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Performance Evaluation of Solar dryer for Medical leaf drying

*[1]Sadik U.,[1]Umar A.B, [1]Salihu M. A., [2]Muhammad A. and[1]Uthman M. I.
[1]*Department of Physics. Abdullahi FodioUniversity of Science and Technology, Aliero Kebbi. Nigeria.*
[2]*Department of Mechanical Engineering, Abdullahi FodioUniversity of Science and Technology, Aliero.*
Contact Author: S. Umar, Department of Physics, Abdullahi FodioUniversity of Science and Technology, Aliero, P.M.B 4411, Aliero, Nigeria.

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ABSTRACT
The use of solar dryer for medicinal and herbal drying is becoming an interesting area for traditional medicine more especially in the rural areas of the developing countries where a higher percentage of the populace uses herbal plant and leaf to cure diseases and infections. In this study, an experiment was conducted to evaluate the performance of solar dryer of two different medicinal leaves Tamarind (*TamarindusIndica)* and Moringa (*MoringaOleifera*) with an initial weight of 84.4g and 105.1g using natural convection solar dryer, and its daily drying efficiency was compared with the open sun drying under the climatic condition of Aliero Town in Northern Nigeria. The maximum drying chamber temperature of 52.°C was recorded throughout the experiment. This complies with the medicinal leaf drying consideration (not exceed 60°C). The moisture content of the leaves was reduced: Moringa from 97.7% to 17% and from 97% to 18% for 105.1g and 84.4g initial weigh respectively and, for Tamarind from 95.3% to 15% and 78.19% to 11% for 105.1g and 84.4g respectively. The daily average drying efficiency of solar drying compared to open drying shows that solar dryer dried faster than open sun drying. The use of solar dryer for medicinal leaves drying provide the hygienic product by shielding the drying leave from all form of contaminations contrary to the traditional open sun drying method. Therefore, adopting solar drying method for drying medicinal leaves would give heathy and more bioactive product.

Key words: moisture content, medicinal leaf, Moringa, Tamarind, solar dryer, drying.

I. INTRODUCTION

The use of herbal medicines has been increasing rapidly in the last decades worldwide[1]. It is an alternative to modern medications and consideredis safe with no side effects. More than 70 % of the population of the developing countries, uses herbal medicine for preventing and curing diseases as reported by Food and Agriculture Organization [2, 3]. Equally, 25% of modern drugs are produced from medicinal plants [4]. The Moringa and Tamarind leave used for medicinal herbs are required to be dried either for preservation or process to be used as medicine. Tamarind (*TamarindusIndica)* and Moringa (*moringaOleifera*) are among the medically essential trees that have good nutritional and medicinal values and also pharmacological effects [1, 5, 6]. Nearly all parts of the trees (root, branches, Leaves) are rich in nutritional values such as protein, minerals, vitamins, iron, etc. and have many health benefits like antioxidant, antibacterial, antidiabetic, antimalarial and antimicrobial[5, 7-10]. These leaves are used as a traditional medicine in Africa for the treatment of many diseases such as stomach disorder, cold, fever, dysentery, gastrointestinal infection, diarrhoea, jaundice, hypertension etc.They are also rich in essential amino acid [11, 12].

The Tamarind (*TamarindusIndica)* and Moringa (*moringaOleifera*) trees are grown in Nigeria.The leaves of the trees contain some moisture which could perish, if not process. Therefore, the leaves need to be dried for further processing or storage to reduce the moisture content and avoid spoilage due to the various reactions and prevent possible contamination by unwanted microbial attacks [13, 14]. In the drying process, besidesthe removal of water, the drying process needs to retain the highest value of bioactive ingredients of the plants for safe storage [15]. The essence of drying medicinal plant is not only for storage but also for the immediate pharmaceutical application that cannot be provided when the medicinal leaf is fresh. The leaves of the trees Moringa and Tamarind inclusive could be affected by higher heat which may lead to discolouration because of high temperature as their colour, and some vital constituents are sensitive to direct sun radiation [1, 16].

In the rural areas of most African countries, where medicinal herbs are often used as a source of medications, most of these herbs need to be dried before use. These herbs are predominantly dried in a traditional way (open sun drying) by spreading the herbs on a thin layer of mats, trays, or paved grounds [15].Although it is very cheap and practice, however, these drying herbs are of poor quality due to contamination by insects, birds and dust, discoloration by UV radiation and slow drying time [16, 17]. In the industries and laboratories for pharmacological applications the herbs are sometime dried conventionally (either sun drying or oven drying) the use of either of these may result in some negative consequences on the product. The use of oven requires extra energy and may also be contaminated by discoloration which reduce the quality of the product. Therefore, solar drying is the most economical and hygienic method of drying among all the methods [15].

