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INVESTIGATING DRYING PROFILES OF NATIVE GINGER RHIZOMES USING CABINET DRYING TECHNIQUE

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Abstract

Ginger (Zingiber Officinale Roscoe) is an ancient and essential medicinal spice with a rich history of cultivation across the globe. As one of the oldest spices and condiments, it holds significant cultural, economic, and health importance. Nigeria, a major global producer of ginger, contributes approximately 8% of the world's ginger production, with Kaduna state being a prominent production hub. The country produces diverse varieties, including 'Tafin-Giwa' and 'Yatsun-Biri,' alongside indigenous types such as Umudike Ginger I (UG I) and Umudike Ginger II (UG II). These varieties flourish in different regions, with high yields and consequential economic implications.

Drying is a prevalent preservation technique employed to extend the shelf life of various agricultural products. Thin layer drying, which focuses on moisture removal through evaporation, is a widely studied method. Its application ensures reduced microbial spoilage, minimized physical and chemical changes, and prolonged storage capacity. The drying process significantly impacts the quality of ginger and is crucial for the production of dried powder, ginger split dried, and extracts. Researchers continually explore innovative drying methods to reduce energy consumption and drying time while maintaining product quality.

Understanding the drying behavior of agricultural products is vital for efficient storage, processing, and equipment design in post-harvest operations. Investigating the drying kinetics of ginger, especially the split and whole rhizomes, is a fundamental step towards optimizing drying methods and enhancing food productivity. Experimental and analytical studies play a pivotal role in improving agricultural product characteristics, preserving nutritional value, and enhancing

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appearance. This study aims to analyze the drying kinetics of different ginger varieties using a cabinet dryer, while also evaluating treatment effects on split and whole ginger rhizomes. The insights gained from this research will contribute to better post-harvest processing techniques, reduced losses, and increased income for farmers.

1. INTRODUCTION

Ginger (Zingiber Officinale Roscoe) remains the most basic and essential medicinal spices in the world (Prabhakaran, 2013). It is one of the oldest of all the spices and condiments that have been under cultivation for millennia in many parts of the world (Spore, 1992; Guwo, 2008).Nigeria is among the major producers of ginger globally, with an annual production of about 160,000 metric tons (MT) on 48,910 hectares, representing about 8% of world production (FAO, 2018).

Kaduna state is the main producing zone accounting for over 95% of the country's total production (Okafor, 2002). According to Fumen et al. (2003) and Yiljep et al. (2005), Nigerians produces two main varieties namely, 'Tafin-Giwa,' a yellowish variety with plump rhizomes, and 'Yatsun-Biri,' which is black variety and has small compact rhizomes (Ngwoke and Nzekwe, 2010). In the south eastern Nigeria, the production of indigenous varieties include the yellowish variety known as Umudike Ginger I (UG I) and the black variety which is referred to as Umudike Ginger II (UG II). Farmers and cultivators do record high yield of ginger rhizomes production for both varieties in the south east, which increases its economic value chain (Onwuka, 2015).

Drying is one of the most common food preservation. It is the act of removing moisture in a product up to a specific threshold value by evaporation through heating (Doymaz, 2004). This process reduces the moisture content and water activity, minimize physical and chemical changes, extending the storage life of product. (Darvishi and Hazbavi, 2012).The method of drying in a thin layer of sample particle is known as thin layer drying (Panchariya et al., 2002). The layer's depth (thickness) should be consistent, without exceeding three layers of particles (ASAE, 2018). The aim is to minimize deterioration and microbial spoilage by reducing the water level to a certain threshold.

The majority of the ginger grown in Nigeria is processed and exported as ginger dried powder, or ginger split dried and extracts. New drying methods are studied to minimize the drying time and energy consumption without changing their quality (Mortaza et al., 2008). In the past six decades, the study of drying behaviour of different materials has been the subject of interest for various investigators on theoretical and practical grounds (Mohammadi et al., 2008). 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). Thus, improving food productivity, reducing heavy post-harvest losses and increasing farmers' income by recommending the best drying method for preserving ginger rhizomes (Nwinuka et al., 2015).

