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THIN LAYER DRYING KINETICS OF INDIGENOUS GINGER RHIZOM, FOR BLANCHED AND UNBLANCHED TREATMENTS, USING ACTIVE SOLAR ENERGY

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Abstract: The thin layer drying kinetics of indigenous ginger rhizomes of two varieties which are Umudike Ginger I (UG I) and Umudike Ginger II (UG II) was investigated in an active solar dryer. The blanching experiment was conducted at temperature of 50∘C for 3mins, 6mins and 9mins for whole and split samples of peeled and unpeeled treatments before drying. There is a significant difference between the drying curves for whole and split samples which is due to the effect of blanching on the samples. For the unpeeled samples, gradual moisture removal was noted during the drying period. This shows that the thick skin of the unpeeled samples reduces moisture diffusion; it was observed that the drying rate decreased with sample treatments. The result for the effect of splitting on drying characteristics of UG I and UG II samples of peeled and unpeeled treatments under active solar dryer indicates that splitting increases the drying rate. The study indicates that the general objective concerning experimental and analytical studies of thin–layer drying process of ginger rhizomes for an active solar drying of the two ginger varieties were met.
Keywords: Ginger, Solar, drying, blanched and unblanched

INTRODUCTION

Nigeria is among the major producers and exporters of ginger globally, with an annual production of about 160,000 metric tons (MT) on 48,910 hectares, which is 7.9% of world production (FAO, 2013). Although, it is grown in some States of Nigeria, namely Kaduna, Nasarawa, Benue, Niger, and Gombe. Southern Kaduna in Kaduna State, is the main producing zone with over 95% of the country's total production (Okafor, 2002). According to Fumen *et al*. (2003) and Yiljep et al. (2005), the two popular ginger varieties produced in the country are the 'Tafin–Giwa,' a yellowish variety with plump rhizomes, and 'Yatsun–Biri,' which is black variety and has small compact rhizomes. Ginger has in abundant volatile and fixed oil, as well as pungent compounds, minerals, resins, starch and protein. (Ravindran and Nirmal, 2005). Drying is a useful food preservation method widely practiced globally. It is the act of extracting the moistness in a product up to a specific threshold value by evaporation. In this way, the product can be stored for an extended period to decrease the product's water activity, reduces microbiological activity, and minimizes physical and chemical changes encountered when stored (Darvishi and Hazbavi, 2012). As cooling is not a viable option to extend ginger's life shelf, an alternative is drying and operations of dryers and improving the existing drying systems. The goal of modern drying nowadays is to minimize the consumption of energy and providing a high quality of product with a minimal increase in economic inputs, which is attracting an increasing number of applications in the drying process (Darvishi *et al.*,2013).

The method of drying in a thin layer of sample particle is known as thin layer drying (Panchariya *et al.,* 2002). It is also a portion of sample that's fully exposed to air during drying; the layer's depth (thickness) should be consistent, without exceeding three layers of particles (ASAE, 1999). Most agricultural samples are dried by thin–layer drying because of its faster drying rate without losing much of nutrients (Kumar *et al.,* 2011). It is believed that the entire particles are exposed to the drying medium to understand the drying rate and time. The drying periods' knowledge enables us to establish the most economical and practical operating conditions for drying agricultural products. It is a form of carrying out drying tests on specific materials at various air temperatures, relative humidity, and air velocities (Kumar *et al*., 2011).

The aim is to minimize deterioration and microbial spoilage by reducing the water level to a certain threshold. Doungporn *et al.* (2012) reported that Fick's second law is usually used to explain liquid diffusion theory, which describes agricultural products' drying phenomenon when employing thin–layer drying equations.

The knowledge of the changes in agricultural products characteristics when subjected to drying process is of fundamental importance for correct storage, processing and the design, fabrication, and operation of equipment applied during the post–harvest processing of these products (Bleoussi *et al.*, 2010). Thereby, it improves food productivity, reduces heavy post–harvest losses, and increases the farmers' income by recommending the best drying method for preserving ginger rhizomes. Thus, there is a great need to clearly understand the drying principles and estimate the energy needed to dry ginger rhizomes using the drying method of thin layer drying.

This work's general objective is to carry out thin layer drying kinetics of ginger rhizome using active solar energy and also Determine the effects of treatment, blanched and unblanched for [Split (peeled and unpeeled), Whole (peeled and unpeeled)] on the drying of ginger rhizomes. Justification of this research work can be based on Experimental and analytical studies of thin layer process of drying which are essential for performance improvements of drying systems (Alibas, 2012). Many countries dry vast amounts of food to extend their shelf–life, reduce packaging costs, reduce shipping weights, boost appearance, encapsulate original taste, and keep nutritional value (Gunhan *et al.*, 2010). Imagine what happens when the dryers are improperly produced, the objective of drying will not be achieved, and the product quantity and quality would be compromised.

MATERIALS AND METHODS

Material selection and preparation

A custard bowl (4 kg) for each of the two ginger varieties, that is Umudike Ginger I (UG I) and Umudike Ginger II (UG II), were purchased, from the National Root Crop Research Institute (NRCRI), Umudike, Abia State, Nigeria. The ginger varieties which were whole, were sorted by their appearance and size, It was kept in the laboratory to obtain a uniformed room atmosphere for about 24 hours of purchase. It was also noted that the ginger varieties were purchased after about five days to one week of harvest.

Experimental treatments

Four Kilograms each of UG I and UG II was cleaned and separated into samples. One of the samples (4kg) was peeled and splitted with a sharp stainless–steel knife. The UG I and UG II split and whole (peeled and unpeeled) were blanched with the aid of an Electric water bath (DK420 model, Techmel and Techmel, USA) in the Soil and Water Laboratory, Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture, Umudike, Abia State. The UG I and UG II, were blanched for 3, 6, and 9 minutes, at temperature of 50°C, respectively. Each sample with various treatments was subjected to active solar drying in sequence. Also, unblanched UG I and UG II split and whole (peeled and unpeeled) were subjected to active solar drying to determine the drying rate, drying time, drying efficiency.

Figure 1: UG I and UG II unblanched samples with various treatments (whole peeled, whole unpeeled, split peeled and split unpeeled) using solar dryer.

