Short Research Article

Design and fabrication of a multi-functional electric-solar driven dryer: Performance evaluation using cassava and red pepper.

ABSTRACT

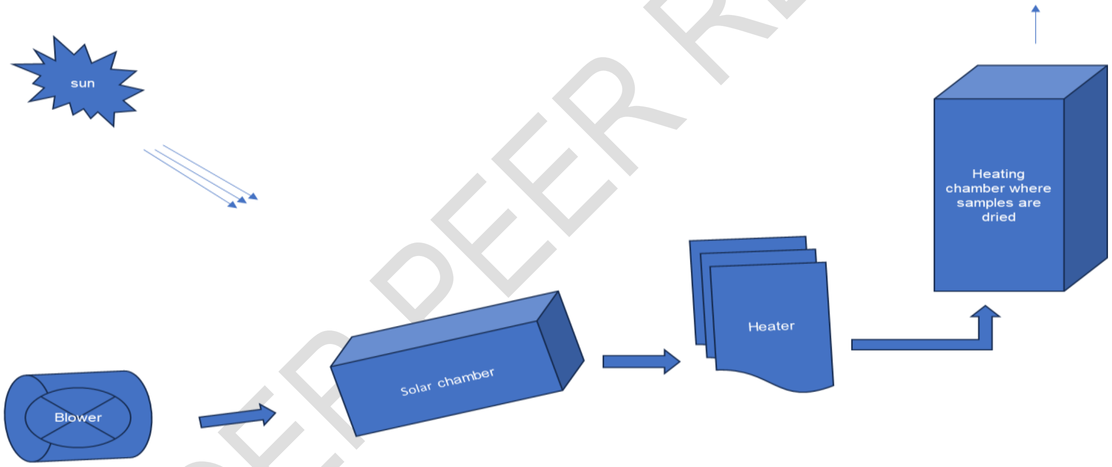
In this study, a multi-functional dryer utilizing electric and solar energy sources was designed and fabricated. Its performance and efficiency were evaluated at 55°C, 60°C, and 65°C using cassava and red pepper. The blower, solar chamber, heater, and heating chamber were the major components of the dryer. The Bill of Engineering Measurement and Evaluation revealed a total of $260 was spent. The weight and moisture content were reduced as the drying time and temperature were increased for both the cassava and the red pepper. Higher removal of moisture was noticed at the initial stage of drying before constant weight was attained after some drying periods. For red pepper, the percentage of moisture removed was 71.51%, 74.5%, and 80.77% while the dryer performance was 14.89 kg/hr, 18.63 kg/hr, and 25.24 kg/hr at 55°C, 60°C and 65°C respectively. For cassava, the percentage of moisture removed was 84.66%, 89.3%, and 90.62% while the dryer performance was 33.86 kg/hr, 35.71 kg/hr, and 41.43 kg/hr at 55°C, 60°C and 65°C respectively. In conclusion, the designed and fabricated multi-functional electric-solar driven dryer was effective for drying the examined products and can be adopted by local farmers due to its high efficiency and low cost.

Keywords: Drying time, moisture content, dryer performance, design, fabrication

1. INTRODUCTION

In Africa, one of the sustainable development goals is to ensure food security and sustainability. However, food shortage has been linked to inadequate food preservation as a result of high-cost, inefficient, and unreliable preservative sources/devices (Gallali et al. 2000). Usually during hot climates, degradation of the nutritional contents of agricultural products is experienced resulting from inadequate preservation methods between the point of harvest and sale. Many of these products get spoilt before they are transported to the urban areas for consumption. This discourages many farmers from investing their little income, with little or no financial support from the government, in farming. The little products that arrive at their respective destinations in good form are sold at high prices to the consumers. Good preservation is essential to maintain their life spans and ensure better income from their sale. Of all the traditional preservation methods (canning, smoking, sun drying, canning, freezing, use of chemical additives, packaging, and so on), the usually adopted low-cost preservative method that an average farmer can afford is sun-drying (Abubakar et al. 2018). The mechanism involves lowering or stopping the bacteria growth rate which is the major agent of decay (Wang et al. 2018). However, this can only handle a small volume of perishable fruits and other agricultural products. Not only this, but goods are also marred with rodents, pathogens, and insect contamination alongside roadside dust, sand, and other inorganic junk materials.

Food spoilage has been linked to the volume of their moisture content. Hence, this calls for advanced and thorough research to improve the efficiency of the drying method being the most cost-effective means that can reduce food and agricultural products' water content for efficient preservation. Drying of crops is used in most areas of the world especially those without a high humidity during the harvesting season. Farmers would achieve some reasonable savings if the drying of produce were widely adopted. These could help strengthen the economic situation of numerous developing countries while agricultural products are still delivered at the required nutritional values. Thus, this brings the need to design more effective and efficient food drying techniques (Zoungrana et al. 2021). Recent studies are focusing on the design of dryers for the preservation of agricultural products via renewable energy sources (solar energy) owing totheir availability and low cost (Table 1). However, there is a need for improvement in its ability to handle large volumes of different products with high efficiency at low cost (Ekechukwu et al. 1999, Hayatu et al. 2022).



Graphical Abstractof multi-functional electric-solar driven dryer.

