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Simulation of discretized element of ginger on thin layer drying using MATLAB PDES for optimal programming

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Abstract

This paper presents the simulation for thin layer drying of ginger Rhizome considering two important features, moisture content and thermal conductivity of ginger samples under blanched, unblanched, peeled, unpeeled condition at varying drying time of 2 – 24 hours and for6 temperature levels ranging from 10^oC – 60^oC using Matrix Laboratory (MATLAB)for the finite element for the temperature distribution while drying. This research work is an extension of the previous work done with the ARS-680 environment chamber for the drying and TD 1002A-linear heat conduction experimental equipment used in measuring the thermal conductivity of the ginger at 6 temperature levels ranging from 10^0C -60^0C and drying time of 2-24hours. The partial differential equation toolbox was employed to PDES for diffusion heat, transfer, structural mechanics, electrostatics, magnetostatics, and AC power electromagnetics, as well as custom, coupled system of PDES. The discretized mesh of the ginger rhizomes samples have 545 nodes (element) and 1024 (triangles) and the high temperature distribution is responsible in the colour change obtained for the final product. An equation for moisture content was derived from the data.

Keyword: Blanched, Drying Ginger Rhizomes, Partial Differential Equation, Peeled, Thermal Conductivity, Simulation, Unblanched, Unpeeled

1. Introduction

Thin layer drying can be employed to remove volatile liquids from porous materials such as food stuffs, ceramic products, clay products, wood and so on. Porous materials have microscopic capillaries and pores which cause a mixture of transfer mechanisms to occur simultaneously when subjected to heating or cooling. The drying of moist porous solids involves simultaneous heat and mass transfer. Moisture is removed by evaporation into an unsaturated gas phase. Owing to the complexity of the process, no generalized theory currently exists to explain the mechanisms of internal moisture movement (Hoque *et al.*, 2013).

Since the actual process of drying is a conjugate problem; the heat and mass transfer to and fro the porous solid have to be studied along with the flow field. Conjugate analysis of drying shows that the drying behaviour differs from that which is obtained by decoupled analysis due to temperature and concentration of non-homogeneities at the solid-fluid interface. Drying behavior of the material is influenced by temperature, relative humidity, permeability, and sorption-desorption characteristics, and thermo-physical properties of the material being dried. Transfer of non-condensable gases, vapours, and liquids occurs in porous bodies. Inert gases, and vapour transfer can take place by the molecular mass in the form of diffusion. And molar means as a filtration motion of the steam-gas mixture under the pressure gradient. Transfer of liquids can occur by means of diffusion, capillary absorption, and filtration motion in the porous material arising from the hydrostatic pressure gradient. The possible mechanisms of transfer of liquid within the porous material proposed by (Gavrila et al., 2008) include:

- Liquid diffusion caused by concentration gradient.
- Liquid transport due to gravity.
- Liquid transport due to capillary forces.
- Liquid transport due to suitable temperature gradient.
- Liquid transport due to the difference in total pressure caused by external pressure and temperature.
- Evaporation and condensation effects caused by differences in temperature.
- Vapour diffusion due to shrinkage and partial vapour-pressure gradients.
- Surface diffusion in liquid layers at solid interface due to surface concentration gradient.

Drying is essentially important for preservation of agricultural crops for future use. It preserves crops by removing a good quantity of moisture from them to avoid decay and spoilage. For example, the principle of the drying process of ginger rhizomes involves decreasing the water content of the product to a lower level so that micro-organisms cannot decompose and multiply in the product. The drying process unfortunately can cause the enzymes present in ginger rhizomes to be killed, and such dry products can be preserved for a long time.

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Thin layer drying studies provide the basis for understanding the unique drying characteristics of any particular food material. The results of such studies have been widely used to simulate dryers under deep-bed drying conditions and for quantifying parameters for the design of specialized drying equipment. In thin layer drying, the moisture content of a bio-material exposed to a stream of drying air of known relative humidity, velocity and temperature is monitored over a period of time. A number of mathematical models have been developed to simulate moisture movement and mass transfer during the drying of many agricultural products.

The porous material that will be used for this study is ginger. The thermophysical properties of ginger will be obtained and used in the resulting mathematical equations.

Figure 1 Raw materials for the experiments (Ginger Rhizomes)

Ginger is an herbaceous perennial plant known as *Zingiberofficinale*, which belongs to the order *scitamineae* and the family *zingriberaceae*.

Ginger rhizomes are popular in most countries throughout the world (Omeni, 2015) Ginger rhizomes are edible and are cultivated in warm, very hot and humid (tropic and subtropical) regions. The harvesting season differs from a country to another or continent. In the southern hemisphere locales such as Kano State, Nigeria harvesting season is in July while in the northern hemisphere locales such as Hawaii and USA harvesting season is in December. Ginger rhizomes grow from 60-125cm high under viable environments and they are cultivated annually (Nishina et al., 2013; Salathe et al., 2014)Ginger rhizome is grown for its pungently aromatic underground stem or rhizome which is an important export crop valued for its powder, oil and oleoresin, all of which have both food and medicinal values(NEPC, 1999)

1.1 Statement of the Problem

Nigeria is presently the fifth top producer of ginger in the world and one of the principal exporters of ginger (FAO, 2008).The most important form in which ginger enters international trade is as a dried product; next in importance are a preserved ginger and the trade in fresh ginger of least significance (Edwards, 1975) The quality of fresh ginger produced in Nigeria is the best in the world. However, it has been observed that the quality of its dried ginger has been declining due to low level of mechanization of ginger production and processing (Onu and Okafor, 2003)With the attendant mold growth and loss of some important ginger qualities because of which Nigerian ginger attracts the cheapest price in the world market (Ekundayo et al., 1988).Therefore, there is dire need for systematic study of the drying process of ginger rhizome. In this work, attention will be directed towards the use of thin layer drying process to determine the drying characteristics of ginger rhizome slices in a convective environment.

1.2 Aim and Objectives of the Study

The aim of this work is to study the thin layer drying characteristics of ginger rhizome slices in convective environment.