Figure 2: UG I and UG II blanched samples @ 50°C for 3minutes, 6minutes, and 9minutes respectively for the various treatments (whole peeled, whole unpeeled, split peeled and split unpeeled) using solar dryer. Various treatments (whole peeled, whole unpeeled, split peeled and split unpeeled) using solar dryer.

Experimental set–up and procedures

— Active solar drying method

An existing active solar dryer in the Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture, Umudike, was used in the experiment. It consists of a solar collector, solar panel 180W, DC aspirator fan, drying chamber, heat storage unit, drying trays and a solar battery rated 200Ah. The dryer body was constructed using a transparent cover made of perplex material. The solar panel traps solar energy and uses it to charge the dc battery, which powers the control box; the control box was programmed to regulate the dc blower periodically to aid the moisture removal at the drying chamber. The drying chamber houses the dried products placed in perforated metal trays and has a door to allow for easy loading and unloading of crops in the tray. The heat storage unit was incorporated with black pebbles that trap the sunlight that falls on it and stores it in the form of heat for further use when there is no solar radiation.

There was an aspirator on top of the dryer that forces air from the inlet opening through a solar collector section through the product bed in the drying chamber. Solar radiation falling on the dryer was utilized to heat the air passing through the samples. Heated air is blown through the drying chamber. At the top of the drying chamber, vents were provided through which moisture is removed.

During the experiment, solar radiation intensity, ambient air, drying chamber, collector temperature, relative humidity, wind speed, and material weight loss were measured and recorded at 2 hours intervals. The samples were spread in a thin layer on the metal trays and dried until equilibrium moisture content was achieved. This procedure was followed for blanched and unblanched treatments for Split–Peeled (SP), Split–Unpeeled (SU), Whole–Peeled (WP), and Whole–Unpeeled (WU), respectively. Drying started from 8.00 a.m to 6.00 p.m daily till equilibrium moisture content was reached. The experiment was replicated three times, and the average value was used for further calculations.

Figure 3: A pictorial view of an active solar dryer used for the experiment

— **General observations for active solar drying**

Ginger samples, UG I and UG II, were dried for both blanched and unblanched treatments, respectively.

For Blanched treatments, the initial weight of UG I and UG II samples were recorded as $w0_1$, $w0_2$ and $w0_3$, for the three replicates, respectively, and that of weight loss after blanching, was also recorded as $w1_1$, $w1_2$ and $w1_3$, while the weight loss after solar drying at two hours intervals was recorded as $w2_1$, $w2_2$ and $w2_3$.

For unblanched treatments, the initial weight of UG I and UG II samples was recorded as $w0_1$, $w0_2$ and $w0_3$, while the weight loss after solar drying at two hours intervals was recorded as $w1_1$, $w1_2$ and $w1_3$.

The solar dryer's temperature collector, the wind gauge, and the ambient wind gauge were also determined. The environmental factors (relative humidity, temperature, wind speed, and sun intensity) were determined with digital instruments, wind gauge meter, and thermometer aid during the solar drying period.

— **Moisture content determination**

UG I and UG II initial moisture contents were determined for about 300g sample quantity, using Mermet oven at 105°C for 24 hours until constant weight reached according to the method described by AOAC (1990). The experiment was replicated three times. The following equation was used to calculate the moisture content on a wet basis:

$$\text{Mc (w.b) \%} = \frac{W_w - W_d}{W_w} \text{x} \frac{100}{1} \quad (1)$$

where;

Mc = (W.b) moisture content wet basis

Ww = weight of the wet sample (g)

Wd = weight of the dried sample (g)

— **Determination of moisture ratio (MR)**

The moisture ratio (MR) of UG I and UG II was determined using equation [2] (Babalis et al., 2004).

$$\mathrm{MR} = \frac{\mathrm{Mt-Me}}{\mathrm{Mo-Me}} \quad (2)$$

The moisture ratio is further simplified according to Goyal et al (2007) as:

$$\mathrm{MR} = \frac{\mathrm{Mt}}{\mathrm{Mo}} \quad (3)$$

where;

MR = moisture ratio

Mt = the moisture content at any time t (g water/g dry matter)

Mo = the initial moisture content (g water/g dry matter)

Me = the equilibrium moisture contents, (g water/g dry matter), respectively

All values expressed as g water/g dry matter. Me's values were determined as the moisture content at the end of drying when the sample ceased to lose mass.

— **Drying rate calculation (DR)**

The drying rate was calculated as expressed by (Ceylan et al., 2007; Doymaz, 2007; Ozbek and Dadali, 2007)

$$D_r = \frac{M_{t+dt} - M_t}{dt} \quad (4)$$

where,

M_t = moisture content at a specific time (g water/g dry matter)

M_{t+dt} = moisture content t+dt (g water/g dry matter)

t = drying time (hr)

— **Determination of effective moisture diffusivity**

The effective moisture diffusivity (D_{eff}) for a lumped parameter approach considers all possible resistances to moisture transport. When interpreted for an infinite slab in one dimension, assuming negligible temperature gradient within the product, constant temperature, and diffusivity, and no significant external resistance, Moisture transfer during the falling rate drying period of the samples was determined using Fick's Second law as expressed in equation 5 (Aghbashlo et al., 2008).

$$MR = \frac{8}{\pi^2}\sum_{n=0}^{\infty}\left(\frac{1}{2n+1}\right)\exp\left(-\frac{(2n+1)^2\pi^2 D_{eff}t}{4L^2}\right) \quad (5)$$

where; MR is the moisture ratio

D_{eff} = effective diffusivity (m^2/s)

n=1,2,3, the number of terms taken into consideration

t = the time of drying in second

L=the thickness of the sample (m)

Equation (3.5) is further simplified as shown in equation (3.6) by (Lopez et al., 2000)

$$MR = \frac{8}{\pi^2}\exp[\frac{\pi^2 D_{eff}t}{4L^2}] \quad (6)$$

$$MR = \frac{8}{\pi^2}\exp(-kt) \quad (7)$$

The slope k was determined by plotting In (MR) versus time (t)

$$k = \frac{\pi^2 D_{eff}}{4L^2} \quad (8)$$

RESULTS & DISCUSSION

EFFECT OF TREATMENTS ON DRYING CHARACTERISTICS OF UMUDIKE GINGER (I AND II) USING ACTIVE SOLAR DRYER

The solar drying was carried out from February to March 2019. During the drying experiment, the initial moisture content of 71.12 and 72.47% (wb) for UG I and UG II were reduced to a final moisture content of 6.09 and 6.94% (wb). The results of the experiment under different treatment and controlled conditions are presented and discussed.