Experimental and analytical studies of thin layer process of drying are essential to successfully improve shelf-life, reduce packaging costs, reduce shipping weights, boost appearance, encapsulate original taste, and keep nutritional value of agricultural products (Zogras et al., 1999; Panchanyaet al., 2002). Therefore, this work aims to determine the drying kinetics of two varieties of ginger using cabinet dryer and treatment effects for split and whole ginger rhizomes.

2. MATERIALS AND METHODS

2.1 Experimental material selection, preparation and treatments

A custard bowl (4 kg) for each of the two ginger varieties namely Umudike Ginger I and II (UG I and II) were purchased from the National Root Crop Research Institute (NRCRI), Umudike, Abia State, Nigeria. The samples were kept in the laboratory to enable them equilibrate with the ambient condition and also to obtain a uniformed condition before applying sample treatment. The ginger varieties were purchased after about five days to one week of harvest. The UG I and UG II samples was cleaned separated and grouped into unblanched (whole-peeled, wholeunpeeled, split-peeled and split-unpeeled) and blanched (whole-peeled, whole-unpeeled, splitpeeled and split-unpeeled) sample treatments. The samples were peeled and splitted with a sharp stainless-steel knife. The UG I and UG II (whole-peeled, whole-unpeeled, split-peeled and splitunpeeled) were blanched for 3, 6, and 9 minutes at 50ºC with the aid of an electric water bath (DK420 model) 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 ginger varieties, subjected to unblanched (whole-peeled, whole-unpeeled, split-peeled and split-unpeeled) and blanched (whole-peeled, whole-unpeeled, split-peeled and split-unpeeled) sample treatments, were placed for cabinet drying in sequence. The cabinet dryer was used to determine the drying rate, drying time, drying efficiency. The samples were now shrunken in appearance (shrivelled and distorted) and rough texture generally after the cabinet drying. Case hardening effect was also experienced on all the samples but noticeable mainly on the blanched samples.

2.2 Experimental set-up and procedures

An existing cabinet dryer in the Department of Agricultural and Bioresources Engineering, Michael Okpara University, Umudike, was used in performing this experiment. The cabinet dryer has 105cm length, width of 65cm, and depth 85cm. It consists of four flat metal trays (length 100cm, width 60cm, and depth 10cm), the drying cabinet for drying of agricultural materials, and a heat exchanger. The blower circulates heat inside the drying chamber. It also has an exit vent. The cabinet dryer's primary source of heat was from a kerosene cooking stove which aided the regulation of its burning heat pressure.

2.2.1 General observation for cabinet drying

Cabinet dryer was used to dry UG I and UG II samples with two treatments, Blanched and unblanched treatments respectively. During the drying period, the samples weight lost were recorded at 1 hour intervals for both blanched and unblanched treatments, until constant rate of drying is reached. With unblanched treatments, the initial weights of UG I and UG II samples were recorded as $w\,0_1$, $w\,0_2$ and $w\,0_3$, while the weight loss after cabinet drying at one hour intervals was recorded at $w\,1_1$, $w\,1_2$ and $w\,1_3$. At Blanched treatments, the initial weight of UG I and UG II samples was recorded at $w\,2_1$, $w\,2_2$ and $w\,2_3$ and the weight loss after blanching was also recorded at $w\,3_1$, $w\,3_2$ and $w\,3_3$, while the weight loss after cabinet drying at one-hour intervals was recorded as $w\,4_1$, $w\,4_2$ and $w\,4_3$. The cabinet dryer's temperature was regulated to 50°C with the aid of a thermostat inserted in the drying chambers. Figure 1 shows the cabinet dryer used for the experiment.

Figure 1: Experimental Cabinet dryer

2.3 Experimental Design

This experiment was based on a factorial experiment in Randomised Block Design consisting of three factors, The three factors are Temperature, which has one level (50°C), Treatments which has eight levels (blanched whole peeled, Blanched whole unpeeled, blanched split peeled, blanched split unpeeled, unblanched whole peeled, unblanched whole unpeeled, unblanched split peeled, unblanched split unpeeled) and varieties, which has two levels (UG I and UG II). The independent variables include blanching temperature (T_{50C}); peeling (P, UP); splitting (SP, SUP); varieties (UG I, UG II); drying methods (C); time and unblanched while dependent variables include drying rate and drying quality (phytochemical, proximate composition)**.** These experiments were replicated thrice and the average value was used for further calculations.