Nigeria, like most of the sub-Saharan African countries, is blessed with abundant solar radiation and have average sunshine of 6.5 hours daily. It also received average daily solar radiation of 5.535kwh/m^2/day [18]. With this available free source of energy drying, herbal medicine is promising and achievable using solar collector devices.

Based on this availability of solar energy in Nigeria, several solar dryers were developed, and their performances were evaluated with mostly farm produce [19-21]. Still, only a few consider drying herbal medicine despite the need for that due to the acute shortage of electricity for oven drying and low quality of modern medicine in the country. Therefore, this study evaluates the performance of a simple natural convection solar dryer on drying of two medicinal herbs (Leaves) (Tamarind (*TamarindusIndica)* and Moringa (*MoringaOleifera*)) under the climate condition of NorthernNigeria.

1.1. DESCRIPTION AND PRINCIPLE OF OPERATION OF SOLAR DRYER

The solar dryer has two units; the collector unit, where air entering the dryer from below (inlet) is first preheated by radiation transmitted through the glass cover before going into the chamber, and the drying chamber where the item to be dried is placed on the tray inside opaque cabinet[16]. This type of dryer is suitable for green medicinal leaves drying because the solar radiation is not directly incident on the product for drying, as this may lead to colour changes and other thermal damages [16]. The heated air circulates through including over the wet material to be dried to provide heat for the moisture evaporation by convective heat transfer between the hot air and wet item. Drying takes place due to the difference in moisture concentration between the drying air and the air vicinity of the fresh item [22].

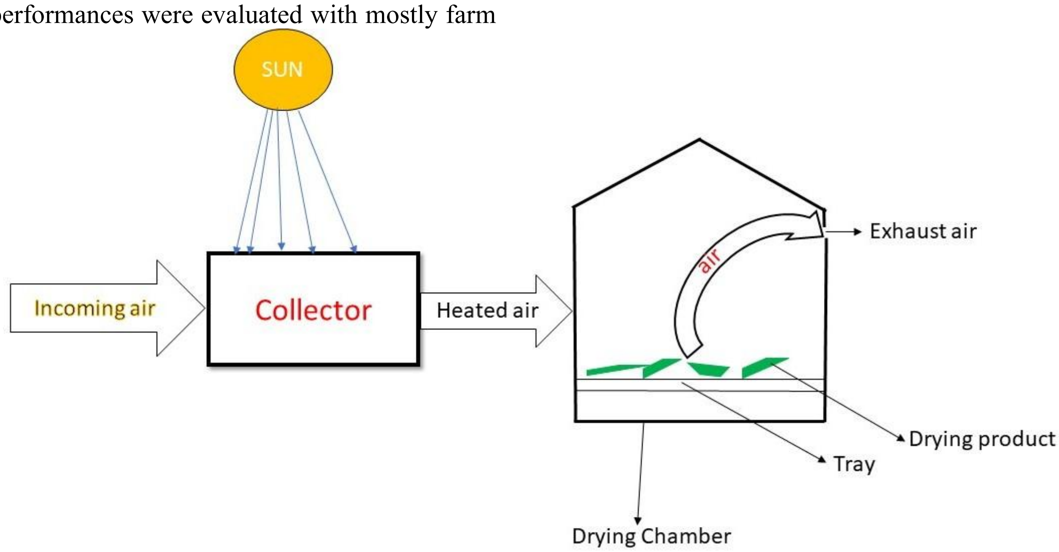

Figure 1.1: Schematic diagram of the drying process of the solar dryer

The schematic diagram of the drying process is presented in Figure 1.1. The natural convection solar dryer was made from the locally available materials. The collector of 0.43m^2 area which was made from 4mm galvanised iron (GI) sheet with 1 (one) inch foam in between the wooden case and GI as an insulator. The top of the collector was glazed with 3mm thickness glass for greenhouse. The mash wire was used to make the tray where the drying product was placed for drying.

The wooden case of the dryer of both collector and chamber was painted brown to avoid spoil from rainwater.

II. METHODOLOGY

The experimental test was carried out under the prevalent climatic condition of Kebbi State University of Science and Technology (KSUST) Aliero, Kebbi State, Nigeria at latitude 12° 17'37"N and longitude 4°28'5'E, during April 2025. Fresh green leaves of both Tamarind and Moringa were gotten from the trees in the premises of the Kebbi State University of Science and Technology, Aliero (KSUSTA), Nigeria. The experiments were carried out outside the premises of Faculty of Agriculture, KSUSTA at the meteorological Centre. The green leaves were weighed before putting it inside the drying chamber. Two different samples of each leaf (Tamarind and Moringa) were weighed and evenly arranged in a single layer on drying tray, as thin layer is more suitable for medicinal plant drying since the depth for plant drying should not exceed 0.5m[15]. For the open drying, the samples were spread in the open tray to compare solar drying with open sun drying. The hot air circulated into the drying chamber and escaped from the duct provided at the rear side near the top of the drying chamber after taking the moisture away from the leaves kept inside the chamber.