— **Drying characteristics of Unblanched UG I and UG II varieties of ginger rhizomes**

Figure 4 to 7 show the drying curves of unblanched and blanched UG I and UG II ginger varieties for the whole peeled, whole unpeeled, split peeled, and split unpeeled treatments dried under solar drying process.

Unblanched treatment, there was an initial high moisture removal at the falling rate period, followed by slow moisture removal at the constant rate period of drying, as shown in Figure 4 to 7. At the continuation of drying, the rate of moisture released to the drying air tends to reduce.

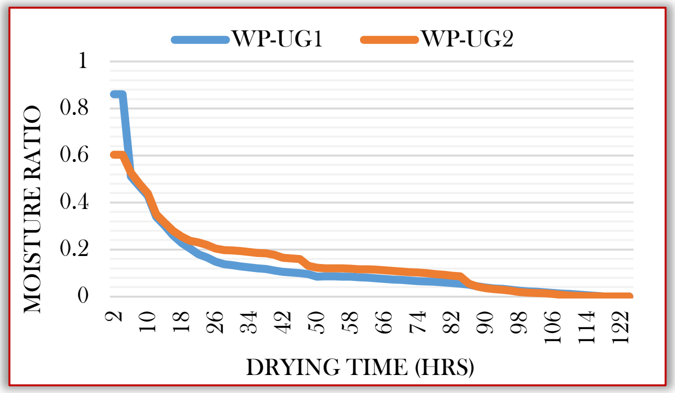

Figure 4. Effect of peeling on the drying characteristics of UG I and UG II (a) whole peeled

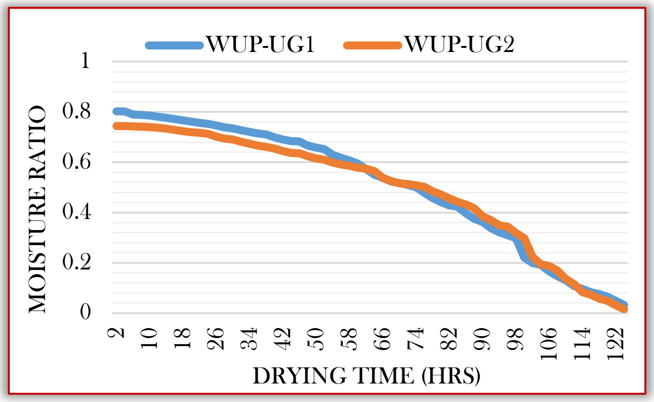

Figure 5. Effect of peeling on the drying characteristics of UG I and UG II (b) whole unpeeled

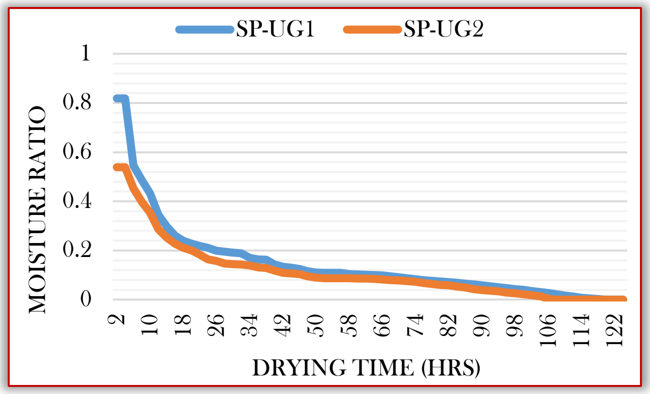

Figure 6. Effect of spliting on the drying characteristics of UG I and UG II (c) split peeled

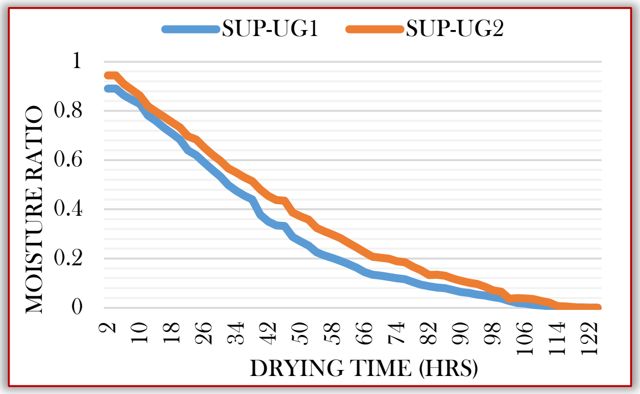

Figure 7. Effect of spliting on the drying characteristics of UG I and UG II (d) split unpeeled

The process of drying continues till equilibrium moisture content was attained. It can also be observed that moisture content decreased continuously with drying time. The drying process for the samples ended in the range of the falling rate period. This implies that diffusion is the most physical mechanism governing moisture movements in the materials, which are dependent on the moisture content of the samples (Akpinar *et al*., 2003; Doymaz, 2007b, Prachayawarakorn *et al*., 2008)

The curves of both drying rate periods agree with the results of other studies on basil, plantain, and banana (Rocha *et al*., 1993; Saeed *et al*., 2006).

— **Effect of Blanching time on the Drying characteristics of UG I and UG II**

The results of the effect of blanching time on the drying characteristics of UG I and UG II samples of whole peeled, whole unpeeled, split peeled, and split unpeeled treatments dried under active solar dryer are shown in Figures 8 to 15, respectively. Blanching increases the drying rate (Bala, 1997).