Table 1: Different solar dryer types for different agricultural products for present and previous studies

Dryer Type	Design	Product	Drying Conditions	Dryer Efficiency	Reference
Double-pass solar drier	Forced convection indirect type	Red chilli	32 h to attain 10% moisture content	24.04% with a drying cost of 0.077	Banout et al. 2011

				US$/kg	
Cabinet drier	Conventional	Red chilli	73 h to attain 10% moisture content	11.52% with a drying cost of 0.126 US$/kg	Banout et al. 2011
Double-layer solar dryer	Top and bottom airflow mechanism	Banana	1 m/s air flow rate and moisture difference of 3.1%	Top airflow (27.5%), Bottom airflow (38.21%)	Hegde et al. 2015
Double-compartment solar dryer	Convective air movement after heating in a compartment	Tomatoes	Solar radiation = 700W/m^{2}, 58 ^{o}C, 350g for 2 h, and Moisture content reduced from 90 % to 26.7 %	87.8%	Balogun et al. 2017
Solar dryer	1000 mm x 410 mm x 700mm, galvanized sheet, and the glass (800 mm x 380 mm)	Scotch bonnet pepper	200 g for 3 weeks and 81.3% moisture content was removed	28.4%	Kilanko et al. 2019
Dual-energy source solar dryer	Four opposite side walls are covered with ¾" thick plywood sheets and a glazing material of 3 mm thick glass.	Tomatoes	47 ^{o}C, air mass flow rate = 0.025 kg s^{-1}, and drying rate = 0.03906 kg h^{-1}. Moisture content reduced from 94% to 4% in three days on a wet basisunder drying time for 24 h	64%	Hayatu et al. 2022
Multi-functional electric-solar driven dryer	Transparent glass of 2 mm thick, insulator asbestos, 5 cm high flat plate collector, and solar chamber inclined between 15^{o} to 30^{o}.	Cassava	Drying between 55 - 65 ^{o}Cfor 12 hrs. Percentages of moisture removed were 84.66%, 89.3%, and 90.62%.	Performance of 33.86 kg/hr, 35.71 kg/hr, and 41.43 kg/hrat 55 ^{o}C, 60 ^{o}C, and 65 ^{o}C respectively	This study
Multi-functional electric-solar driven dryer	Transparent glass of 2 mm thick, insulator asbestos, 5 cm high flat plate collector, and solar chamber inclined between 15^{o} to 30^{o}.	Red pepper	Drying between 55 - 65 ^{o}C for 12 hrs. Percentages of moisture removed were 71.51%, 74.5%, and 80.77%.	Performance of 14.89 kg/hr, 18.63 kg/hr, and 25.24 kg/hr at 55 ^{o}C, 60 ^{o}C, and 65 ^{o}C respectively	This study

Studies have shown high drying time with high levels of contamination for products dried via previously adopted drying methods (Purohit et al. 2006, Bhuyan et al. 2019, Ayanlade et al. 2019). This is because the drying process is often conducted in the open air. Not only this, there is a necessity to design and construct a highly efficient multi-energy source as well as a multi-purpose dryer that would remove higher moisture content from food products within a very short period for better preservation (Lingayat et al. 2020). In this study, a multi-purpose dryer utilizing double energy sources was designed and fabricated and its performance was evaluated via drying of red pepper and cassava. These two products were examined because of their high consumption and potentialto produce various foods from them (Egwu 2016). The drying rate of each of the examined food products was adequately monitored. It is double-energy sourced as it derives its heat energy from two power sources to reduce the overall drying time and it is multi-purpose to be generally used to dry more than one food product.

2. MATERIAL AND METHODS

This includes sample preparation, the working mechanism of the dryer and its description, material selection, and design of the major components.

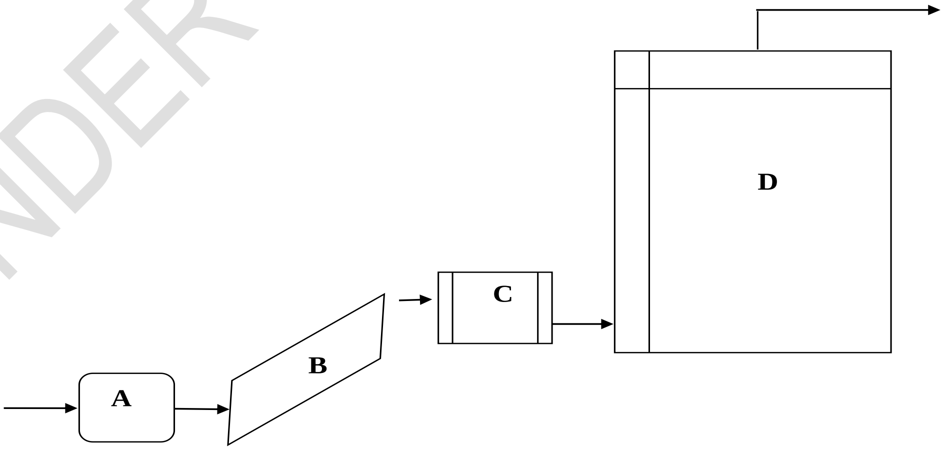
2.1 Sample Preparation

The sample preparation for the study involved several steps. Firstly, the cassava tubers were obtained, peeled, and the loss in weight due to peeling was about 30% of the fresh weight. These tubers were then sliced into thin pieces, washed thoroughly, and soaked for a few hours to reduce the hydrogen cyanide content, particularly in bitter cassava varieties. After soaking, the slices were drained thoroughly and spread on trays for drying.

The samples used in the load tests, which included both cassava and red pepper, were sourced from the locality of Ogbomoso town, Oyo State, Nigeria. The initial weight of these test samples was determined after they were peeled, sliced, washed, and allowed to drain.