Objectives

To achieve the aforementioned aim, the following are the objectives of the study:

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- To estimate the moisture content at optimum temperature and drying time.
- To determine the thermal conductivity of variously treated ginger rhizomes experimentally at different moisture contents, drying time and temperature using linear heat conduction equipment.
- To compare the thermal conductivities of the variously treated ginger rhizomes samples as a function of moisture contents.
- To benchmark and recommend a guideline for thin layer drying for ginger rhizomes which will in turn improve the quality of the products from Nigeria.
- To establish the best drying model for the various drying characteristics of ginger rhizome slices.

1.3 Relevance of the Study

The drying of the porous material was conducted experimentally under free and forced convection environmental conditions. Ginger rhizomes used were peeled, unpeeled, split and then cut into slices before drying at elevated temperatures in environmental chamber. The heat and mass transfers were studied using available correlations of boundary layer equationsas as shown in figure 2.

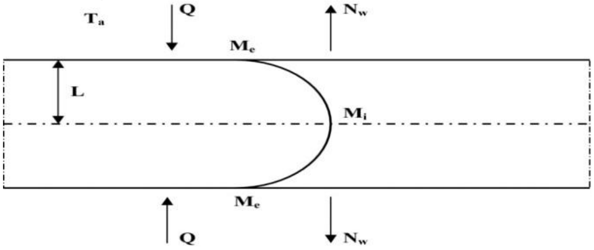


Figure 2 Schematic view of thin layer drying, if drying occurs from both sides (Erbay and Icier, 2010)

$$t = 0, -L \leq x \leq L, M = M_t \qquad (1)$$

$$t > 0, x = 0, {}^{dM}/_{dx} = 0 \qquad (2)$$

$$t > 0, x = L, M = M_e \qquad (3)$$

$$t > 0, -L \leq x \leq L, T = T_a \qquad (4)$$

Assumptions made in thin layer equations formulations:

i. The particle is homogenous and isotropic;
ii. The material characteristics were assumed constant and shrinkages neglected;
iii. The variations in pressure were overlooked;
iv. Evaporation occurs only at the surface;
v. At the beginning, moisture distribution is uniform (Eq. 1) and symmetrical during process (Eq. 2);
vi. Surface diffusion is ended, so the moisture equilibrium arises on the surface (Eq. 3);
vii. Temperature distribution is uniform and equals to the ambient drying air temperature, namely the lumped system (Eq. 4);
viii. The heat transfer is done by conduction within the product and by convection outside of the product;
ix. Effective moisture diffusivity is constant versus moisture content during drying.

The economy of Nigeria had since mid-1960s of oil boom deviated from agriculture to petroleum. This has placed an undue pressure on the oil reserves in volatile Niger Delta region and agriculture and its produce has been neglected. Therefore, any adverse influence on oil both locally and internationally affects the economy of Nigeria drastically. The present administration of President Muhammad Buhari has promised Nigerians better days, change in all sectors and improved agricultural outputs. Nigeria needs to process its agriculture produce in order to derive the desired benefits available in the international markets. This research seeks to find solutions to the prevailing low quality of dried ginger in Nigeria.

1.4 Scope and Limitation

This study on the thin layer drying characteristics of ginger rhizomes produced in Nigeria will be experimental and analytical. It will not delve into production methods, harvesting techniques and marketing strategies. For the purpose of this study; the gingers are classified as Blanched, Unblanched, Peeled and Unpeeled.

The ginger rhizomes obtained for the study required a minimum duration of six to eight months of planting and will be dried to 7 – 15% moisture content. The Ginger rhizomes used in this study were obtained from one region. It is assumed that most ginger produced in Nigeria have similar quality and characteristics.

2.0 Material and methods

The Ginger rhizomes used in this study were gotten from Kachia in Southern Kaduna in Kaduna State of Nigeria and stored at room temperature before being used in the experiments. The drying experiments were carried out at the Electronic Manufacturing Engineering Laboratory (ERMERG) Hawkes building, University of Greenwich.

The ginger rhizomes that were used for the experiment were given various treatments: Blanched, Unblanched, Peeled and Unpeeled (Gbasouzor, 2020). The variously treated ginger samples were cut into slices of 30mm diameter and 18mm thickness by scoopers designed for this purpose. ARS – 0680 Temperature and Humidity Chamber was used to dry the samples. The Ginger Drying experiment will be conducted according to ASAE Standard S352.2. Before the commencement of the experiment, the whole apparatus was operated for at least 15-30 minutes to stabilize the humidity, air temperature and velocity in the dryer. Drying started by 08:00am and continued until the specimen reached the final moisture content. The weight losses of the sample in the environmental chamber were recorded during the drying period of 2 and 24 hours with electronic balance (EK-200g, Max 200±0.01g). After the end of drying, the dried samples were collected for the measurement of their thermal conductivities using the linear heat conduction equipment, TD1002A - Linear Heat Conduction Experiment Unit (LHTEU).

MATLAB toolbox was used to generate a computer programme to analyze the drying of ginger rhizomes and statistical method was used to establish the best drying model for the variously treated ginger rhizomes samples.

2.1 Developed Computer Programming

The MATLAB Partial Differential Equation Toolbox™ has the capabilities of solving partial differential equations (PDEs) in 2-D, 3-D and time using finite element analysis. It can specify and mesh 2-D and 3-D geometries and formulate boundary conditions and equations. The PDE Toolbox was employed to PDEs for diffusion, heat transfer, structural mechanics, electrostatics, magnetostatics, and AC power electromagnetics, as well as custom, coupled systems of PDEs. In this study, the Boundary condition chosen for the heat transfer problem is the Dirichlet Boundary condition and the PDE specification employed is the elliptic which is mathematically expressed as:

Dirichlet Boundary Condition:

$$hu = r \tag{5}$$

Where h is a matrix, u is the solution vector, and r is a vector.

Elliptic PDE specification:

$$-div(k * grad(T) = Q + h * (T_{ext} - T) \tag{6}$$

Where T is temperature, Q is heat source, $K$is the coefficient of heat condition, h is the convective heat transfer coefficient,T_{ext} is the external temperature.

2.1.1 Heat Transfer of Ginger Rhizomes using MATLAB in Analysing the Simulation and Modelling of the Temperature Distribution of the Ginger Samples and Comparing Different Plots, Moisture Content, Moisture Ratio

A computer programme was also developed in MATLAB to easily compute, analyse and conduct simulations for the ginger drying.