The experiment started around 9:00 am and end 6:00 pm each day for the period of the study. The weight of samples, ambient temperature, drying chamber temperature and collector temperature, as well as wind speed, was measured at every 1 hour, as shown in figure 2. 1. To determine the moisture loss and collector performance. The process continued until there is no significant change in the mass of the drying leaves observed. The temperatures were measured using digital thermocouple thermometer by placing each terminal at a given point. The air velocity was measured using Anemometer by mounting it at the same level and near the collector. Other parameters like solar radiations and relative humidity of the same days of the experiment were also measured at the same location (department of Physics, Faculty of Physical Sciences), KSUSTA.

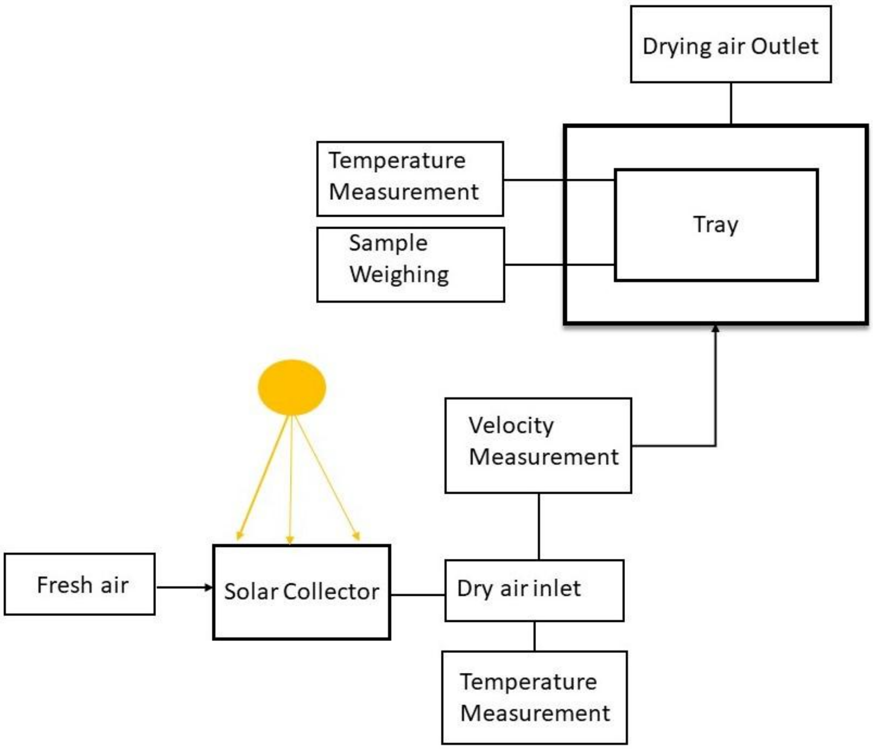

Figure 2.1: Flow chart of Experimental procedure of solar drying system.

The data from the experiment was used for the calculation of mass loss, moisture content (M.C) and efficiency of the solar collector using the following equations. The moisture content of the leave to be dried can be calculated from equation 1 as given by [23]

$$M.C = \frac{W_i - W_f}{W_i} \times 100 \quad (1)$$

Where, W_i is the weight of the leaves before drying, W_f is the weight of the leaves after drying.
The amount of water evaporated from the drying sample is given by

$$W_{ev} = W_i - w_f \quad (2)$$

The efficiency of the collector is estimated from equation (3)

$$\eta_c = \frac{W_{ev\,L}}{I_c A_c \times t} x\ 100\% \quad (3)$$

L is the latent heat of vaporisation of water (2320 KJ/Kg), I_c is the solar radiation received by the collector (w/m^2), t is the time and A_c is the area of the collector (m^2).

III. RESULTS AND DISCUSSION

The performance evaluation of natural convection solar dryer for medicinal leaf drying was carried out in this study. The experimental data obtained and recorded were on an hourly basis and is used to compute the moisture content on a wet basis and drying efficiency of the dryer. The results were depicted in figure 3.1 to 3.10

Figure 3.1 and 3.2 present the graph of variation of moisture content on a wet basis of the medicinal leaves with time at an initial weight of 105.1g and 84.5g, respectively. It can be observed from the figures that the moisture content decreases drastically with time for both medicinal leaves. The moisture content of moringa leaves was reduced from 97% to 17% and 95% to 13% for the initial leave weight of 105.1g and 84.5g respectively at the end of the day. The average moisture loss for moringa leave at M_{84g} was 81.8%, and $M_{105.1g}$ was 82.7%. For the Tamarind leave the average moisture content removed were 88% and 86% for $T_{84.4g}$ and $T_{105.1g}$ respectively. These were within the same range as 84% moisture loss recorded by Emmanuel *et al.*[24] and Kilanko*et al.*[23] whose use the mixed-mode solar dryer to remove up to 82 % moisture content of the pepper.

