Application of Temperature Distribution on Discretized Element of Dried Ginger Using MATLAB PDES for Optimal Preservation

Gbasouzor Austin Ikechukwu, *Member IAENG*, Joshua Depiver, Jude Ebem Njoku

***Abstract* – This paper presents the convective drying of ginger rhizomes under blanched, unblanched, peeled unpeeled condition using matrix laboratory (MATLAB) for finite element 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 10024a-linear heat conduction experimental equipment used in measuring the thermal conductive 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 meshed of the ginger rhizomes samples have 545 nodes (element) and 1024 (triagles) and the high temperature distribution could be responsible in the colour change obtained for the final product.**

Keyword: Blanched, Conductivity, Discretized element, Dried, Ginger Rhizomes, Matrix laboratory, Nodes, Peeled, Temperature distribution, Triangles, Unblanched, Unpeeled.

I INTRODUCTION

In numerical analysis, finite elements method is a numerical technology for finding approximate solution to partial differential equations and their systems. (PDES) The pratical application of finite element method, FEM is known as Finite element analysis, FEA. Finite element analysis has become a common place in recent yeas that even complicated strees problems can now be obtained with it.

Convective drying can be employed to remove volatile liquid 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.

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Moisture is removed by evaporation into an unsaturated gas phase. Drying is essentially important for preservation of agricultural crops for future use.

Crops are preserved by removing enough 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.

Ginger is the rhizome of the plant *Zingiber officinale*. It is one of the most important and most widely used spices worldwide, consumed whole as a delicacy and medicine. It lends its name to its genus and family *zingiber aceae*. Other notable members of this plant family are turmeric, cardamom, and galangal. Ginger is distributed in tropical and subtropical Asia, Far East Asia and Africa.

Fig. 1: Fresh Ginger Rhizomes

Ginger is not known to occur in the truly wild state. It is believed to have originated from Southeast Asia, but was under cultivation from ancient times in India as well as in China. There is no definite information on the primary center of domestication. Because of the easiness with which ginger rhizomes can be transported long distances, it has spread throughout the tropical and subtropical regions in both hemispheres. Ginger is indeed, the most wildly cultivated spice (Lawrence, 1984). India with over 30% of the global share, now leads in the global production of ginger.

Heat transfer of the Ginger rhizomes using MATLAB Partial Differential Equation Toolbox™ (PDE Toolbox) and Computer programme developed.

The MATLAB Partial Differential Equation Toolbox™ have 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 are mathematically expressed as:

Dirichlet Boundary Condition:

$$h * T = r \qquad (1)$$

Where h is the weight of the sample, r is the temperature

Elliptic PDE specification:

$$-div(k * grad(T) = Q + h * (T_{ext} - T) \qquad (2)$$

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.

II METHODOLOGY

Discretization Method

Partial differential equations (PDEs) are widely used to describe and model physical phenomena in different engineering fields and also in microelectronics fabrications. Finite element formation works on a large number of discretized elements and on different kinds of meshes within the domains. It also provides good results for a coarse mesh.

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

Figure 2 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.

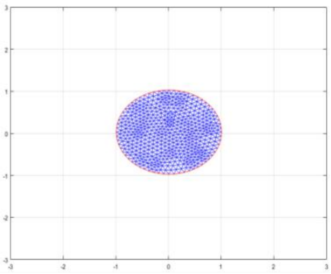

Figure 2: Discretized mesh with 545 nodes and 1024 triangles

Figure 3 describes the temperature distribution of unblanched, blanched, peeled and unpeeled ginger samples at temperatures: 10°C, 20°C, 30°C, 40°C, 50°C and 60°C. In Figure 3, the temperature distribution for the unblanched ginger at 10°C transmits heat radially from 10°C to a final peak temperature of 60°C. For the blanched ginger as shown in figure 4, the heat is transmitted radially from 10°C to a final peak temperature of 70°C. In Figure 5, at 10°C for the peeled ginger rhizome, it can be clearly seen that the temperature distribution is radial from 10°C to a final peak temperature of 60°C while for the unpeeled ginger rhizomes in Figure 6, the distribution radiates from 10°C to a final peak temperature of 70°C.