2.4 Moisture Content Determination

UG I and UG II initial moisture contents were determined for about 300g sample quantity, using Mermet oven at 105ºC for 24 hours until constant weight reached according to the method described by AOAC (2015). Moisture content on a wet basis was calculated using Equation (1):

$$\boldsymbol{M\,c\ (w\,.\,b)\,\%} = \frac{\boldsymbol{W_w - W_d}}{\boldsymbol{W_w}} \boldsymbol{x} \frac{\boldsymbol{100}}{\boldsymbol{1}} \qquad [1]$$

where:

Mc = moisture content wet basis(%)

Ww = weight of the wet sample (g)

Wd = weight of the dried sample (g)

2.5 Determination of Moisture Ratio (Mr)

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

$$\boldsymbol{MR} = \frac{\boldsymbol{Mt - Me}}{\boldsymbol{Mo - Me}} \qquad [2]$$

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

$$\boldsymbol{MR} = \frac{\boldsymbol{Mt}}{\boldsymbol{Mo}} \qquad [3]$$

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

Me values were determined as the moisture content at the end of drying when the sample ceased to lose mass.

2.6 Drying Rate (Dr) Calculation

The drying rate was calculated using Equation (4) as expressed by (Ceylan et al., 2007; Doymaz, 2007; Ozbek and Dadali, 2007)

$$\boldsymbol{D_r = \frac{M_{t+dt} - M_t}{dt}} \quad [4]$$

where,

D_r = Drying rate

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)

dt = drying time (hr)

2.7 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].

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

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 = drying time (s)

L=the thickness of the sample (m)

Equation [5] is further simplified to Equation [6] by (Lopez et al., 2000)

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

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

The slope k was determined by plotting ln MRversus time (t)

$$\mathbf{k} = \boldsymbol{\frac{\pi^2 D_{eff}}{4L^2}} \quad [8]$$

3. RESULTS AND DISCUSSION

3.1 Drying Characteristics of Unblanched Ug I and Ug II Varieties of Ginger Rhizomes 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). There was an initial high moisture removal (constant rate period) followed by slow moisture removal in the latter stages (falling rate period) of drying, as shown in Figure 2 A – D. At the continuation of drying, the rate of moisture released to the drying air tends to reduce which is similar to the studies of Senadeera et al., (2003). The process of drying continues till the equilibrium moisture content was attained. It can also be observed that moisture content decreased continuously with drying time which is agreement with the findings of Ngwoke and Nzekwe (2010). 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).