2.2Working principle and dryer description

Figure 1 presents the process flow diagram of the working principle of the dryer. Ambient air is sucked from the environment via a centrifugal fan which acts as the blower (A). It then forces it through the solar chamber (B) where the air is heated first with the help of solar energy incident on the flat plate collector. The heated air is then blown across the heater (C) into the heating chamber (D). The heating chamber comprises a double-layered wall lagged with fiberglass to prevent heat loss. The inner walls were made of galvanized steel sheet to resist corrosion while the outer wall was made of mild steel. The dry hot air picks up moisture from the material in the heating chamber and becomes humid. The humid air is then passed out through the chimney with the aid of an axial fan to prevent condensation on the walls of the dryer.



A = Blower, B = Solar Chamber, C = Heater, D = Heating Chamber and → = Air Flow

Figure 1: Schematic showing the working principle of the dryer.

2.3Material selection and design of multi-functional electric-solar dryer major components

2.3.1 The solar chamber

The solar chamber comprises a flat plate collector, thermic-absorber, and insulating material. A 2 mm thick transparent glass was used to compose the flat plate collector. The thermic-absorber is made up of sheet metal, painted black to maximize its heat-absorbing capacity. The flat plate collector can collect solar energy between 60°C – 70°C and asbestos was used as the most suitable insulator. The flat plate collector is placed above the absorber plate at approximately 5 cm to minimize the heat losses from the front surface. To trap more effective solar heat, the solar chamber was inclined at an angle between 15° to 30°.

2.3.2The blower

The blower is a centrifugal fan which consists of impeller blades. It blows air into the heating chamber via the impeller blades and thus, enhances the drying of food products at a faster rate within a short time. The products are placed in the tray to allow the hot air blown by the blower to penetrate the surface for the drying process to occur. The flow lines of the hot air from the thermic-absorber channel are passed against its sides. The hot air has high velocity when it comes out of the fan but the air which is just behind it, above, below, or on the sides that has not been through it has a low velocity. An air diffuser was used to reduce the friction generated due to the different air velocities, as well as turbulence, which leads to loss in energy. The shape of the dryer was reconsidered in order to present an aerodynamic profile to the airflow. Equations 1, 2, 3, and 4 represent the theoretical head flow (*Hm)*, actual head flow (*Ha*), slip factor (S_f), and the power (*P*) developed by the blower respectively.

$$H_m = \frac{1}{g}\left[U_2 V_{w2} - U_1 V_{w1}\right] \qquad (1)$$

where g = acceleration due to gravity (m/s^2), U_2 = tangential velocity of impeller outlet (m/s), V_{w2}= whirl velocity at impeller outlet (m/s), U_1 = tangential velocity of impeller inlet (m/s) and V_{w1}= whirl velocity at impeller inlet (m/s).

$$H_a = S_f\,(H_m) \qquad (2)$$

$$S_f = 1 - \left[\left(\frac{0.63\pi}{N}\right)\left(\frac{V_f}{U^2}\right) Cot\ \beta_2\right] \qquad (3)$$

where N = number of blades, V_f = air flow velocity (m/s), U = impeller tangential velocity (m/s) and β_2 = blade outlet angle (^{o}).

$$P = \frac{1}{\eta_{rev}} = \frac{F_a}{3,600}.\Delta P_i \qquad (4)$$

where η_{rev} = ventilator output, F_a = required flow rate (m^3/s) and ΔP_i= total energy loss due to friction (Pa).

2.3.3 The Heater

The selection of the heating elements was based on the design specification of the multi-functional electric-solar dryer. They are flat heaters having heating power of 1800 W each. The heat temperature is monitored within the chamber via an incorporated thermostat. The required heat to dry the food items in the drying chamber is determined by both the electrical heat supplied by the heater and the solar heat transferred to the heating chamber. The electrical heat supplied (Q_e) can be determined using Equation 5.

$$Q_e = IVt \qquad (5)$$

where I = current supplied to heater (A), V = voltage rating of the heater (V) and t = time duration of heating (min).

2.3.4 The Heating chamber

The actual drying of the food products occurs in the heating chamber which is a double-layered wall lagged with fiber-glass to prevent conductive heat losses. The inner and outer walls were made of galvanized steel sheets (because of their high durability and resistance to corrosion attribute) and mild steel sheets (due to their readily availability and lower cost) respectively. The chamber consists of trays made of stainless steel due to its high corrosion resistance. The mesh is selected to promote an even distribution of airflow within the chamber. Factors that determine the required energy for water dehydration/evaporation from food products are (1) drying time/duration (2) inlet air temperature and (3) moisture content after drying. Equation 6 was utilized to determine the amount of moisture removed during and after drying (M_w, kg).

$$M_w = \frac{(M_1 - M_2)}{100 - M_2} \times M_t \qquad (6)$$

where M_1 = initial moisture content of fresh product (%), M_2 = final moisture content of fresh product (%), and M_t = quantity of fresh product to be dried after pre-drying processing (kg). The energy required for drying (Q) is determined using Equation 7.

$$Q = mc\theta \qquad (7)$$

where m = mass of sample (g), c = specific heat capacity of food item (KJ/g.K), and θ = temperature change which is the difference between dryer temperature and ambient temperature (^oC).

2.4Fabrication procedure

The steps involved in the multi-functional electric-solar dryer fabrication are measurement and marking out, cutting welding, and drilling.

2.4.1Measurement and marking out.

This is the first step of fabrication. Here, measuring and marking out some materials was executed before they were cut. Square pipes, measuring tape, metal sheets, steel rule, and scriber were used. Some of the materials that were subjected to this operation were galvanized sheets, mild steel, square pipes, and angle iron.

2.4.2Cutting

This operation involved the use of a hack saw for cutting the angle iron, shear, and chisel for cutting mild steel and galvanized sheets. It is the process of separating the required dimensions earlier marked out from the entire materials.