Figure 3 shows the discretized meshed of the ginger rhizome in line with the cut geometry for the different case under study. The discretized samples have 545 nodes and 1024 triangle elements.

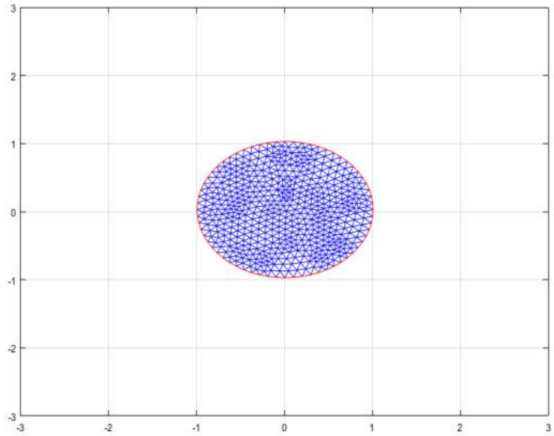


Figure 3 Discretized mesh with 545 nodes and 1024 triangles

Figures 4-9 describe the temperature distributions of unblanched, blanched, peeled and unpeeled ginger samples at temperatures: 10℃, 20℃, 30℃, 40℃, 50℃ and 60℃. In Figure 3, the temperature distribution for the unblanched ginger at 10℃ transmits heat radially from 10℃ to a final peak temperature of 60℃. For the blanched ginger, the heat is transmitted radially from 10℃ to a final peak temperature of 70℃. At 10℃for the peeled ginger rhizome, it can be clearly seen that the temperature distribution is radial from 10℃ to a final peak temperature of 60℃ while for the unpeeled ginger rhizomes, the distribution radiates from 10℃ to a final peak temperature of 70℃.

Similarly, at a temperature of 20℃. The temperature distributionsfor the unblanched and peeled rhizomes respectively, look alike as both figures radiate from 10℃ to a final peak temperature of 60℃. In contrast, the temperature radiates from 10℃ to a final peak temperature of 80℃ while the temperature rose steadily from 10℃ to 70℃.

For the temperature distributions at 30℃ to 60℃ as typified, the peak radial temperatures were seen to be higher than what was obtained initially at 10℃ and 20℃. A thorough look shows that the temperature distribution at 40℃ was remarkably higher than those obtained at 30℃ and 60℃ but compare relatively to the values obtained at 50℃. The high temperature distribution is responsible for the colour changes obtained for the final product.