It can be observed from the figures for all the experiment that at the begging of the investigation i.e. early morning, the drying product loss much of its water content quickly. Furthermore, the rate of water moisture loss is proportional to the intensity of the heat energy, hence the temperature of the chamber, which was always at its peak between the 1:00 pm and 2: 00 pm.

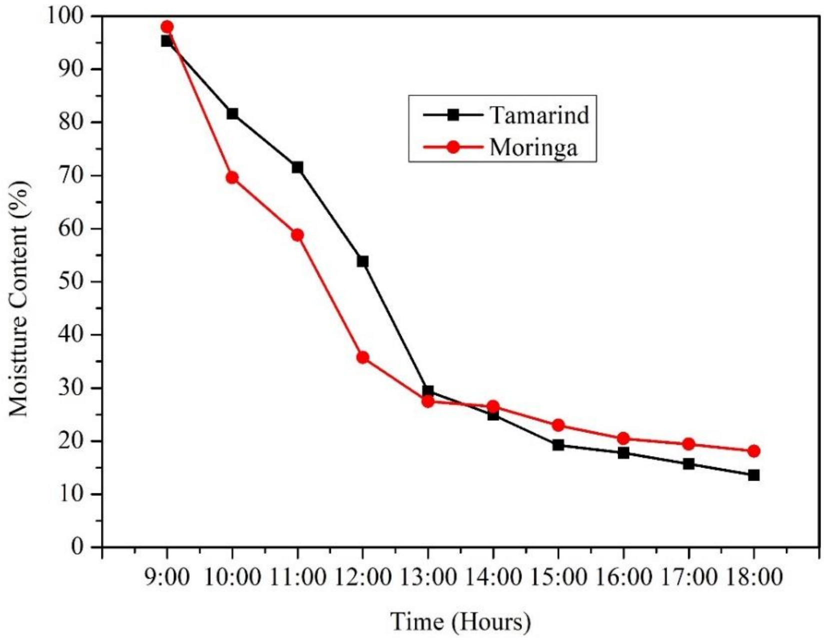

Figure 3.1: Moisture content against the time at 105.1g initial weight of the drying leaves

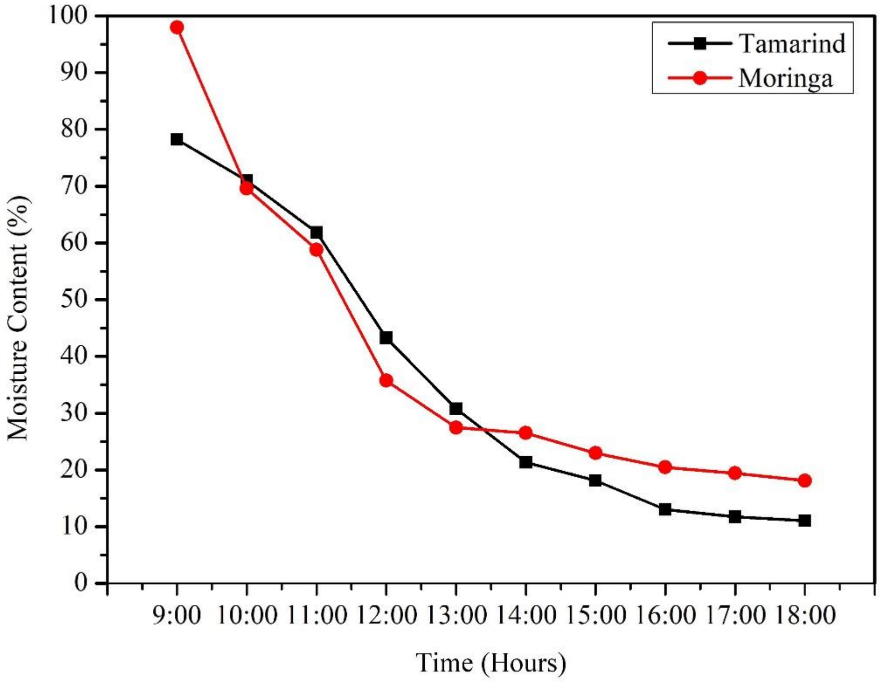

Figure 3.2: Moisture content against the time at 84.4g initial weight of the drying leaves

The temperature variations of ambient temperature and drying chamber temperature are shown in Figure 3.3 to 3.6. The drying chamber temperature was quite similar for both experiments. The ambient temperature was low at the early hours of the morning when the isolation is low and increases with the increase in radiations. Though the solar radiation intensity drops quite drastically in the post noon period, i.e. afternoon, ambient at this point does not fall drastically. This is due storage effects of insulation which help to retains the heat, being air a good insulator and absorbs the heat radiated by the earth.