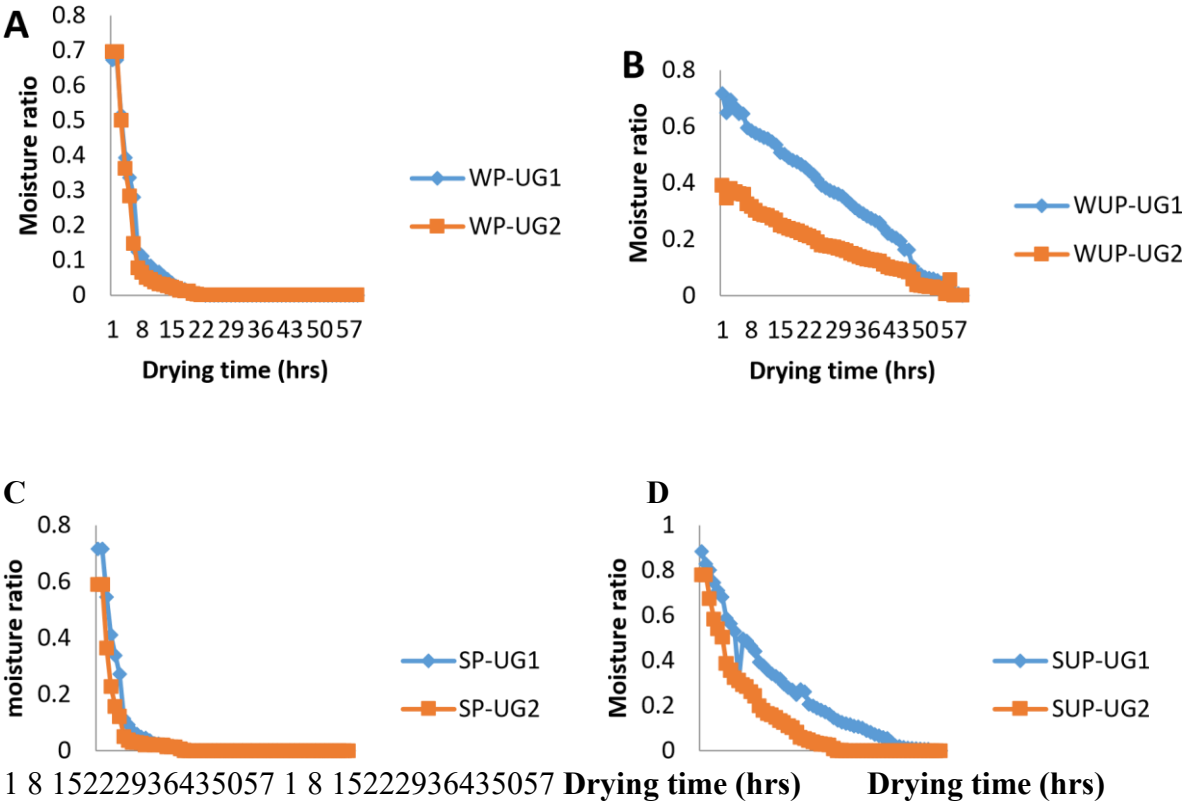


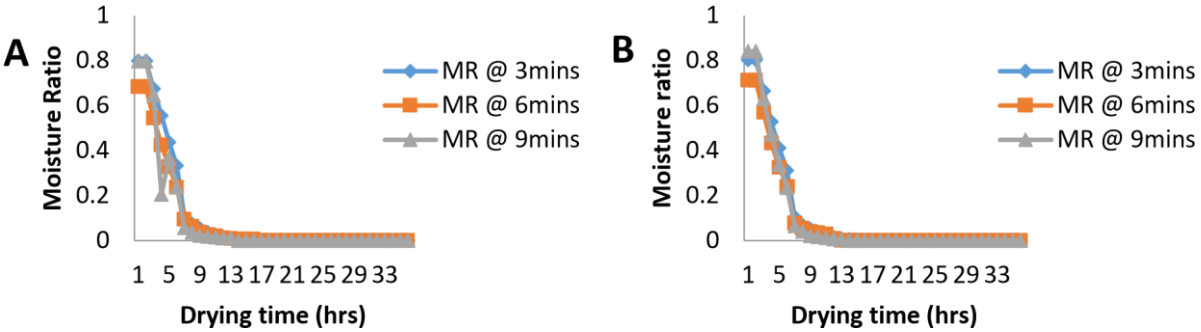
Figure 2: Drying characteristics of unblanched ginger

(A) Effect of peeling on the drying characteristics for Whole peeled UG I and UG II

(B) Effect of peeling on the drying characteristics for Whole unpeeled UG I and UG II (C) Effect of splitting on the drying characteristics for Split peeled UG I and UG II (D) Effect of splitting on the drying characteristics for Split unpeeled UG I and UG II.

3.2 Effect of Blanching Time on Drying Characteristics of 50°C Blanched Ug I And Ug II

The effect of blanching time on drying characteristics of UG I and UG II samples are shown in Figure 3, A to H respectively. Blanching increased 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 minimum 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 have been disrupted or loosened. As a result, moisture diffusion was higher, and hence the drying rate was higher.