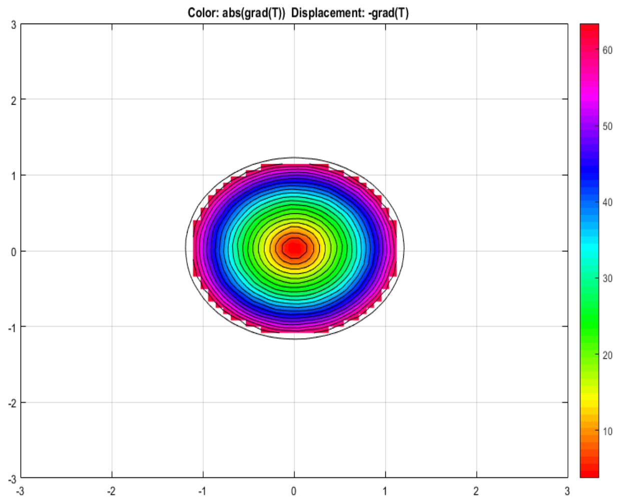


Figure 4 Temperature distribution for theUnblanched at 10℃

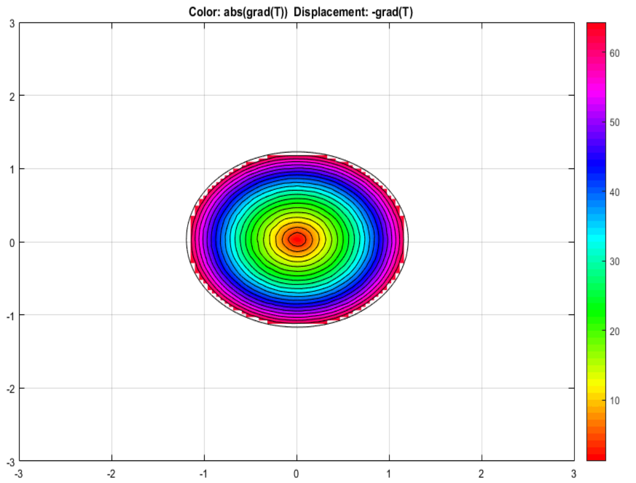


Figure 5 Temperature distribution for the Unblanched at 20℃

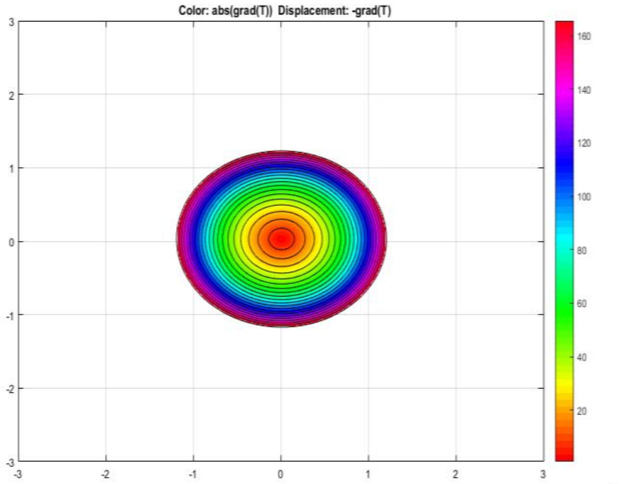


Figure 6 Temperature distribution for the unblanched at 30℃

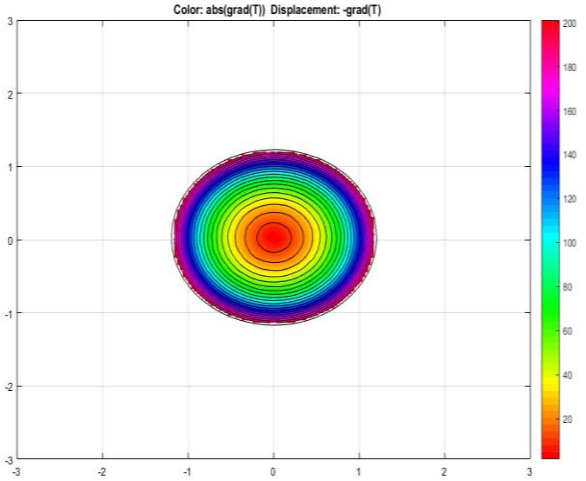


Figure 7 Temperature distribution for the unblanched at 40℃

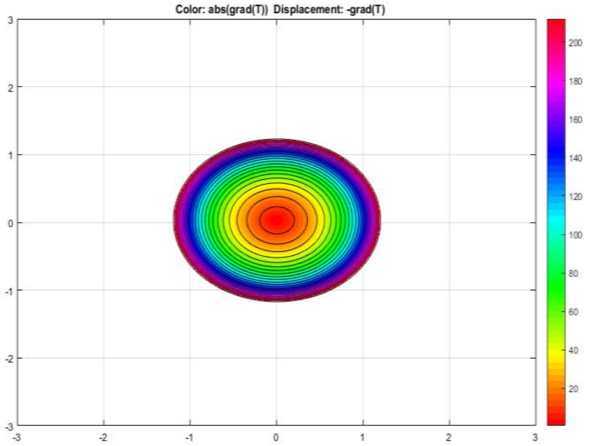


Figure 8 Temperature distribution for the unblanched at 50℃

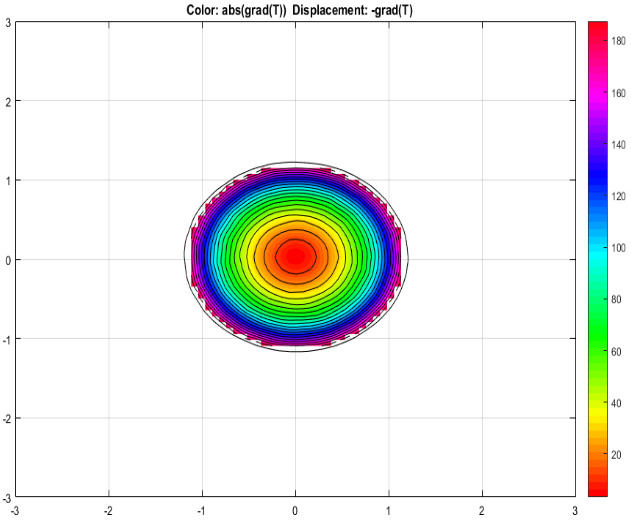


Figure 9 Temperature distribution for the unblanched at 60℃

Figures 4-9 presents the MATLAB generated temperature distribution profiles for variously treated ginger samples at different temperature levels. The profile shows that temperature increased from the core to the outermost contour.This is clearly demonstrated in figures 10 to 15. The diameter of each sample was 30mm and the thickness was 18mm. The distance from the outermost contour to the core of the sample is about 15mm. The MATLAB simulated temperature distribution shows that at chamber temperature of 10^{o}C, the core temperature of blanched ginger sample was 10^{o}C and those of other treatments were below 10^{o}C (figure 10). Also from figure 10, it can be observed that the temperature increased linearly from the center (core) to the outermost contour. Similar trend could be noticed for other chamber temperatures (see figures 11 to 15).

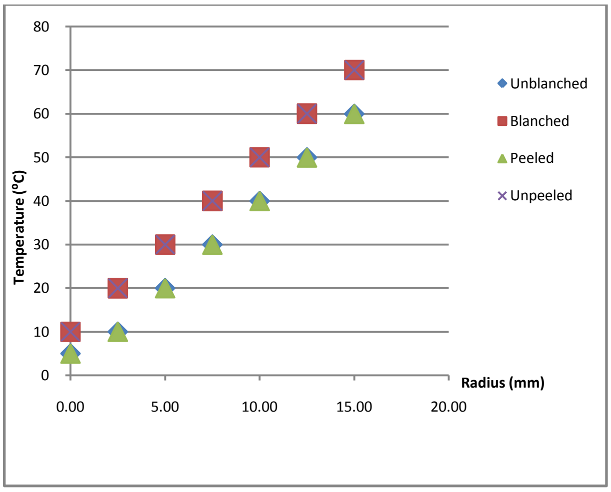


Figure 10: Simulated temperature distribution for variously treated ginger samples at 10°C

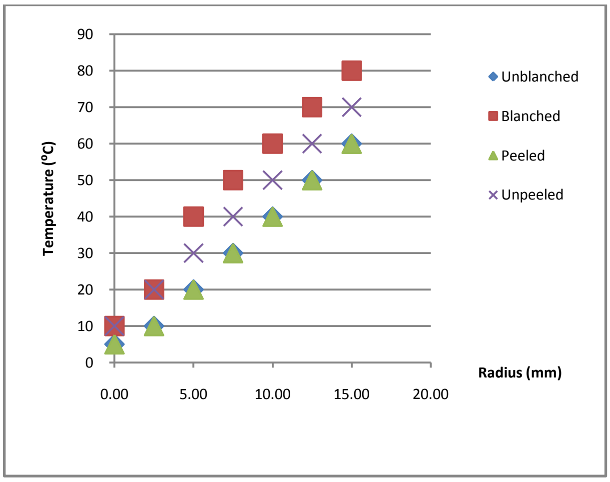


Figure 11: Simulated temperature distribution for variously treated ginger samples at 20°C

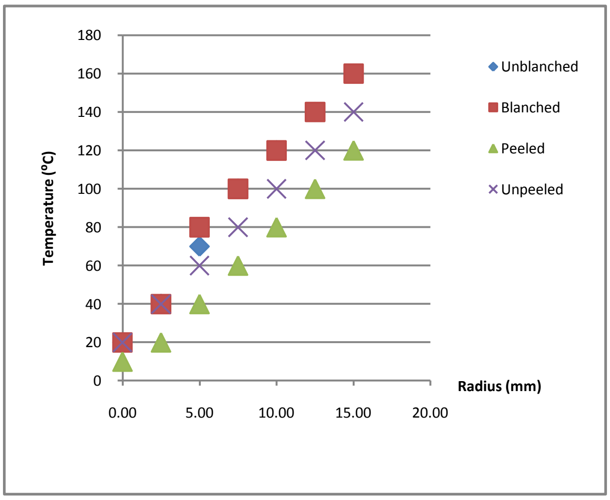


Figure 12: Simulated temperature distribution for variously treated ginger samples at 30°C