As it was reported in the figures, that the drying chamber temperature was higher than the ambient temperature from 9: 00 am till late evening around 5:00 pm after which the ambient was relatively higher than drying chamber temperature as shown in figure 3.7 and 3.8. This is because the drying chamber temperature depends on the energy received by the collector from the sun and at the late evening there was low sun energy to be transferred to the drying chamber by convection, and ambient temperature takes a long time before it decreases, as air can serve as a good insulator. Figure 3.7 and 3.8 present the difference between the drying chamber temperature and ambient temperature with solar radiation as a function of time. As seen in the figures, the average temperature difference ranged from 2^o C to 17^o C. This was similarly observed by Bolaji and Olalusi[21] and Kilanko[23]. The maximum drying chamber temperature recorded for all the experiment was 52.5^{o}C which is within the range of the proposed as the optimum temperature for drying fruit, vegetables, and medicinal leaves[25]

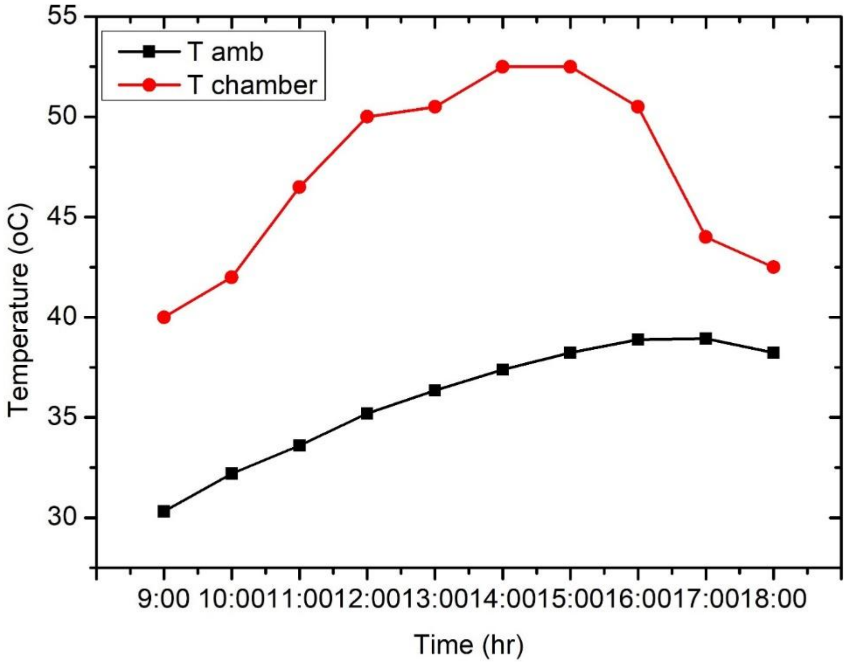

Figure 3.3: Temperatures against Time for Tamarind @ 105.1g

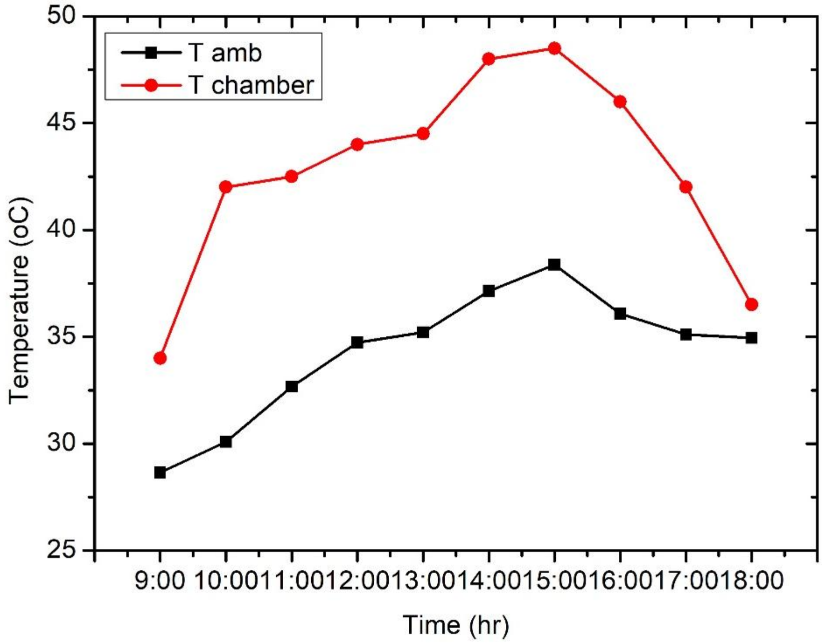

Figure 3.4: Temperatures against Time for Tamarind @84.4g

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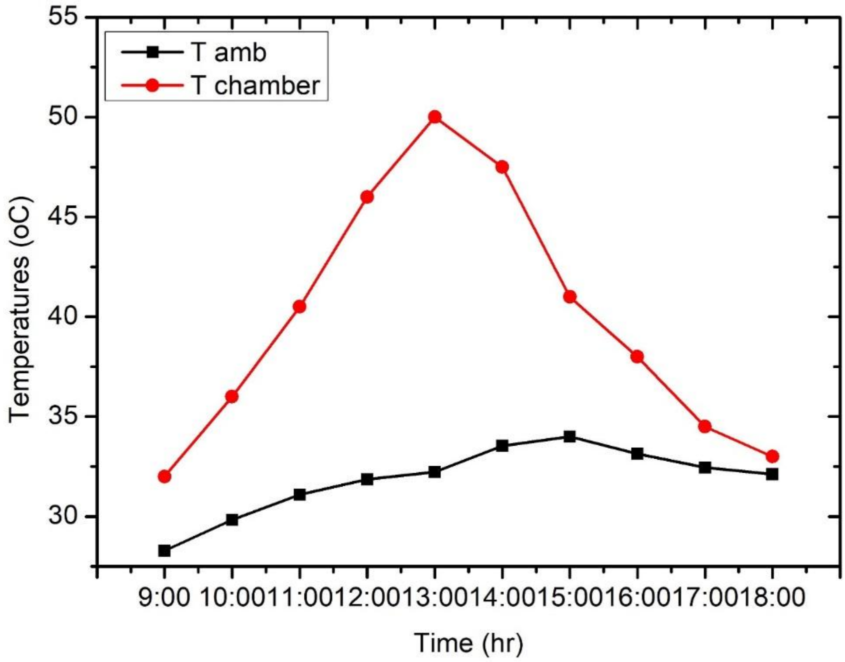

Figure 3.5: Temperatures against time for Moringa @105.1g

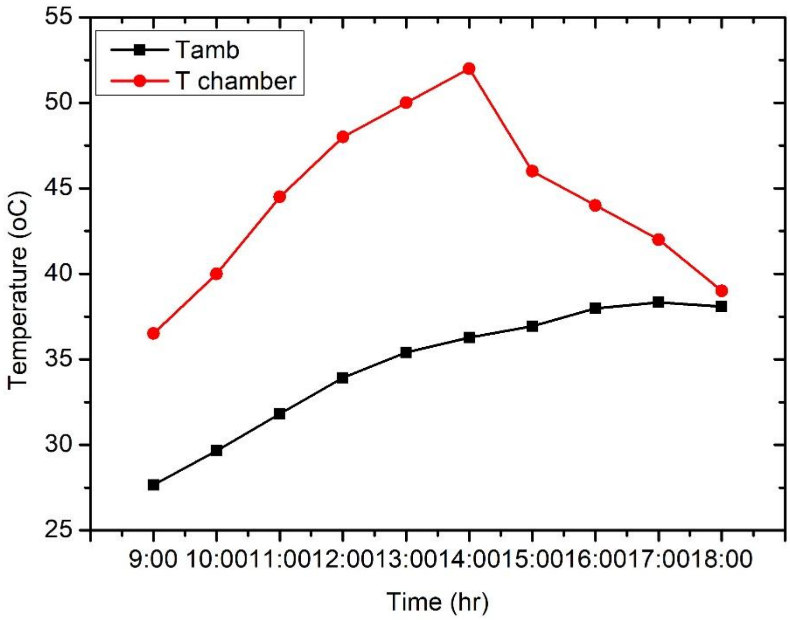

Figure 3.6: Temperatures against Time for Moringa at 84.4g

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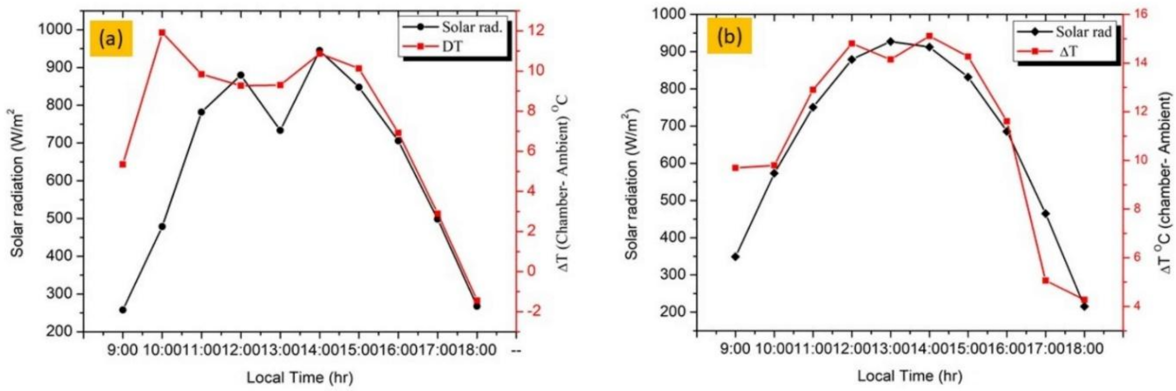

Figure 3.7: Variation of temperature difference (chamber – ambient) with Solar radiation as a function of time for Tamarind leave at (a) 84.4g and (b) 105.1g initial weight.