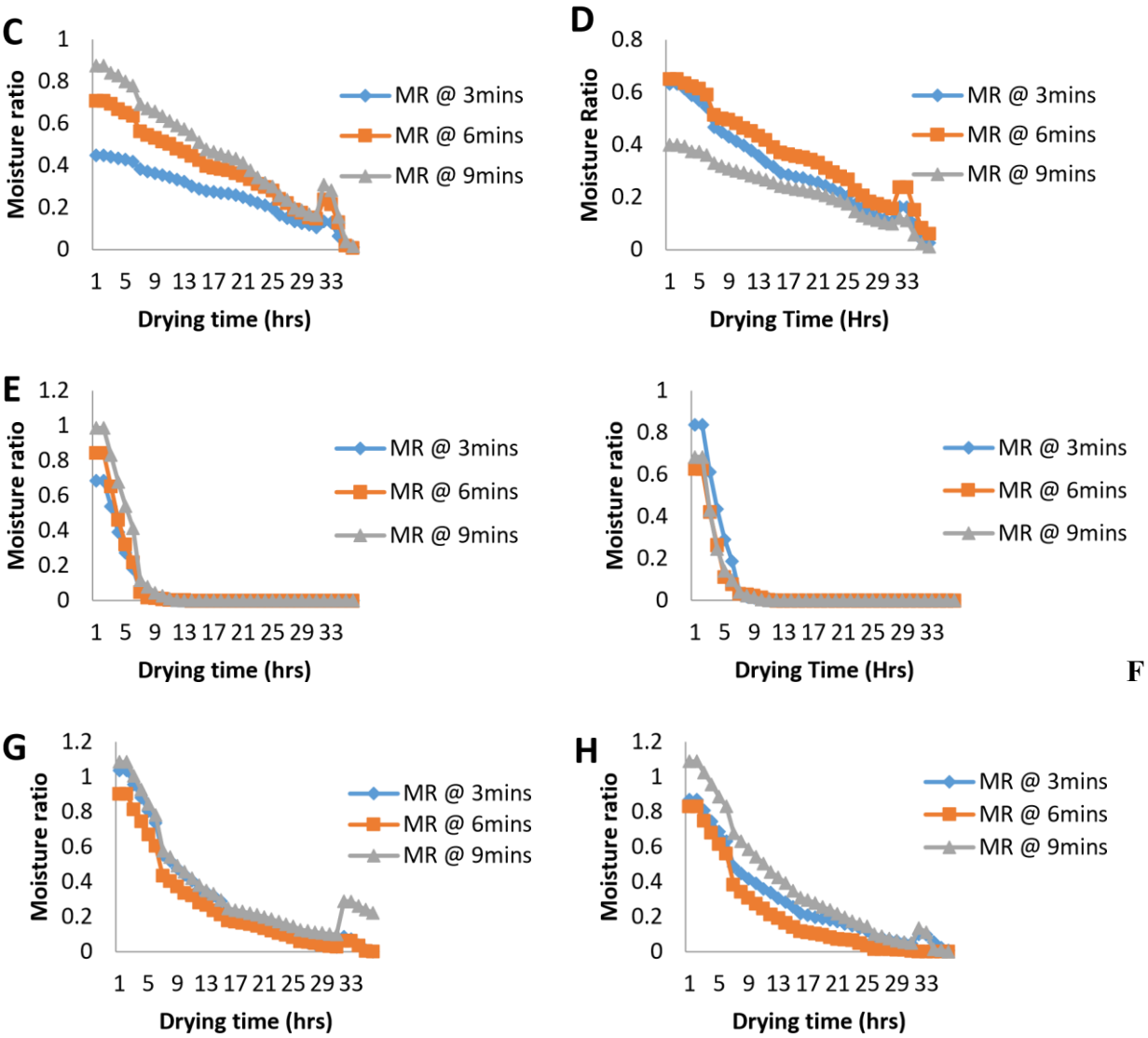


Figure 3: Drying characteristics of blanched ginger

(A) Effect of blanching time on the drying characteristics for Whole peeled UG I

(B) Effect of blanching time on the drying characteristics for Whole peeled UG II

(C) Effect of blanching time on the drying characteristics for Whole unpeeled UG I

(D) Effect of blanching time on the drying characteristics for Whole unpeeled UG II

(E) Effect of blanching time on the drying characteristics for Split peeled UG I

(F) Effect of blanching time on the drying characteristics for Split peeled UG II (G) Effect of blanching time on the drying characteristics for Split unpeeled UG I (H) Effect of blanching time on the drying characteristics for Split unpeeled UG II.