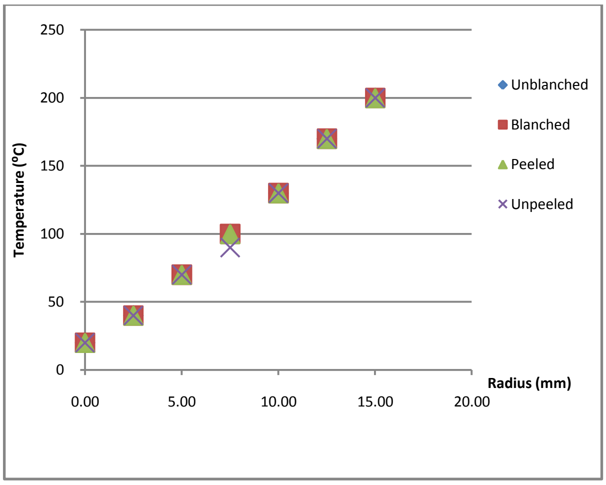


Figure 13: Simulated temperature distribution for variously treated ginger samples at 40℃

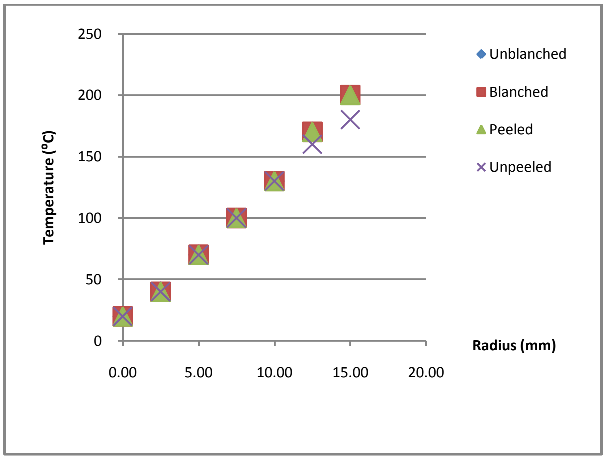


Figure 14: Simulated temperature distribution for variously treated ginger samples at 50℃

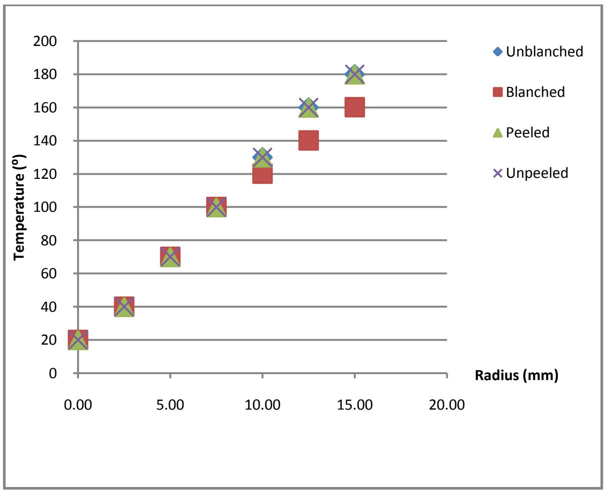


Figure 15: Simulated temperature distribution for variously treated ginger samples at 60℃

From Fourier's law of heat conduction, it can be seen that the amount of heat flowing through a sample is given as
$Q = kA\frac{\Delta T}{\Delta r}$ (7)

From the plot of temperature variation against radius, the thermal conductivity, k, can be evaluated using the relationship:

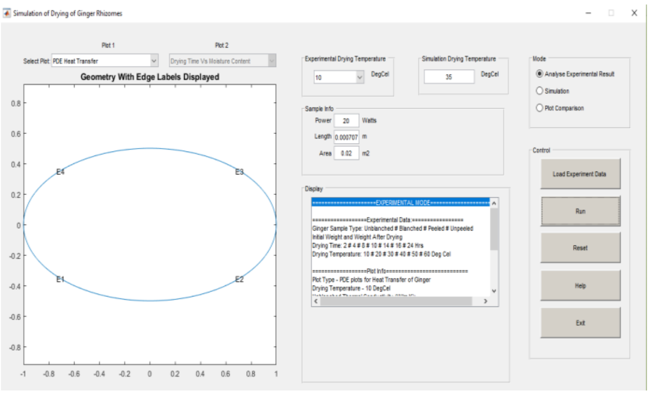
$$k = \frac{Q}{slope \times A} \qquad (8)$$

Table 1 presents the slopes of figures 9 through 14 for variously treated ginger samples. The values in table 1 were used to generate table 2 using equation 8. The average value for each treatment was evaluated and highlighted in table 2.

Figure 21 compares the experimental and simulated thermal conductivities. The average values of thermal conductivities of the variations in thermal conductivity of the ginger samples with temperature at drying time of 2 hours and that of thermal conductivity values from the simulated solution were used in the comparison. It could be seen that the plots followed the same trend for various treatment, although the plot for the simulated thermal conductivity was somehow higher that of the experimental.

Comparing the thermal conductivities for the unblanched at 10^0C shows those of the results obtained by simulation being about 45.6% larger than those obtained from the experiment. Similarresults are obtained for other systems. The large difference may have occurred from the values of parameters used for simulation.