2.4.3 Welding

Electric arc welding was adopted for the fabrication to permanently secure two or more parts joined to an¾ inch square pipe used for the framework. It involves the use of an electric welding machine and electrode (gauge twelve, Olecon) to form the permanent joints of the parts.

2.4.4 Drilling

Drilling of the parts was undertaken to allow the use of bolts and nuts to secure two parts temporarily. The support of each element and blower was drilled to allow bolts and nuts to hold them firmly to the support.

2.4.5Bolting and Nutting

Bolts and nuts were used to secure parts temporarily when the parts might be separated in the future either for repair or modification.

2.4.6Painting

Painting was done to prevent corrosion attacks and rusting. Red oxide was used for the first coating before another coat of paint was applied for a good appearance.

2.4.7 Maintenance

The longevity, efficiency, and reliability of the dryer will depend majorly on maintenance activities carried out regularly during the use of the dryer to its lifespan. These include: (1) cleaning the trays at the end of each drying activity, (2) freeing the glass of dust or materials that could impede its transparency and (3) the axial fan and centrifugal fan should be free from dust or any external body that could affect the working condition.

2.4.8Axial Fan

This is attached to the air outlet situated at the upper frame of the heating chamber. It sucks up dense air from the heating chamber to prevent condensation by the walls of the dryer. It helps to boost the overall airflow in the dryer.

2.5Bill of Engineering Measurement and Evaluation

Table 2 presents the Bill of Engineering Measurement and Evaluation (BEME) itemizing the materials used and their quantity, unit price, and total price for fabricating the multi-functional electric-solar dryer. A total of $260 was spent. This is a bearable cost for an average farmer as compared to the commercial purposes of this dryer.

Table 2: Bill of Engineering Measurement and Evaluation

Materials	Quantity	Unit price ($)	Total price ($)
Gauge 20 sheet metal	3	12.80	38.40
Gauge 20 sheet metal (galvanized)	2.5	35.73	89.33
½ inch angle iron	1	3.20	3.20
¾ inch square pipe	5	2.61	13.07

Fibre glass	1 bag	12.27	12.27
2ft x 4ft Glass	1	4.80	4.80
Electrodes	¼ packet	2.19	2.19
Rivets	2 dozens	0.13	0.27
Door hinges	2	0.27	0.53
Roofing sheets	3	2.40	7.20
Heating elements (1800W)	2	1.60	3.20
Axial fan	1	5.87	5.87
Temperature regulator	1	13.33	13.33
Red oxide	¼ tin	6.40	1.60
Black oxide	$^{1}/_{8}$ tin	6.40	0.80
Silver paint	$^{1}/_{8}$ tin	6.40	0.80
Centrifugal fan	1	20.27	20.27
Contactor	1	3.20	3.20
Electrical components	-	6.67	6.67
Rectifier	1	5.33	5.33
Door handle & catcher	1	0.64	0.64
Miscellaneous	-	-	26.67
TOTAL			**260**

3. RESULTS AND DISCUSSION

3.0Performance Evaluation

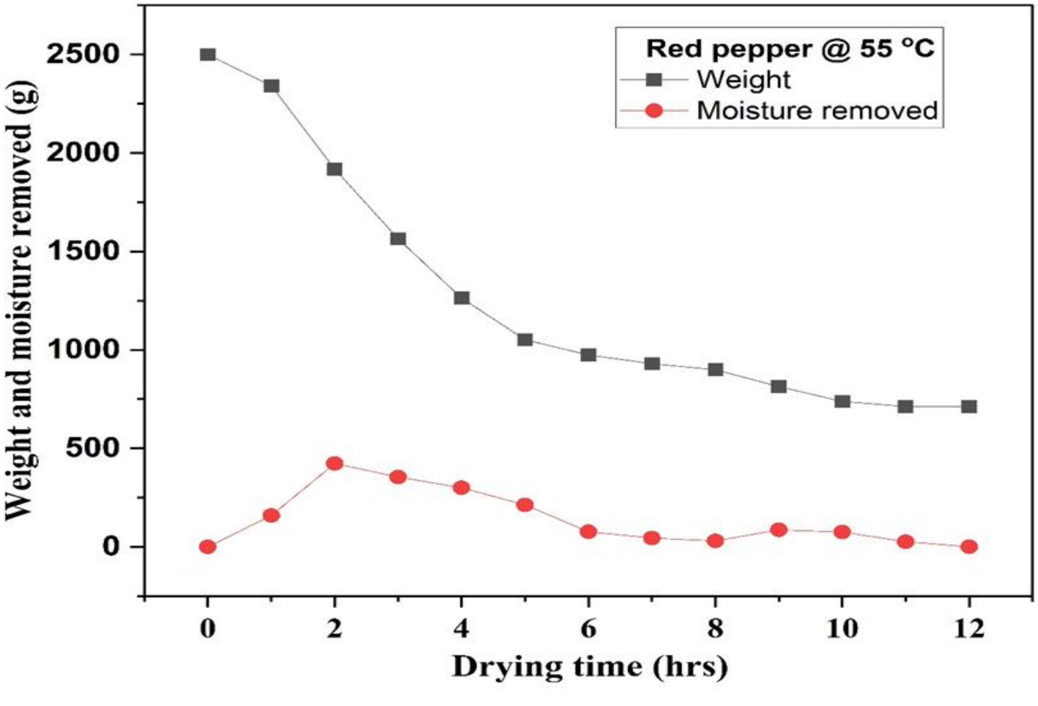
The performance of the dryer was tested using cassava and red pepper obtained from a market within the locality. The tests were carried out at 55 ^{o}C, 60 ^{o}C, and 65 ^{o}C. The selection of the temperature range was based on the drying attributes of the agricultural products (Ingram et al. 1972, Jakubczyk et al. 1982). This is to ascertain the most effective drying temperature concerning the time taken for the drying to be completed and also to know the temperature effect on the quality of tested samples. A thermostat and contactor were used to achieve this purpose. The cassava tubers were peeled and sliced into thin pieces alongside the red pepper. The initial and the final weights were monitored using an electric scale. The slices were then spread on the trays in the heating chamber. The dried weights were calculated at 1 h intervals until a constant weight was reached to record the moisture loss which can be calculated using Equation 8. The dryer performance (P_{dryer}) can also be determined using Equation 9.