There is a significant difference between the drying curves for blanched and unblanched samples for whole and split UG I and UG II samples. This difference becomes minimal for whole peeled, split peeled and split unpeeled treatments. This might be because, during blanching, the samples were partially cooked, and some cells or tissues of split peeled, split unpeeled and whole peeled UG I and UG II samples might be disrupted or loosened. As a result, moisture diffusion was higher, and hence the drying rate was higher. Similar results have been reported by Hossain *et al*. (2007) for red chili.

The moisture content of the whole unpeeled UG I and UG II samples, gradual moisture removal are noted during the drying period, and this is true for either blanched whole unpeeled UG I and UG II samples and unblanched whole unpeeled UG I and UG II samples. This shows that the thick skin of the whole unpeeled UG I and UG II samples reduces moisture diffusion through the skin.

At Figure 8 and 15, it was observed that split peeled UG I and UG II, blanched at 50℃ for 3mins, gained moisture from the environment over the night, which affected the slope of the Figure.

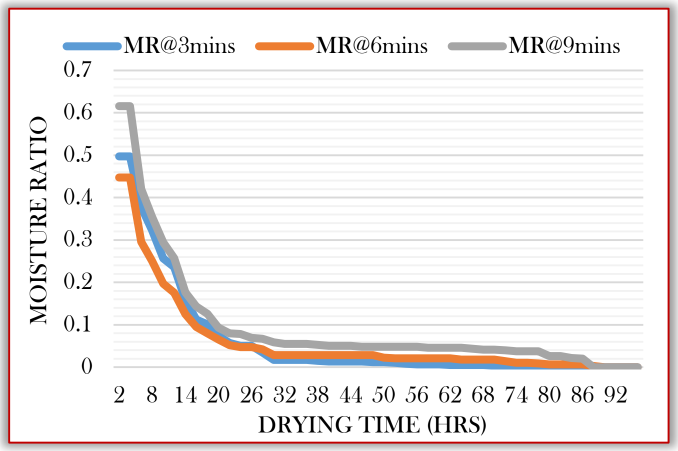

Figure 8. Effect of blanching time on the drying characteristics of Whole peeled UG I

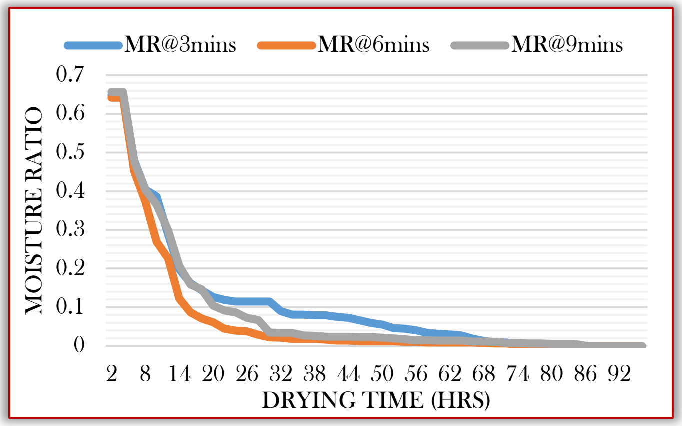

Figure 9. Effect of blanching time on the drying characteristics of Whole peeled UG II

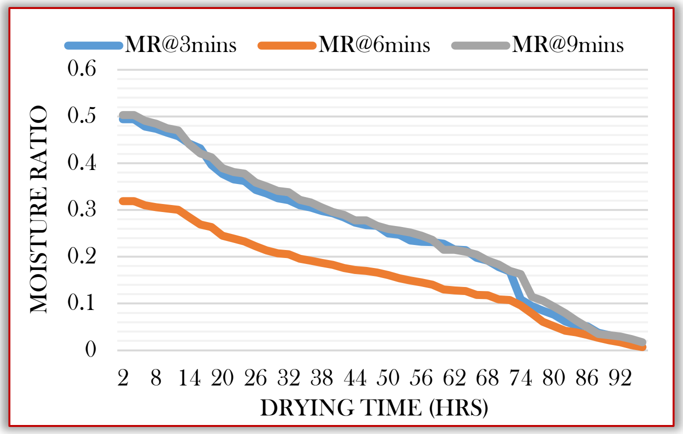

Figure 10. Effect of blanching time on the drying characteristics of Whole unpeeled UG I

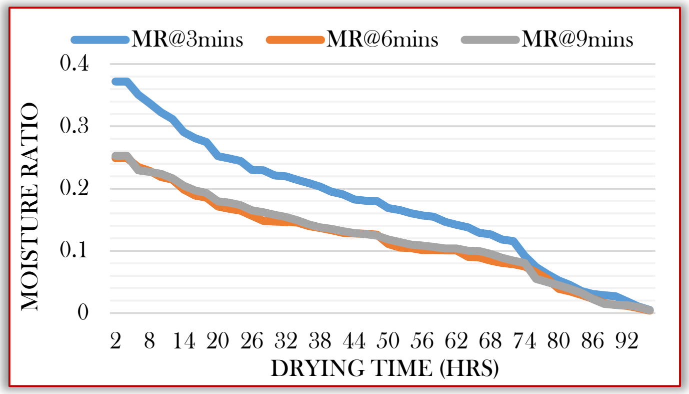

Figure 11. Effect of blanching time on the drying characteristics of Whole unpeeled UG II

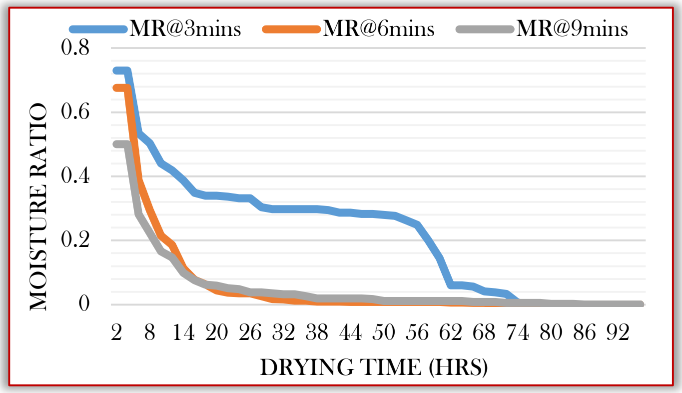

Figure 12. Effect of blanching time on the drying characteristics of Split peeled UG I