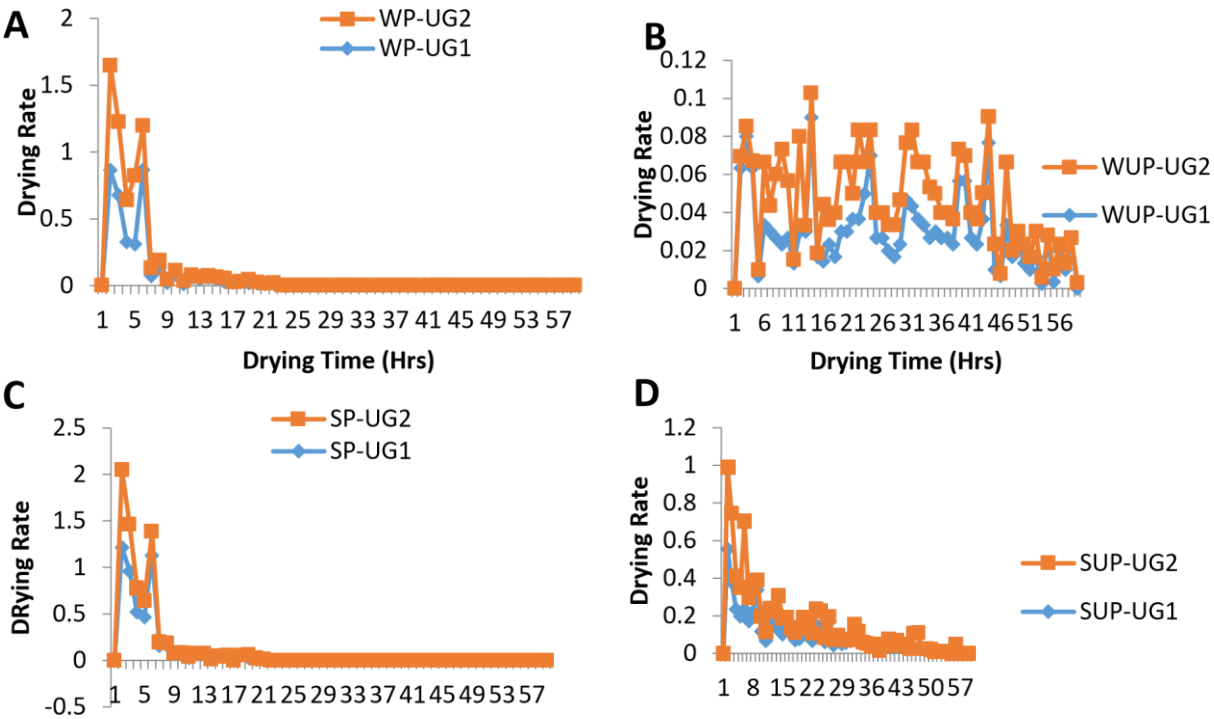
The effect becomes more prominent with the increase of the blanching temperature. Similar results have been reported by Hossain et al. (2007) for red chilli. The moisture content of the whole unpeeled UG I and UG II samples remained almost constant during the drying period, and this is true for either 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 prevents moisture diffusion through the skin.

3.3. Drying Rate of Ug I and Ug II Blanched and Unblanched

Figure 4 and Figure 5 show the plot of drying rate against time at different treatments for unblanched and blanched UG I and UG II for blanching time of 3, 6, and 9 minutes, and at steady temperature of 50°C. The drying rate decreased with an increase in the drying time. During the drying period, a reduction in moisture migration from the interior to the product's surface ensues. The drying rate was observed in both constant and falling rate periods. In the beginning, it was high because the moisture was high too. As the drying approached the falling rate period, the drying rate reduces until it became constant, signalling the equilibrium moisture content stage. This corresponds with Pathare and Sharma (2006) for onion slices, Mohapatra and Rao (2005) for parboiled wheat, and Doymaz (2005) for the green bean.

3.4 Effective Moisture Diffusivity

The results for effective moisture diffusivity for unblanched and blanched UG I and UG II treatments dried under cabinet dryer are presented in Tables 1 and 2.The effective moisture diffusivity for unblanched treatment during cabinet drying was high for split peeled (UG I) while that of whole unpeeled (UG II) was low. The slope (k) and effective moisture diffusivity (Deff) of unblanched UG I and UG II range from -0.01215 to -0.02972 $(hr\ s)^{-1}$ and 1.579×10^{-4} to $7.335 \times 10^{-4} m^2/s$ respectively. The effective moisture diffusivity (Deff) of blanched UG I and UG II at 50°C and slope (k) range from 1.068×10^{-3} to $7.308 \times 10^{-4} m^2/s$ and -0.072 to 0.09567 $(hr\ s)^{-1}$ respectively. This indicates that the effective moisture Diffusivity for blanched treatment at 50°C, during cabinet drying for split unpeeled (UG II) MR at 9mins was high, while that of whole peeled (UG I) MR at 6mins was low. However the values are within range for drying of food materials.