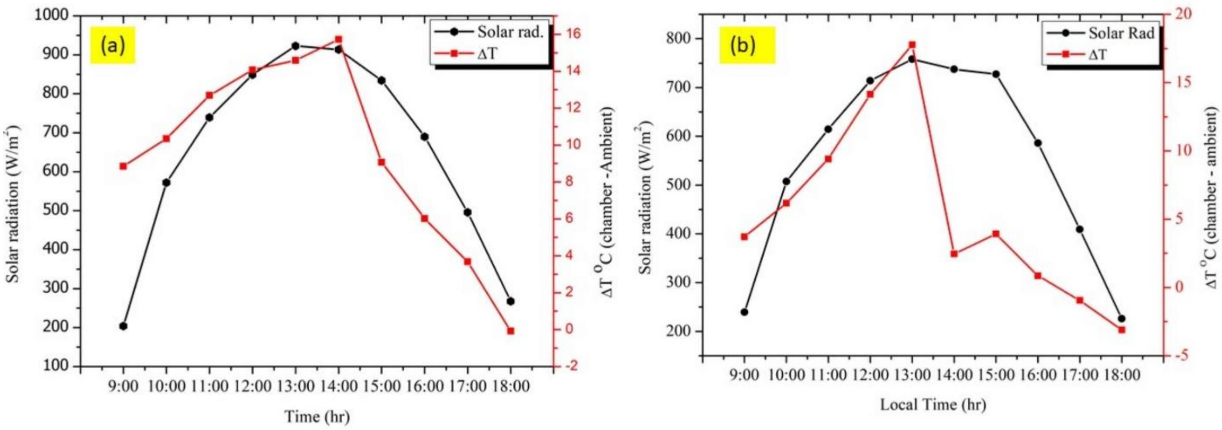

Figure 3.8: Variation of temperature difference (chamber – ambient) with Solar radiation as a function of time for Moringa leaves at (a) 84.4g and (b) 105.1g initial weight

The drying efficiency of the system was calculated using equation (3). Figure 3.9 and 3.10 present the efficiency variation of the solar drying for moringa and tamarind leaves at 84.4g and 105.1g initial weight of the leaves. The result from the graphs shows that the highest efficiencies of 35% and 32% were achieved for Moringa and Tamarind respectively for 105.1g initial weight of the samples. The efficiency follows the solar radiation trend, that is it increases with an increase in solar energy. At the early hours of the morning like 9 am when the experiment starts, low efficiency was always recorded. This is because the experiment was just started, and the set up was not yet stabilised at the time. The increase in efficiency during the evening when the solar radiation drops can be attributed to the storage ability of the insulation thus maintained the air temperature, and hence increase the efficiency. The highest daily average efficiency of 18% was achieved for drying Moringa at an initial weight of 105.1g as shown in figure 3.11. This value is less than the efficiency obtained by Kilanko*et al.* [23] from their galvanised steel collector used for drying pepper but higher than 13.5% efficiency obtained by Arjoo*et al.*[26] when using the solar tunnel for drying garlic. It can be seen from the results that the efficiency for both the leaves drying had not much significant difference even though the experiment was not the same day.

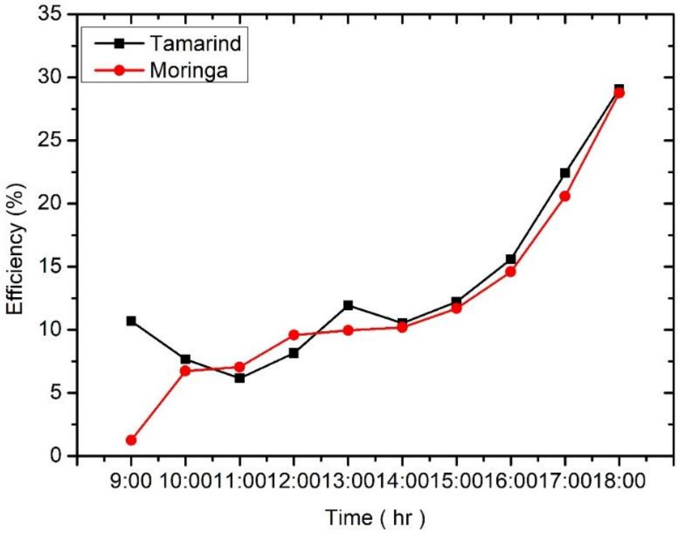

Figure 3.9: Hourly variation of drying efficiency of Moringa and Tamarind leaves at initially weight of 84.4g