2.1.1.1 Screen Shots of the Various Simulations Performed for the Ginger Rhizomes



Select Plot: PDE Heat Transfer

Drying Time Vs Moisture Content

Experimental Drying Temperature: 10 DegCel

Simulation Drying Temperature: 35 DegCel

Mode: ● Analyse Experimental Result ○ Simulation ○ Plot Comparison

Sample Info

Power 20 Watts

Length 0.000707 m

Area 0.02 m2

Display

```
=====================EXPERIMENTAL MODE====================

==================Experimental Data:==================
Ginger Sample Type: Unblanched # Blanched # Peeled # Unpeeled
Initial Weight and Weight After Drying
Drying Time: 2 # 4 # 8 # 10 # 14 # 16 # 24 Hrs
Drying Temperature: 10 # 20 # 30 # 40 # 50 # 60 Deg Cel

==================Plot Info===========================
Plot Type - PDE plots for Heat Transfer of Ginger
Drying Temperature - 10 DegCel
```

Fig 16 Geometry with Edge labels displayed

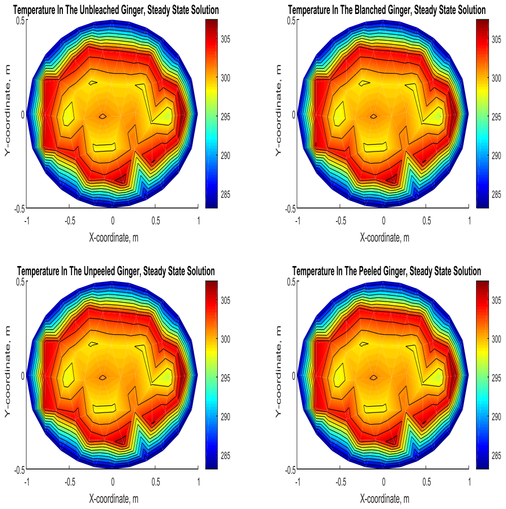


Fig 17 PDE Heat transfer for the Ginger samples at 10

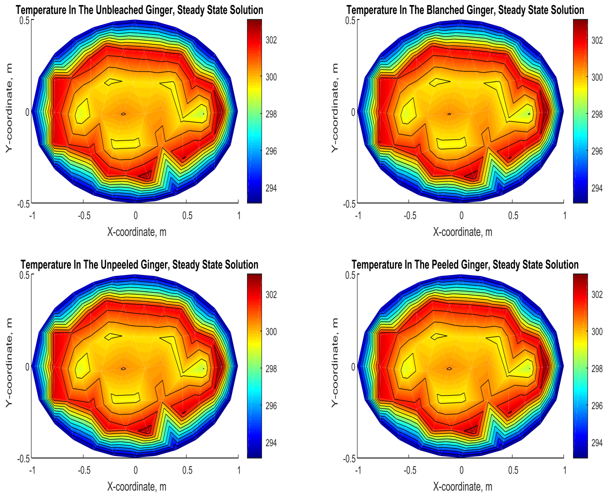


Fig 18 PDE Heat transfer for the Ginger samples at 20°C

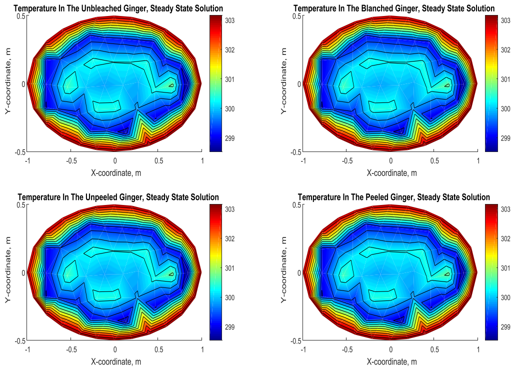


Fig 19 PDE Heat transfer for the Ginger samples at 30°C

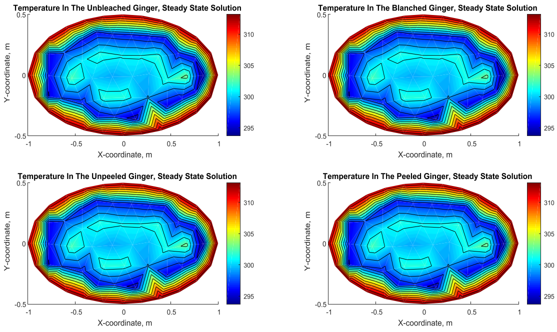


Fig 20 PDE Heat transfer for the Ginger samples at 40°C

The unblanched ginger at 10°C transmits heat radially from 10°C to a final peak temperature of 60°C as shown in figure 17. Similarly, at a temperature of 20°C, the temperature distribution in figure 18 for the unblanched rhizomes, looks like that of figure 17 as both radiate from 10°C to a final peak temperature of 60°C. For the temperature distributions at 30°C to 40°C as typified in figures 20 and 21, the peak radial temperatures were seen to higher than what was obtained initially at 10°C and 20°C. A thorough look in figures 17-21, shows that the temperature distribution at 40°C was remarkably higher than those obtained at 10°Cto 30°C. The high temperature distribution could be responsible to the colour change obtained for the final product.

Table 1: Slope of temperature distribution against radius for various treatment

Temp (°C)	Unblanched	Blanched	Peeled	Unpeeled
10	0.74749	0.70731	0.74749	0.70731
20	0.74749	0.60018	0.74749	0.70731
30	0.29561	0.30009	0.37370	0.35366
40	0.23040	0.23040	0.23040	0.23040
50	0.23115	0.23040	0.23040	0.25397
60	0.25397	0.29561	0.25397	0.25397
Average	**0.41768**	**0.39400**	**0.43057**	**0.41777**

Table 2: Thermal conductivity values from the simulated solution

Temp (℃)	Unblanched	Blanched	Peeled	Unpeeled
10	3.785	4.000	3.785	4.000
20	3.785	4.714	3.785	4.000
30	9.571	9.428	7.571	8.000
40	12.280	12.280	12.280	12.280
50	12.240	12.280	12.280	11.140
60	11.140	9.571	11.140	11.140

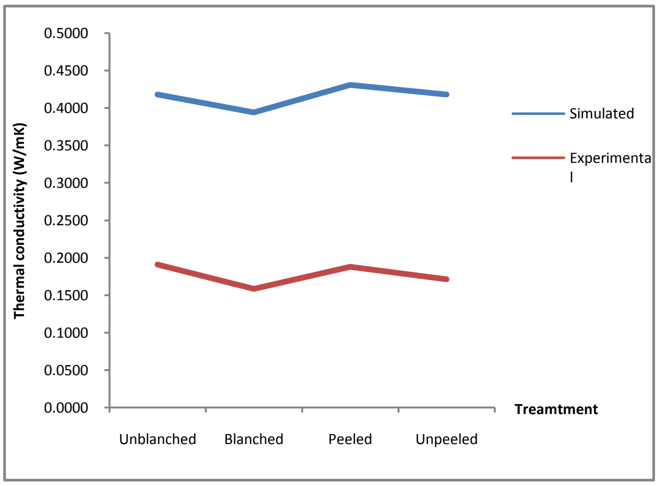


Figure 21: Comparsion of experimental and simulated thermal conductivity

Table 3 Table of Moisture Content (%) and Thermal Conductivity (W/m. K) for Unblanched, Blanched, Peeled and Unpeeled Ginger Rhizomes from 10℃ to 60℃ and drying time of 2 and 24 Hours