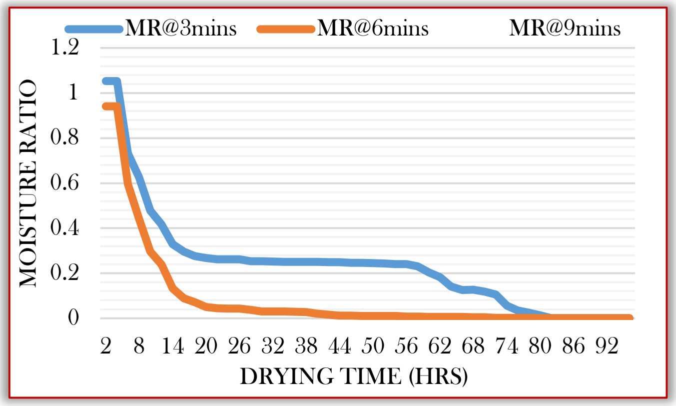

Figure 13. Effect of blanching time on the drying characteristics of Split peeled UG II

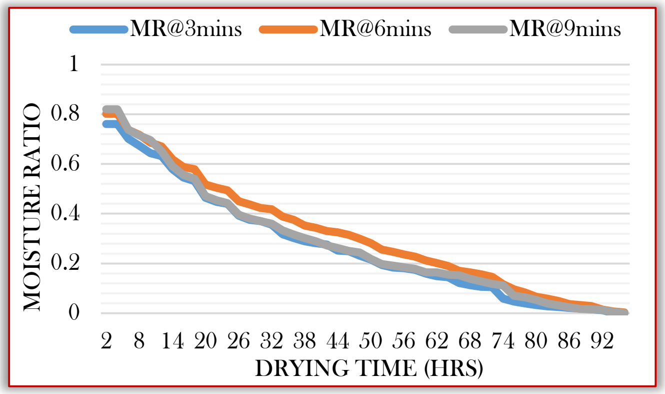

Figure 14. Effect of blanching time on drying characteristics of Split unpeeled UG I

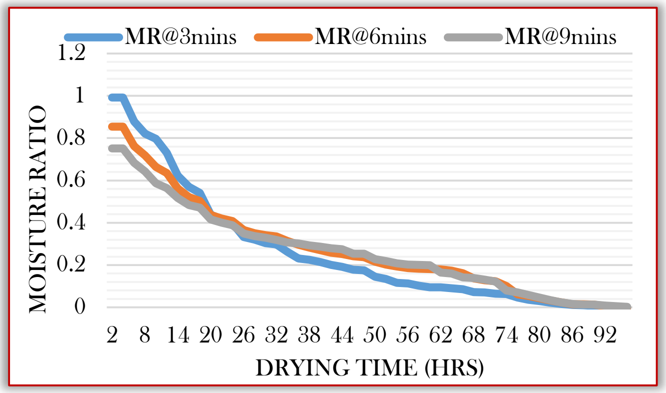

Figure 15. Effect of blanching time on drying characteristics of Split unpeeled UG II

— **Drying rate of UG I and UG II unblanched**

Figures 16 to 27 shows the drying rate curves of unblanched and blanched UG I and UG II samples with various treatments against drying time. It was observed that the drying rate decreased with sample treatments. It could also be observed that drying time increased for a split peeled samples treatment due to decreased drying rate. A similar observation was reported (Maskan *et al.*, 2002; Agarry and Owabor, 2012).

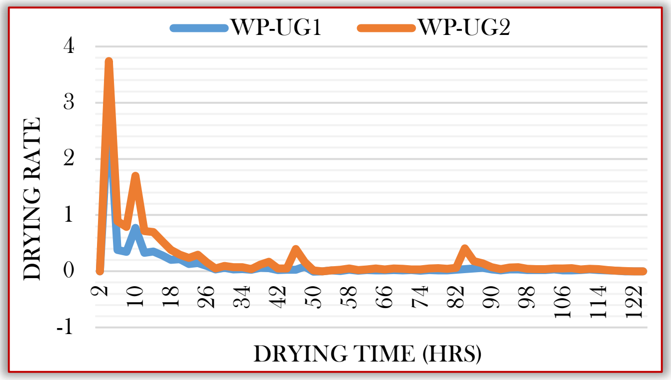

Figure 16. Effect of peeling on drying rate of Whole peeled UG I and UG II

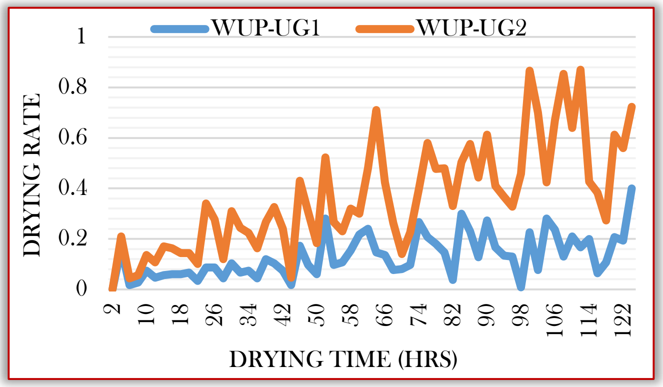

Figure 17. Effect of peeling on drying rate on drying time at whole unpeeled UG I and UG II