Drying Time (Hrs)Drying Time (Hrs)

Figure 4: Drying rate of unblanched ginger

(A) Effect of drying rate on drying time at Whole peeled UG I and UG II

(B) Effect of drying rate on drying time at Whole unpeeled UG I and UG II (C) Effect of drying rate on drying time at Split peeled UG I and UG II

(D) Effect of drying rate on drying time at Split unpeeled UG I and UG II

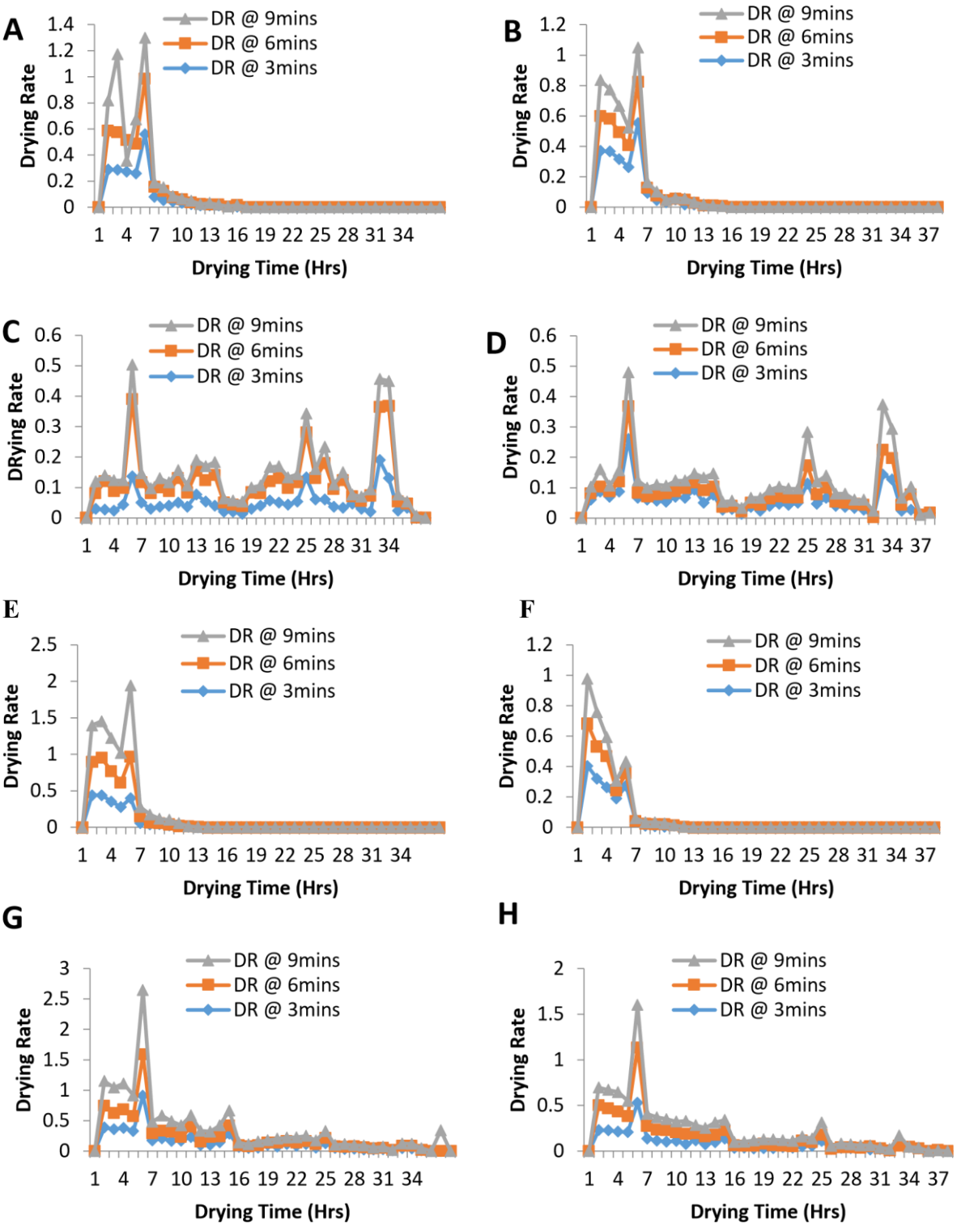


Figure 5: Drying rate of blanched ginger

(A) Effect of drying rate on drying time at Whole peeled UG I
(B) Effect of drying rate on drying time at Whole peeled UG II
(C) Effect of drying rate on drying time at Whole unpeeled UG I
(D) Effect of drying rate on drying time at Whole unpeeled UG II
(E) Effect of drying rate on drying time at Split peeled UG I
(F) Effect of drying rate on drying time at Split peeled UG II
(G) Effect of drying rate on drying time at Split unpeeled UG I
(H) Effect of drying rate on drying time at Split unpeeled UG II

Table 1: Effective moisture diffusivity unblanched and blanched UG I and UG II

	UG I		UG II	
SAMPLE TYPE	K $(Hrs)^{-1}$	Deff (m^2/s)	K $(Hrs)^{-1}$	Deff (m^2/s)
		UNBLANCHED		
WP	-0.02644	6.526E-04	-0.025	6.170E-40
WUP	-0.01215	2.999E-04	-0.0064	1.579E-40
SP	-0.02972	7.335E-04	-0.02049	5.057E-04
SUP	-0.01355	3.344E-04	-0.01953	4.820E-04
		BLANCHED @ 3 Mins		
WP	-0.05292	1.306E-03	-0.01182	2.917E-04
WUP	-0.01182	2.917E-04	-0.01595	3.937E-04
SP	-0.06275	1.549E-03	-0.07487	1.848E-03
SUP	-0.02716	6.703E-04	-0.02104	5.193E-04
		BLANCHED @ 6 Mins		
WP	-0.04328	1.068E-03	-0.05931	1.464E-03
WUP	-0.0181	4.467E-04	-0.01565	3.862E-04
SP	-0.06928	1.709E-03	-0.05897	1.455E-03
SUP	-0.02247	5.546E-04	-0.02961	7.308E-04
		BLANCHED @ 9 Mins		