Temperature	**10°C**		**20°C**		**30°C**		**40°C**		**50°C**		**60°C**	
Time (Hour)	2	24	2	24	2	24	2	24	2	24	2	24
						Final Moisture Content (%)						
Unblanched	88.84	49.55	86.55	47.81	87.34	39.55	79.32	30.12	71.65	17.95	74.16	6.63
Blanched	84.58	41.13	86.29	34.26	86.65	17.48	70.11	17.00	66.64	10.25	63.11	9.04
Peeled	88.74	55.91	87.85	37.49	87.95	27.76	75.93	23.92	65.50	13.21	70.75	8.56
Unpeeled	91.08	62.22	86.17	48.36	87.71	31.15	81.46	26.30	67.85	15.49	74.36	5.98
						Thermal Conductivity (W/m. K)						
Unblanched	0.406	0.161	0.406	0.149	0.107	0.068	0.076	0.056	0.072	0.054	0.076	0.055
Blanched	0.329	0.140	0.292	0.131	0.1006	0.069	0.071	0.056	0.073	0.0556	0.084	0.052
Peeled	0.377	0.143	0.377	0.139	0.1459	0.065	0.072	0.052	0.076	0.0519	0.079	0.048
Unpeeled	0.340	0.171	0.345	0.171	0.1126	0.061	0.072	0.054	0.078	0.0460	0.078	0.046

2.2 Moisture Content Model by Dimensional Analysis

It is known that dimensionally, moisture content is a dimensionless quantity hence we can establish a dimensionless group which relates moisture content with other variables. By dimensional analysis, we have

$$M = f\left(\frac{w}{kTt}\right) \qquad (9)$$

Where M is the moisture content, k is thermal conductivity (W/mK), t is time (sec), W is weight (N), T is temperature (K) and *f* is a function.

Equation 9 can be transformed as

$$M = \alpha\left(\frac{W}{kTt}\right)^{\beta} \qquad (10)$$

Taking the log of equation 10, will give

$$ogM = log\alpha + \beta log\left(\frac{W}{kTt}\right) \qquad (11)$$

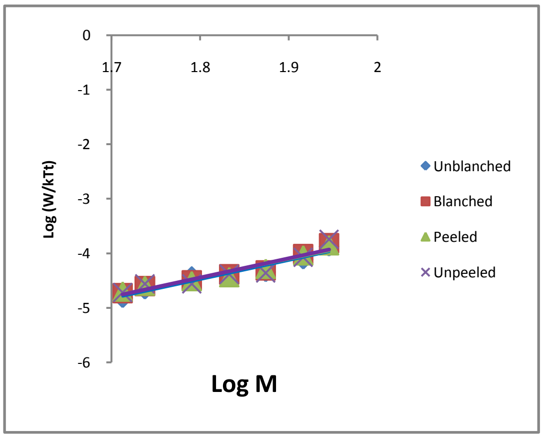


Figure 22: Moisture dimensional plot at 10^{o}C

Using the data of table 3 together with eq. (11), a plot of log(W/kTt) against log(M) at various temperature levels for the ginger samples was made as shown in figures 22 – 27.
The values of the constants α and β are listed on table 5.