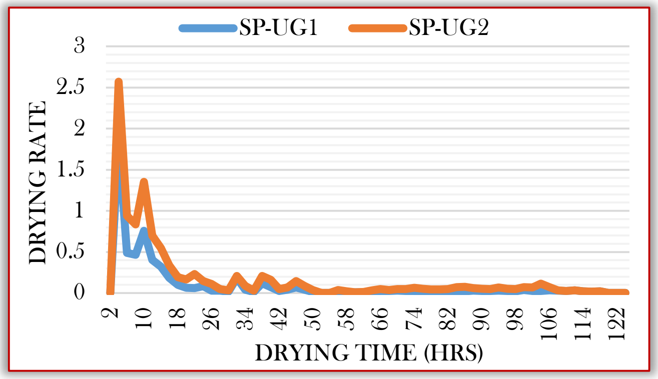

Figure 18. Effect of splitting on drying rate of Split peeled UG I and UG II

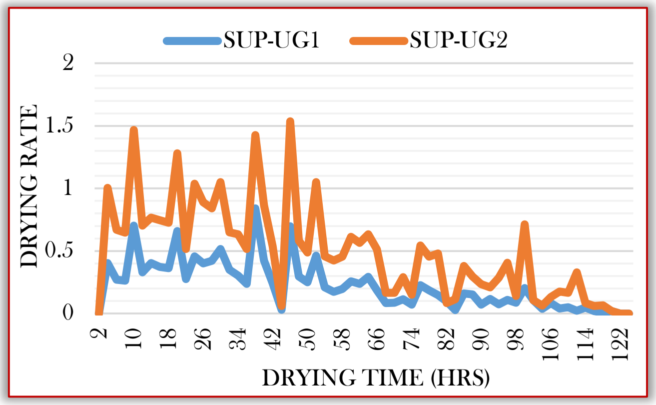

Figure 19. Effect of splitting on drying rate of Split unpeeled UG I and UG II

The highest drying rate was found for split peeled UG I and UG II samples, followed by unpeeled split samples and then whole peeled samples, while the whole unpeeled samples were the least drying rate.

The split peeled samples' highest drying rate might be due to higher diffusion for split peeled samples because of its one cut surface and the peeled back, which has a small diffusion length to travel towards the cut surface.

The diffusion rate of whole unpeeled samples was minimal, and the drying rate was also extremely low. This was also observed during the cabinet drying process.

— **Drying rate of blanched UG I and UG II**

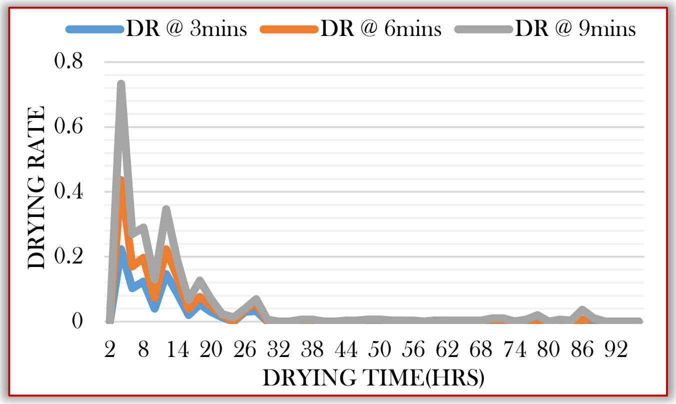

Figure 20. Effect of blanching on drying rate and drying time of whole peeled UG I

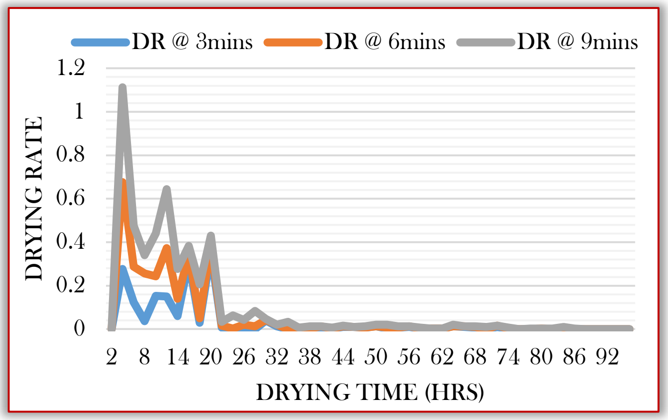

Figure 21. Effect of blanching on drying rate and drying time of whole peeled UG II

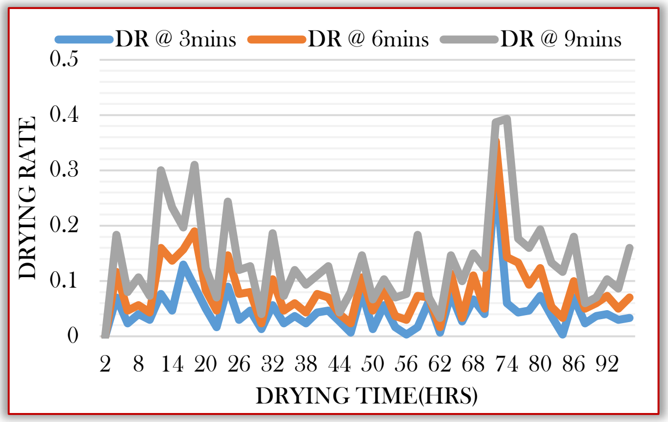

Figure 22. Effect of blanching on drying rate and drying time of whole unpeeled UG I

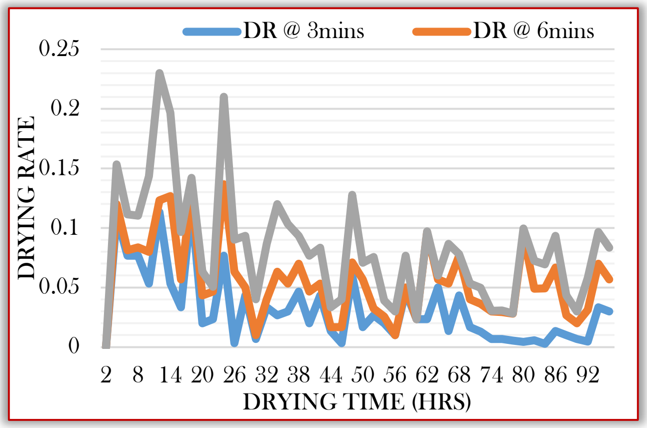

Figure 23. Effect of blanching on drying rate and drying time of whole unpeeled UG II