$$Moisture\ loss = Initial\ Weight - Final\ Weight \qquad (8)$$

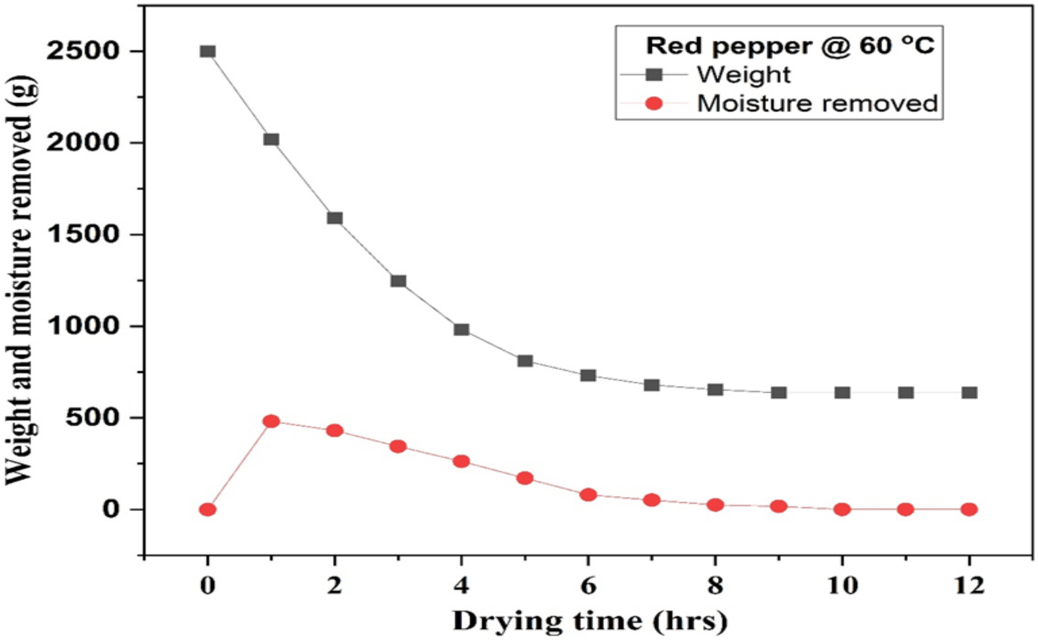
$$P_{dryer} = \frac{Total\ weight\ loss\ of\ sample}{Total\ drying\ time} \times 100\% \qquad (9)$$

3.1 Drying profile and dryer efficiency for red pepper

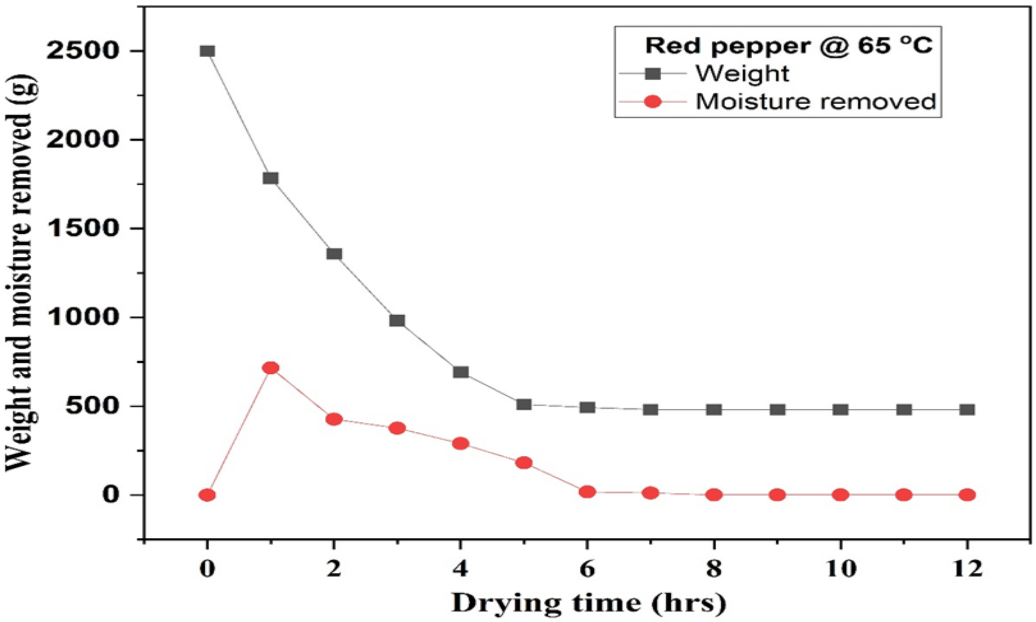
Figure 2 presents the weight loss and moisture content variation of red pepper dried at 55 ^{o}C (Figure 2a), 60 ^{o}C (Figure 2b), and 65 ^{o}C (Figure 2c) using the designed and fabricated multi-functional electric-solar driven dryer. At 55 ^{o}C, the amount of moisture removed increased exponentially to 423 g after the first 2 hrs of drying. This could be attributed to moisture removal on the surface of the red pepper as a result of high moisture content during the initial period of drying. After this point, the amount of moisture removed reduced steadily till a drying period of 12 hrs. A similar observation was recorded for the same product at 60 ^{o}C (Figure 2b) and 65 ^{o}C (Figure 2c) after the first 1 hr of drying with moisture removed to be 480.9 g and 716.2 g respectively. The moisture present in the interstices and intergranular layers of the products was removed after the initial drying stage. The weight of the red pepper was reduced from 2500 g to 712.3 g, 637.2 g, and 480.8 g at 55 ^{o}C, 60 ^{o}C, and 65 ^{o}C respectively after drying for 12 hours. Relatively constant weight was attained after 10 hrs, 7 hrs, and 5 hrs at 55 ^{o}C, 60 ^{o}C, and 65 ^{o}C respectively. Table 3 presents the percentage of moisture removed (71.51%, 74.5%, and 80.77%) determined using Equation 10 and the dryer performance (14.89 kg/hr, 18.63 kg/hr and 25.24 kg/hr) determined via Equation 9 at 55 ^{o}C, 60 ^{o}C and 65 ^{o}C respectively.