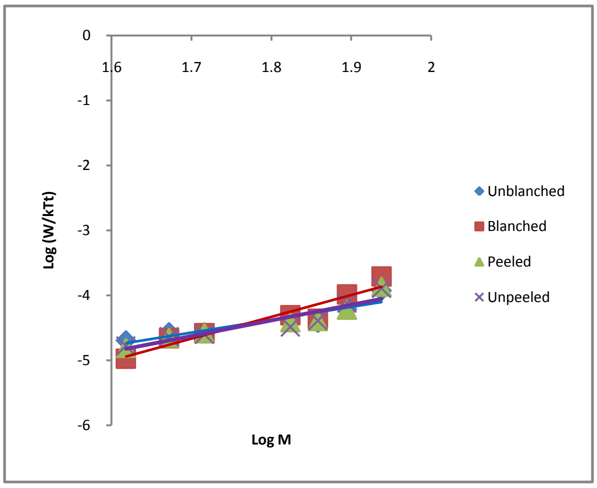


Figure 23: Moisture dimensional plot at 20^{o}C

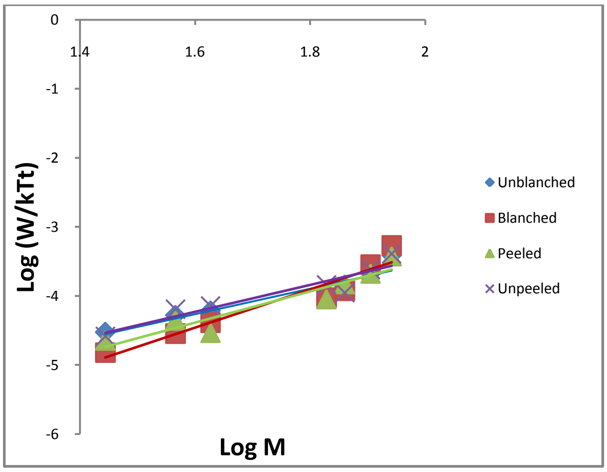


Figure 24: Moisture dimensional plot at 30^{o}C

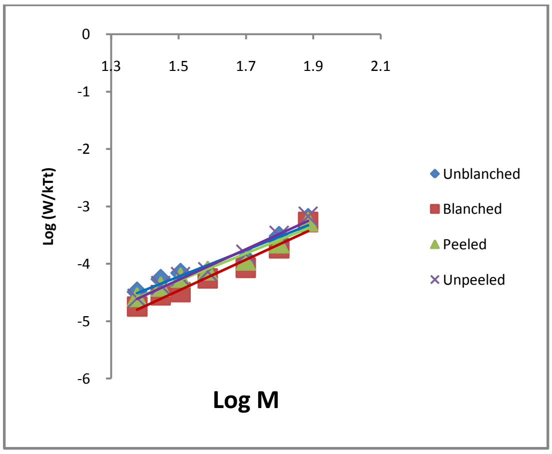


Figure 25: Moisture dimensional plot at 40^{o}C

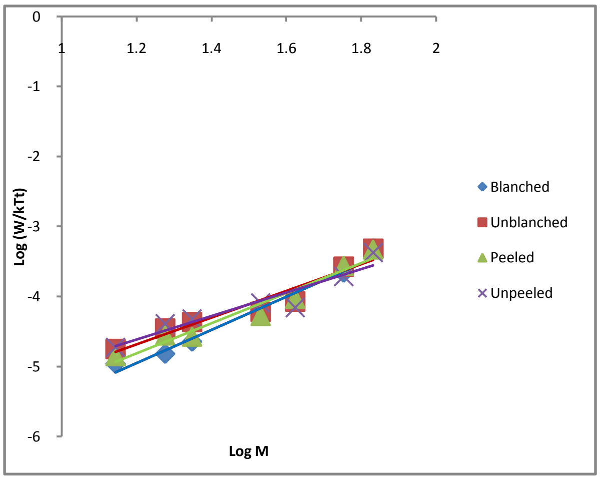


Figure 26: Moisture dimensional plot at 50°C

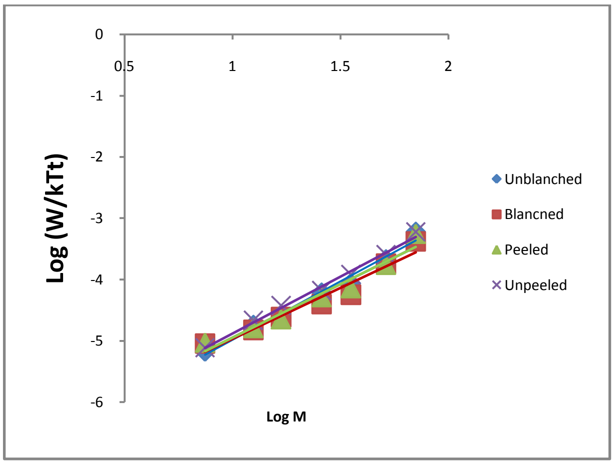


Figure 27: Moisture dimensional plot at 60°C

Table 4: α and β values for the developed moisture content model

	Blanched		**Unblanched**		**Peeled**		**Unpeeled**	
Temperature	α	β	α	β	α	β	α	β
10°C	1121.61	0.282	1215.8	0.287	1316.53	0.297	1138.67	0.283
20°C	1225.03	0.298	10769.92	0.510	4224.55	0.416	4221.15	0.416
30°C	1620.09	0.361	8197.49	0.543	3473.31	0.443	5920.44	0.514
40°C	1431.1	0.371	2062.69	0.430	2020.51	0.420	1266.21	0.374
50°C	1954.73	0.422	3124.38	0.524	2764.05	0.466	9032.77	0.597
60°C	9673.15	0.601	4102.09	0.524	6843.84	0.573	4262.36	0.539
Average	**2837.62**	**0.39**	**4912.06**	**0.47**	**3440.47**	**0.44**	**4306.93**	**0.45**

From eq.(10), the empirical equations relating moisture content to properties of ginger were determined by dimensionless analysis. These equations for the variously treated ginger rhizomes are presented in eqs. (12) to (15). The coefficients and indices are the average values of α and β as contained in Table 4 respectively. These equations might be used to predict the moisture content of the variously treated ginger rhizomes.

$$M = 2837.62\left(\frac{W}{kTt}\right)^{0.39} \quad (12)$$

$$M = 4912.06\left(\frac{W}{kTt}\right)^{0.47} \quad (13)$$

$$M = 3440.47\left(\frac{W}{kTt}\right)^{0.44} \quad (14)$$

$$M = 4306.93\left(\frac{W}{kTt}\right)^{0.45} \quad (15)$$

The indices average to 0.44, differing from 0% to about 11% with the average coefficient of 3874.27 as in eq. (16), giving a generic model equation for moisture content.

$$M = 3874.27\left(\frac{W}{kTt}\right)^{0.44} \quad (16)$$

3.0 Conclusion

In this study the following conclusion was drawn from this study:

- In the study of moisture content of ginger rhizomes, it was deduced that ginger could be dried at different temperatures. Ginger rhizomes dried at short time/low temperature will not reduce the effects of pest and bacterial infections, but when dried at high temperature say 60°C will drastically reduce the effects of pest and bacterial infections associated with moist ginger rhizomes.
- Simulation of discretized elements was applied on the dried ginger rhizomes using MATLABPDES for optimal programming of ginger rhizomes.
- MATLAB gave good approximations by Finite Element method of the temperature distributions within the ginger rhizomes at different drying temperatures.
- The results obtained for moisture content of ginger rhizomes clearly indicate that drying at significantly short time say two hours will not reduce the moisture sufficiently to reduce the effect of pest and bacterial infections.
- The drying rates at higher drying times (24 hours) were 0.889/°C and 0.4437/°C for 2 hours drying, giving 50% by moisture reduction rate. The intercept which theoretically gives the initial moisture content at 0°C is lower at 24 hours drying (59.33%) compared to 95.12%on dry basis at 2 hours drying, as expected. The average drying time for the variously treated ginger sample is 24hours.
- The result of this study shows that the lowest moisture content (5.98%) is obtained for unpeeled ginger(which is comparable with the required range of 4-7%)while the highest is the blanched (9.04%) all for 24 hours drying and at 60°C.
- The average moisture content for 2 hours drying at 60°C was 70.6% while for 24 hours drying; it was an average of 7.55% which is close to the range of 4-7% desired for this research. This is better than the result of 22.54% obtained at 50°C under blanched condition drying for 32 hours by Hoque et at (2013) andEze and Agbo (2011)who reported that the principal processing of ginger rhizomes involved sorting, washing, soaking, splitting or peeling and drying to moisture content 7-12%.
- The thermal conductivity for 24 hours –dried ginger at 60°C approximates to the thermal conductivity of dried ginger and it is 0.05 W/mk

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