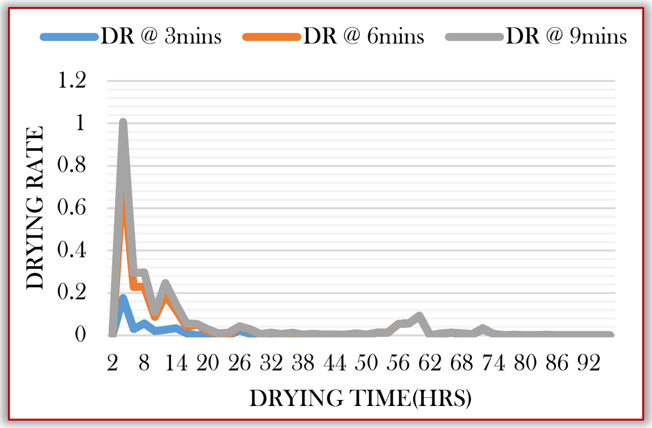

Figure 24. Effect of blanching on drying rate and drying time of Split peeled UG I

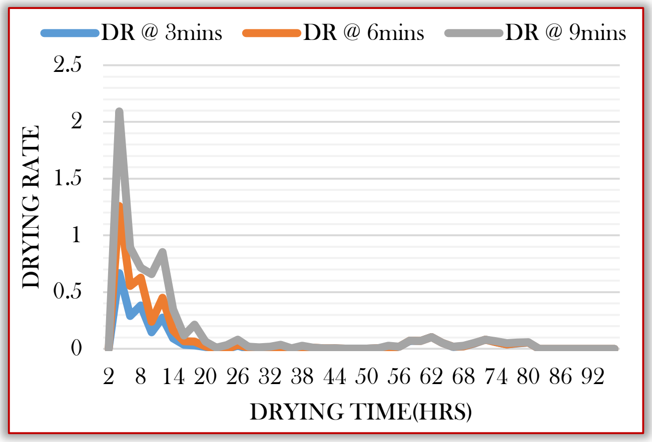

Figure 25. Effect of blanching on drying rate and drying time of Split peeled UG II

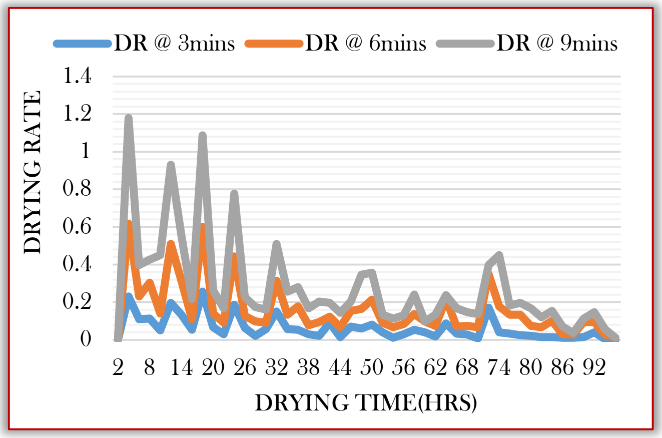

Figure 26. Effect of blanching on drying rate and drying time of Split unpeeled UG I

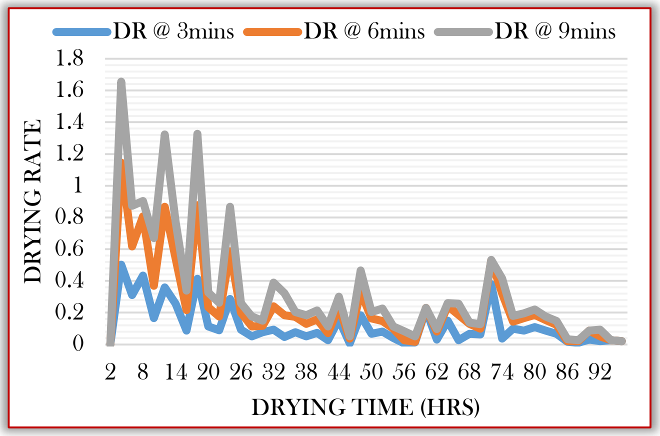

Figure 27. Effect of blanching on drying rate and drying time of Split unpeeled UG II

Figure 28 and 29 show the drying measurement and parameter recorded during the drying duration. The various sample treatments and varieties were loaded with a different tray at the various drying layers, inside the solar drying chamber at the same time intervals.

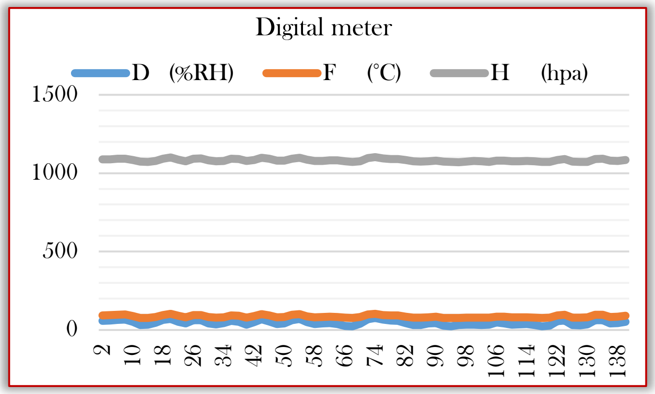

Figure 28. Drying parameter values for solar drying

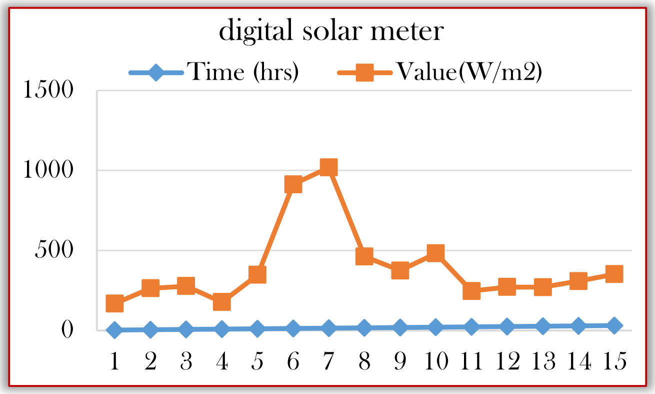

Figure 29. Solar meter reading for sun intensity for two weeks

The drying chamber temperature is shown to approach its peak during the midday at 12:00 pm, and it was always higher than ambient temperature. Solar intensity tends to be highest around 11:30 am to 2:00 pm, after which it starts going down. Relative humidity has a reverse trend of drying chamber and ambient temperature due to the heated air relative humidity decreased sharply towards the noon period. Wind speed was higher during the afternoon and evening periods compared to early morning time. An increase in drying rate coincided with an increase in solar intensity. It was observed that the maximum drying rate occurs between 12:00 pm and 2:00 pm. The drying was carried out from February to March 2019. A period of about a month, between 10 to 70 hours' duration.

