solar Energy Drying System. Appl. Therm. Eng. 195, 117153. [Google Scholar] [Crossref] (2021)

[2]. Villagran, E.; Henao-Rojas, J.C.; Franco, G. Thermo-Environmental Performance Of Four Different Shapes Of Solar Greenhouse Dryer With Free Convection Operating Principle And No Load On Product. Fluids, 65, 183. [Google Scholar] [Crossref] (2021)

[3]. Elzubeir, A.O. Solar Dehydration Of Sliced Onion. Int. J. Veg. Sci., 20, 264–269. [Google Scholar] [Crossref] (2014)

[4]. Fernandes, L.; Tavares, P.B. A Review On Solar Drying Devices: Heat Transfer, Air Movement And Type Of Chambers. Solar, 4, 15–42. [Google Scholar] [Crossref] (2024)

[5]. Edwin Villagran, John Javier Espitia, Fabián Andrés Velázquez And Jader Rodriguez. Solar Dryers: Technical Insights And Bibliometric Trends In Energy Technologies. Advanced Journals Agriengineering Volume 6, Issue 4, 10.3390/Agriengineering6040228. (2024)

[6]. Kumar, M.; Sansaniwal, S.K.; Khatak, P. Progress In Solar Dryers For Drying Various Commodities. Renew. Sustain. Energy Rev., 55, 346–360. [Google Scholar] [Crossref] (2016)

[7]. Prakash, O.; Kumar, A. Historical Review And Recent Trends In Solar Drying Systems. Int. J. Green Energy, 10, 690–738. [Google Scholar] [Crossref] (2013)

[8]. Radhakrishnan, G.; Breaz, T.O.; Al Mahrouqi, A.W.A.; Al Zakwani, N.A.; Al Fahdi, M.H.; Al Shuraiqi, A.S.; Al Awamri, S.A.; Al Aamri, R.S.; Karthikeyan, K.R. A Comparative Management Analysis On The Performance Of Different Solar Drying Methods For Drying Vegetables And Fruits. Sustainability, 16, 775. [Google Scholar] [Crossref] (2024)

[9]. Kumar, M.; Sahdev, R.K.; Tiwari, S.; Manchanda, H.; Chhabra, D.; Panchal, H.; Sadasivuni, K.K. Thermal Performance And Kinetic Analysis Of Vermicelli Drying Inside A Greenhouse For Sustainable Development. Sustain. Energy Technol. Assess. 2021, 44, 101082. [Google Scholar] [Crossref]

[10]. Firfiris, V.K.; Kaffe, Z.D.; Kalamaras, S.D.; Lithourgidis, A.A.; Martzopoulou, A.G.; Kotsopoulos, T.A. A Prototype Passive Solar Drying System: Exploitation Of The Solar Chimney Effect For The Drying Of Potato And Banana. Appl. Sci., 12, 11784. [Google Scholar] [Crossref] (2022)

[11]. Delgado-Plaza, E.; Peralta-Jaramillo, J.; Quilambaqui, M.; Gonzalez, O.; Reinoso-Tigre, J.; Arevalo, A.; Arancibia, M.; Paucar, M.; Velázquez-Martí, B. Thermal Evaluation Of A Hybrid Dryer With Solar And Geothermal Energy For Agroindustry Application. Appl. Sci., 9, 4079. [Google Scholar] [Crossref] (2019)

[12]. Barbosa, E.G.; De Araujo, M.E.V.; De Oliveira, A.C.L.; Martins, M.A. Thermal Energy Storage Systems Applied To Solar Dryers: Classification, Performance, And Numerical Modeling: An Updated Review. Case Stud. Therm. Eng., 45, 102986. [Google Scholar] [Crossref] (2023)

[13]. Gajendra Prasad1, Laxmi Narayan Sethi1, Gajendra Prasad1. Solar Drying Technology For Agricultural Products: Arcc Journals. Agricultural Reviews. A Review Volume 45 Issue 4. 579-589, Doi: 10.18805/Ag.R-2457. (2024)

[14]. Kumar, A. And Tiwari, G.N. Thermal Modelling Of A Natural Convection Greenhouse Drying System For Jaggery: An Experimental Validation. Solar Energy. 80: 1135-1144. (2006)

[15]. Badgujar, C.M., Karpe, O.S. And Kalbande, S.R. Studies On Drying Characteristics And Techno-Economic Analysis Of Sprouted Moth Beans (Vigna Aconitifolia) In Solar Tunnel Dryer. Indian J. Agric. Res. 53(2): 151-157. Doi: 10.18805/Ijare.A-5180. (2019)

[16]. Amir, M., Singh, N. And Upadhyay, R. Solarized IPM Module For Biocontrol Of Root-Knot Nematode On Tomato At Nursery Level In District G.B Nagar, Uttar Pradesh. Agricultural Science Digest. 44(3): 518-522. Doi:10.18805/Ag.D-5863. (2024)

[17]. Norton, B., Fleming, P.D. And Ekechukwu, O.V. Passive Autarkic Solar Drying Techniques. Proceedings Of The Physics And Technology Of Solar Energy, New Delhi, India, D Reidal, Netherlands. (1987)