WP	-0.06259	1.545E-03	-0.06867	1.695E-03
WUP	-0.0227	5.602E-04	-0.0102	2.517E-04
SP	-0.09567	2.361E-03	-0.072	1.777E-03
SUP	-0.02279	5.625E-04	-0.02961	7.308E-04

Table 2: Drying rate slope (unblanched and blanched) UG Iand UG II

SAMPLE TYPE	UG I K $(Hrs)^{-1}$	UG II K $(Hrs)^{-1}$
	UNBLANCHED	
WP	-0.02427	-0.02072
WUP	-0.00019	-0.00048
SP	-0.03753	-0.01858
SUP	-0.00463	-0.0067
	BLANCHED @ **3 Mins**	
WP	-0.01899	-0.02351
WUP	0.000954	-0.00111
SP	-0.03114	-0.02555
SUP	-0.01012	-0.00551
	BLANCHED @ **6 Mins**	
WP	-0.01762	-0.01486
WUP	0.000475	0.000324
SP	-0.03456	-0.01756
SUP	-0.00757	-0.00778
	BLANCHED @ **9 Mins**	
WP	-0.01849	-0.01462
WUP	0.000127	0.000469
SP	-0.03896	-0.01864
SUP	-0.01166	-0.00538

CONCLUSION

The drying characteristics of indigenous ginger rhizomes (UG I and II) were studied under different treatments and shape configurations and the following observations were made. The sample varieties had no effect on the drying rate while peeling effects was observed among various treatment configurations (whole and split), as the peeled samples dried faster than the unpeeled. The drying rate was observed to be high on peeled ginger samples than the unpeeled. The highest drying rate for blanched samples was observed for split-peeled, followed by splitunpeeled, whole-peeled and whole-unpeeled. Blanching increased the drying rate; however there was no significant difference between blanching periods. However, there was significant difference between drying curves for blanched and unblanched samples. This suggests that the two ginger varieties exhibit same drying characteristics under similar drying conditions.

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