— **Determination of Effective Moisture Diffusivity for Active Solar Dryer**

The results for effective moisture diffusivity for unblanched and blanched UG I and UG II treatments dried under Active solar dryer were computed and presented in Tables 1 and 2, using equations 7 and 8, after obtaining k value from plot of In MR versus time.

Table 1. Unblanched and Blanched UG I and UG II

Sample type	UG I		UG II	
	K (Hrs)$^{-1}$	Deff (m^2/s)	K (Hrs)$^{-1}$	Deff (m^2/s)
	UNBLANCHED			
WP	–0.00368	9.082E–05	–0.00358	8.836E–05
WUP	–0.00664	1.639E–04	–0.00608	1.501E–04
SP	–0.00378	9.329E–05	0.00324	7.996E–05
SUP	–0.00763	1.883E–04	–0.00817	2.016E–04
	BLANCHED @ 3 Mins			
WP	–0.00344	8.490E–05	–0.00543	1.340E–04
WUP	–0.00511	1.261E–04	–0.00357	8.8E–05
SP	–0.00711	1.755E–04	–0.00742	1.83E–04
SUP	–0.0078	1.925E–04	–0.00923	2.278E–04
	BLANCHED @ 6 Mins			
WP	–0.00278	6.86E–05	–0.00454	1.120E–04
WUP	–0.00327	8.070E–05	–0.00246	6.07E–05
SP	–0.00511	1.261E–04	–0.00626	1.545E–04
SUP	–0.00811	2.00E–04	–0.00799	1.972E–04
	BLANCHED @ 9 Mins			
WP	–0.00385	9.50E–05	–0.0047	1.160E–04
WUP	–0.00512	1.264E–04	–0.00242	5.973E–05
SP	–0.00304	7.503E–05	–0.00555	1.370E–04
SUP	–0.00799	1.97E–04	–0.0071	1.752E–04

where, WP – Whole peeled; WUP – Whole unpeeled; SP – Split peeled; SUP – Split unpeeled; k – Slope; Deff – Effective moisture diffusivity

The effective moisture diffusivity values increased considerably with the increase in drying rate. This might be explained by the increased heating, which would increase the water molecules' activity, leading to higher moisture diffusivity. These values are consistent with those in literature, 1.26 to 3.32 $\times 10^{-9} m^2/s$ for hot –air drying of garlic (Senadeera et al., 2003), 9.3 $\times 10^{-9}$ to 1.06 $\times 10^{-11} m^2/s$ for convective drying of ginger (Da Silva et al., 2009) and 0.35 to 1.01 $\times 10^{-10} m^2/s$ for hot–air drying of bean slices (Rossello et al., 1997).

The slope (k) was derived from the moisture ratio log variation with drying time used to calculate moisture diffusivity. This implies that the drying constant (k) was obtained from the slope of the plot of the log of moisture ratio against drying time. The higher k values confirm the elevated moisture removal rates and indicate an enhancement of drying potential (Evin, 2011; Darvishi et al., 2014).

The effective moisture diffusivity (Deff) of Unblanched UG I and UG II and slope (k) ranges from 1.501 $\times 10^{-4}$to 9.329 $\times 10^{-5} m^2/s$ and –0.00324 to –0.00817$(hrs)^{-1}$, respectively. This shows that the effective moisture diffusivity for unblanched treatment during solar drying was obtained at split peeled (UG I) higher than the whole unpeeled (UG II).

The effective moisture diffusivity (Deff) of Blanched UG I and UG II at 50℃ and slope (k) ranges from 1.120$\times 10^{-4}$ to 9.50 $\times 10^{-5} m^2/s$ and –0.00242 to –0.00923 $(hrs)^{-1}$ respectively. It shows that the effective moisture diffusivity (Deff) was higher at whole peeled (UG I) MR at 9mins and lower at whole peeled (UG II) MR at 6mins.

Table 2. Unblanched and Blanched UG I and UG II

Sample type	UG I	UG II
	K $(Hrs)^{-1}$	K $(Hrs)^{-1}$
	UNBLANCHED	
WP	–0.00434	–0.00273
WUP	–0.001727	–0.003761
SP	–0.00343	–0.00243
SUP	–0.00371	–0.00346
	BLANCHED @ 3 Mins	
WP	–0.00104	–0.00109
WUP	3.48278E–05	–0.00019
SP	–0.00031	–0.00214
SUP	–0.00119	–0.00228
	BLANCHED @ 6 Mins	
WP	–0.0007	–0.00186
WUP	–4.07982E–05	–0.00037
SP	–0.00245	–0.00238
SUP	–0.00134	–0.00291
	BLANCHED @ 9 Mins	
WP	–0.00099	–0.00201
WUP	7.22789E–05	–0.00014
SP	–0.00073	–0.00367
SUP	–00244	–0.00282

The differences between the results in the literature and present investigation can be explained by the effect of drying methods, unblanched and blanched treatments, and tissue characteristics of the UG I and UG II varieties of the samples, composition, and the proposed model used for calculations.

CONCLUSION AND RECOMENDATIONS

The following conclusions can be drawn from this study:

The result for the effect of blanching on drying characteristics of UG I and UG II samples of whole peeled, whole unpeeled, split peeled, and split unpeeled treatments under active solar dryers, indicates that splitting increases the drying rate. The above indicates that this work's general objective concerning experimental and analytical studies of thin–layer drying process of ginger rhizomes for an active solar drying of two varieties of ginger, UG I and UG II were met.

Further research concerning the effect of initial moisture content, relative humidity, and airflow rate on drying characteristics of UG I and UG II, Whole and Split treatments, for the optimization of the drying process.

These drying methods on thermal properties such as thermal conductivity, specific heat capacity, and thermal diffusivity should also be investigated.

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