(a)



(b)

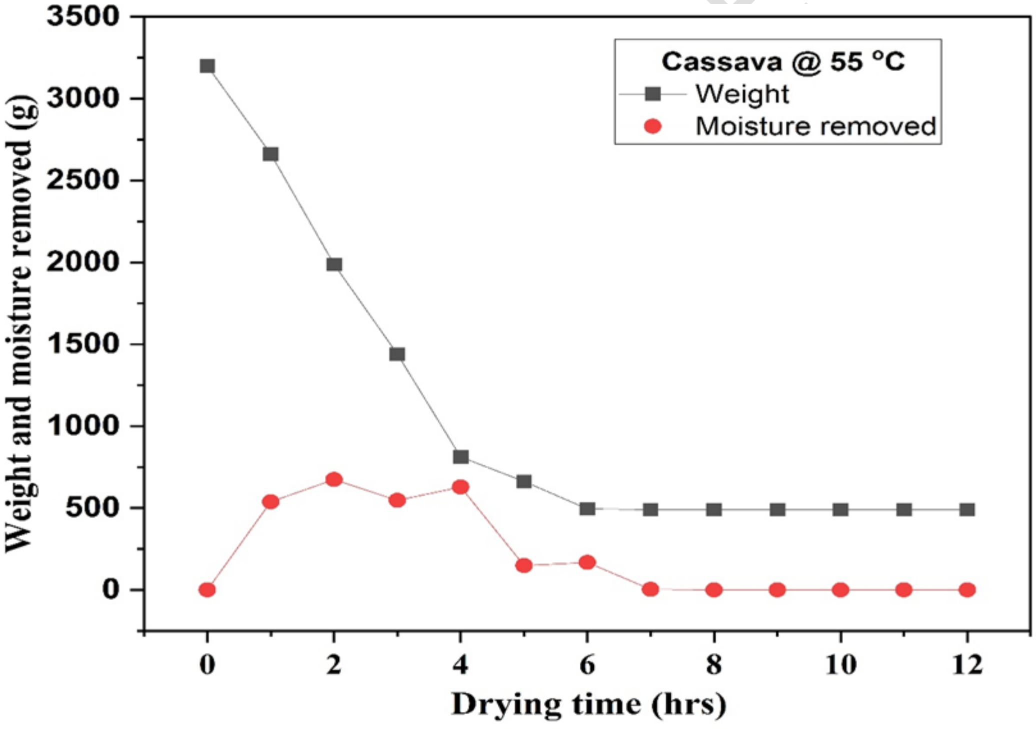


(c)