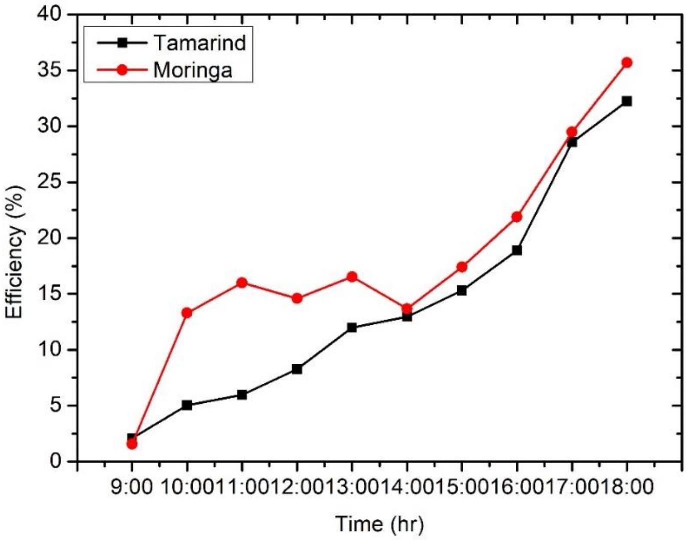

Figure 3.10: Hourly variation of drying efficiency of Moringa and Tamarind leaves at initial weight of 105.1g.

The average daily drying efficiency of solar dryer compared with traditional open drying was presented in figure 3.11. From the figure, the maximum daily efficiency of 18% was achieved by solar dryer when drying moringa leaves of 105.1g initial weight, and hence highest chamber ambient temperature difference of 17^{O}C. This is higher than 13% achieved by Arjoo *et al.*[26]when drying garlic. Moreover, for all the samples used, solar dryer shows a higher performance and dried faster than open drying. This was similarly reported by Emmanuel *et al.*[24] when comparing the mixed-mode solar dryer with traditional open drying of moringa leaves.

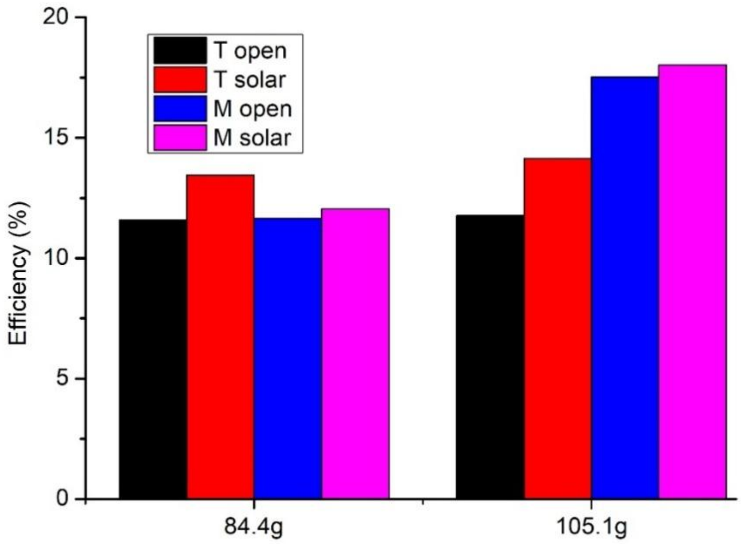

Figure 3.11: Daily efficiency comparison of solar and open sun drying

IV. CONCLUSION

Solar drying provides low cost, clean energy, and temperature thresholds for drying medicinal leaves and plants without adverse effects. In this study, the performance of natural convection solar drying for drying medicinal leaves was analysed. From the results, average moisture content ranged 79%- 82.1% was removed for both the sample at different sample initial weight. This is similar to other dryers in the literature; the 52.5^{o}C maximum drying temperature obtained is within range of the required temperature for drying leaves and vegetables as reported in the literature. Based on obtained result drying medicinal leaves using the solar dryer is the most promising techniques among all the methods of drying. Using this method would provide quality dried product and reduce the cost of drying especially in the rural area of developing countries like Nigeria, where access to modern medicine is challenging and have higher solar radiation intensity. Therefore, it is encouraged for the rural communities to be enlightened to use this simple technology for herbal drying, and the Government should also provide means for mass production to reduce the unit cost.

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Conflicts of interest

The authors declare no conflict of interest

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