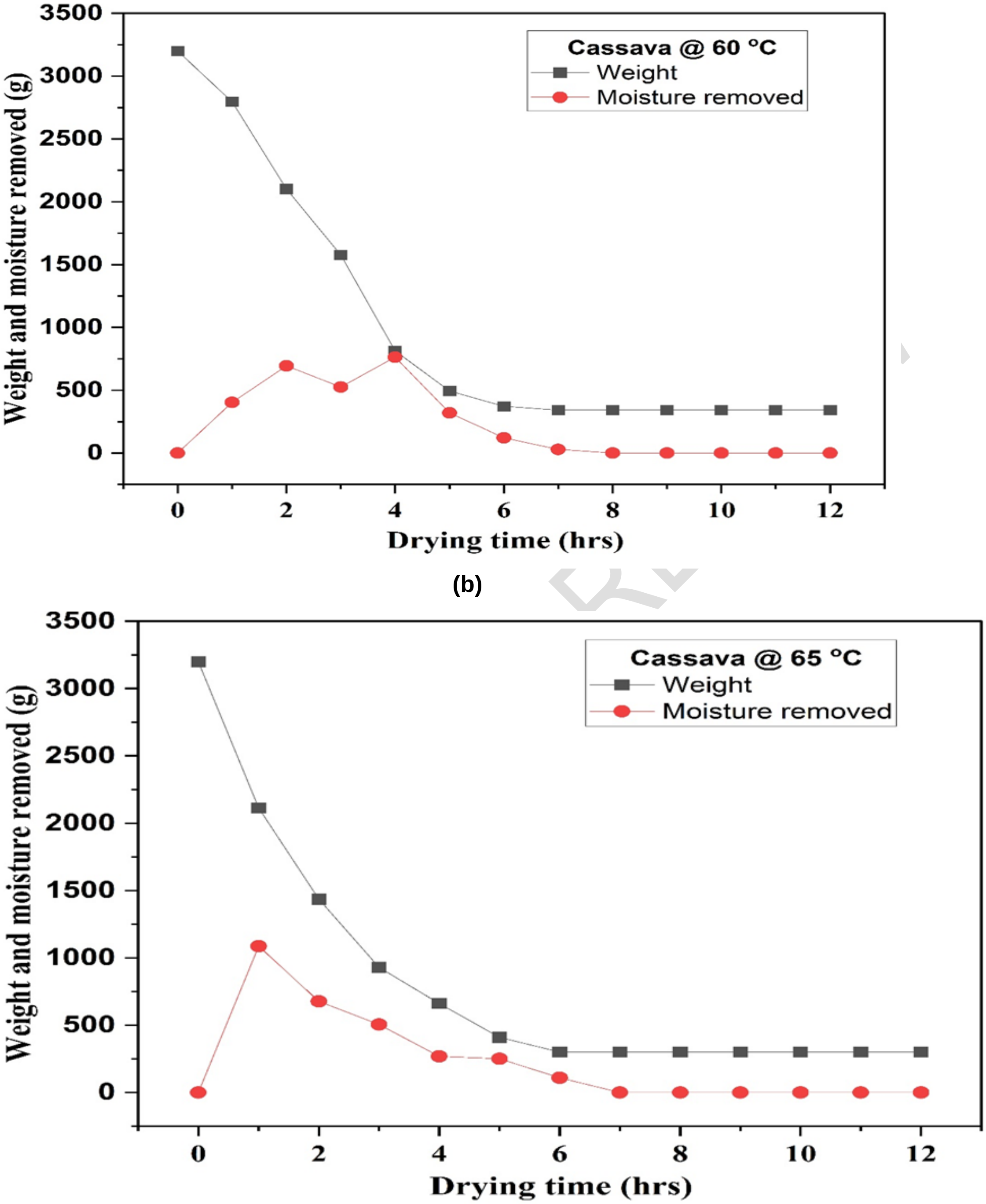
Figure 2: Weight and moisture content variation of red pepper dried at (a) 55 °C (b) 60 °C and (c) 65 °C using a multi-functional electric-solar driven dryer.

3.1 Drying profile and dryer efficiency for cassava

The weight loss and moisture content variation of cassava dried at 55 ^{o}C (Figure 3a), 60 ^{o}C (Figure 3b), and 65 ^{o}C (Figure 3c) using the designed and fabricated multi-functional electric-solar driven dryer are presented. At 55 ^{o}C after drying for 2 hrs, the amount of moisture removed increased rapidly to 674.4 g which resulted from the excess moisture content present on the cassava surface during the initial drying phase. The mass of moisture removed reduced steadily between the drying periods of 2 – 7 hrs after which relatively constant value was recorded till 12 hrs. At 60 ^{o}C, two maximum points at drying time of 2 hrs and 4 hrs were recorded with respective amounts of moisture removed to be 694 g and 763.2 g. The amount of moisture removed then reduced steadily till 8 hrs after which a constant value was observed till 12 hrs of drying the cassava. The drying trend at 65 ^{o}C was similar to the one observed at 55 ^{o}C but a maximum amount of 1087.1 g moisture was removed after 1 hr of drying. In all the drying profiles after the initial drying phase, the removal of moisture present within the cassava granular layers and interstices was removed. The weight of the cassava reduced from 3200 g to 490.8 g, 342.5 g, and 300.2 g at 55 ^{o}C, 60 ^{o}C, and 65 ^{o}C respectively after drying for 12 hours. Relatively constant weight was attained after 6 hrs at all the examined temperatures. The percentage of moisture removed, determined using Equation 10, was 84.66%, 89.3%, and 90.62% at 55 ^{o}C, 60 ^{o}C, and 65 ^{o}C respectively. The dryer performance, determined via Equation 9, was 33.86 kg/hr, 35.71 kg/hr, and 41.43 kg/hr at 55 ^{o}C, 60 ^{o}C, and 65 ^{o}C respectively as presented in Table 3.



(a)



(b)

(c)

Figure 3: Weight and moisture content variation of cassava dried at (a) 55 °C (b) 60 °C and (c) 65 °C using the multi-functional electric-solar driven dryer

$$\%\ Moisture\ removed = \frac{Y - X}{Y} \times 100\% \qquad (10)$$

Table 3: Percentage of moisture removed and dryer performance at different drying temperatures

		Temperature (^oC)		
		55	**60**	**65**
Red pepper	Moisture removed (%)	71.51	74.5	80.77
	Dryer Performance (kg/hr)	14.89	18.63	25.24
Cassava	Moisture removed (%)	84.66	89.3	90.62
	Dryer Performance (kg/hr)	33.86	35.71	41.43

4. CONCLUSION

A multi-functional electric-solar driven dryer was designed and fabricated, and its performance efficiency was tested for cassava and red pepper at 55°C, 60°C, and 65°C. The dryer integrates a blower, solar chamber, heater, and heating chamber—a synergy of components that leverages convective and radiative heat transfer mechanisms to optimize the drying process. This combination embodies the principles of thermal dynamics and fluid mechanics to ensure uniform air distribution and consistent drying. Upon reviewing the Bill of Engineering Measurement and Evaluation, $260 was considered the appropriate amount to spend on this project.

The science behind the drying process is evidenced by the weight and moisture content reduction of the cassava and red pepper as drying time and temperature increased, in line with the expected behavior of hygroscopic materials undergoing moisture desorption. The initial rapid moisture removal can be attributed to the abundant availability of free water on the surface of the products and the higher vapor pressure gradient at the beginning of the drying process. Subsequently, the drying rate decreased, indicating a transition to the falling rate period where diffusion mechanisms became predominant.

For red pepper, the percentage of moisture removed were 71.51%, 74.5%, and 80.77%, while the dryer's performance was measured at 14.89 kg/hr, 18.63 kg/hr, and 25.24 kg/hr at 55°C, 60°C, and 65°C, respectively. For cassava, the percentage of moisture removed was 84.66%, 89.3%, and 90.62%, with performance rates of 33.86 kg/hr, 35.71 kg/hr, and 41.43 kg/hr at the corresponding temperatures. These results confirm the design's efficacy and underscore the importance of temperature control in enhancing the drying kinetics for different materials.

In conclusion, the multi-functional electric-solar driven dryer, underscored by its innovative engineering design and alignment with scientific drying principles, proved effective for drying the examined agricultural products. Its high efficiency and low cost are advantageous for adoption by local farmers, presenting a viable solution that promotes sustainability and improved post-harvest processing in agricultural practices.

REFERENCES

1. Gallali YM, Abujnah YS, Bannani FK (2000) Preservation of fruits and vegetables using solardrier: A comparative study of natural and solar drying, III; chemical analysis andsensory evaluation data of the dried samples (grapes, figs, tomatoes, and onions). Renewable Energy, 19, 203–212.

2. Abubakar S, Umaru S, Kaisan MU, Umar UA, Ashok B, Nanthagopal K (2018) Developmentand performance comparison of mixed-mode solar crop dryers with and withoutthermal storage. Renewable Energy, 128, 285–298.
3. Wang W, Li M, Hassanien R, Hassanien E, Wang Y, Yang L (2018) Thermal performance ofindirect forced convection solar dryer and kinetics analysis of mango. Applied Thermal Engineering, 134, 310–321.
4. Zoungrana A, Çakmakci M (2021) From non-renewable energy to renewable by harvestingsalinity gradient power by reverse electrodialysis: A review. International Journal of Energy Research, 45(3): 3495-522.
5. Ekechukwu OV, Norton B (1999) Review of solar-energy drying systems: II: An overview ofsolar drying technology. Energy Conversion & Management, 40, 615–655.
6. Banout J, Ehl P, Havlik J, Lojka B, Polesny Z, Verner V (2011) Design and performance evaluation of a Double-pass solar drier for drying of red chilli (Capsicum annum L.). Solar Energy, 85, 506–515.
7. Hegde VN, Hosur VS, Rathod SK, Harsoor PA, Narayana KB (2015) Design, fabrication and performance evaluation of solar dryer for banana. Energy, Sustainability and Society, 5, 23.
8. Balogun MB, Anafi FO, Kulla DM (2017) Performance Evaluation of a Double Compartment Solar Dryer. Nigerian Journal of Solar Energy, Vol. 28, 1-8.
9. Kilanko O, Ilori TA, Leramo RO, Babalola PO, Eluwa SE, Onyenma FA, Ameh NI, Onwordi PN, Aworinde AK, Fajobi MA (2019) Design and Performance Evaluation of a Solar Dryer. Journal of Physics: Conference Series, 1378, 032001.
10. Hayatu, F.A., & Dukku, M.M. (2022). Development and performance evaluation of a dual energy source solar dryer for tomatoes. Global Journal of Engineering and Technology Advances.
11. Purohit P, Kumar A, Kandpal TC (2006) Solar drying vs. open sun drying: a framework for financial evaluation. Solar Energy, 80, 1568–1579.
12. Bhuyan J, Mohanty D, Jayapuria D (2019) Comparative study between solar dryer and open sun dried tomato under North Plateau Climatic Zone. Journal of Krishi Vigyan, 8(1), 28-33.
13. Ayanlade A, Atai G, Jegede MO (2019) Variability in atmospheric aerosols and effects of humidity, wind and InterTropical discontinuity over different ecological zones in Nigeria. Atmospheric Environment, 201, 369-80.
14. Lingayat AB, Chandramohan V, Raju V, Meda V (2020) A review on indirect type solar dryers for agricultural crops–Dryer setup, its performance, energy storage and important highlights. Applied Energy, 258, 114005
15. Egwu PN (2016) Impact of agricultural financing on agricultural output, economic growth and poverty alleviation in Nigeria. Journal of Biology, Agriculture and Healthcare, 6(2): 36-42.
16. Ingram JS, Humphries JRO (1972) Cassava Storage – A Review, Tropical Science, 14, 2, 87 – 92.
17. Jakubczyk TE (1982) Roots and Tubers Processing in Some African Countries, In: African Regional Centre for Technology (ARCT). Roots and Tubers Production, Storage, Processing and Marketing in Africa Dakar, 112 – 126
18. Hilly M, Adams ML, Nelson SC. A study of digit fusion in the mouse embryo. Clin Exp Allergy. 2002;32(4):489-98.

19. Jiang, D., Xiao, H., Zielinska, M., Zhu, G., Bai, T., & Zheng, Z. (2020). Effect of pulsed vacuum drying on drying kinetics and quality of roots of Panax notoginseng (Burk.) F. H. Chen (Araliaceae). Drying Technology, 0(0), 1–18

20. Boateng, I. D., & Yang, X. (2020). Effect of different drying methods on product quality, bioactive and toxic components of Ginkgo biloba L. seed. Journal of the Science of Food and Agriculture, 101,3290–3297

21 Benseddik, A., Azzi, A., Zidoune, M. N., Khanniche, R., & Besombes, C. (2019). Empirical and diffusion models of rehydration process of differently dried pumpkin slices. Journal of the Saudi Society of Agricultural Sciences, 18(4), 401–410.