Similarly, at a temperature of 20°C, the temperature distribution in figures 7 and 9, the unblanched and peeled rhizomes respectively, looks alike as both figures radiates from 10°C to a final peak temperature of 60°C. In contrast, the temperature in figure 8 radiates from 10°C to a final peak temperature of 80°C while in figure 10, the temperature rose steadily from 10°C to 70°C.

For the temperature distributions at 30°C to 60°C as typified in figures 11-26, the peak radial temperatures were seen to higher than what was obtained initially at 10°C and 20°C. A thorough look in figures 11-26 show that the temperature distribution at 40°C was remarkably higher than those obtained at 30°C and 60°C but compare relatively to the values obtained at 50°C. The high temperature distribution could be responsible to the colour change obtained for the final product.

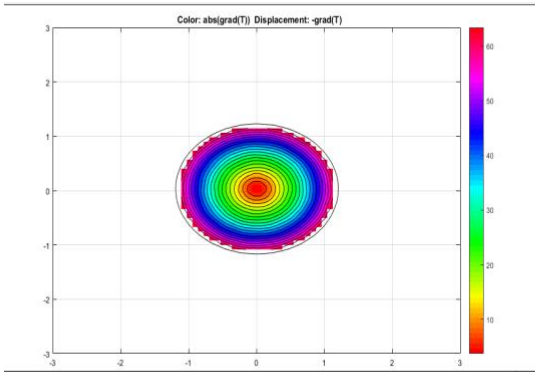

Figure3: Temperature distribution for the Unblanched at 10°C

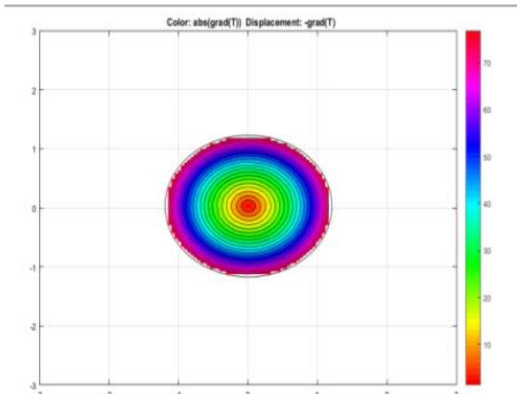

Figure 4: Temperature distribution for the Blanched at 10°C

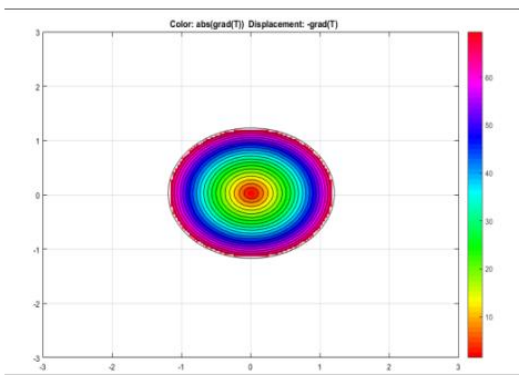

Figure 5: Temperature distribution for the Peeled at 10°C

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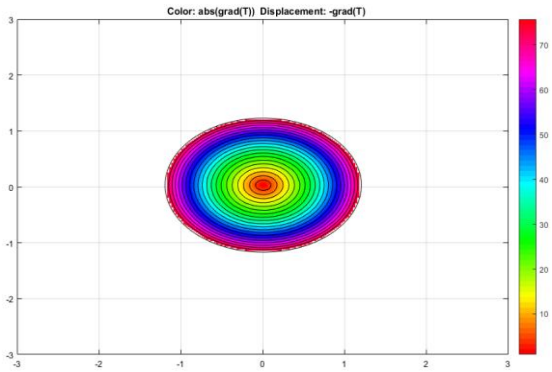

Figure 6: Temperature distribution for the Unpeeled at 10℃

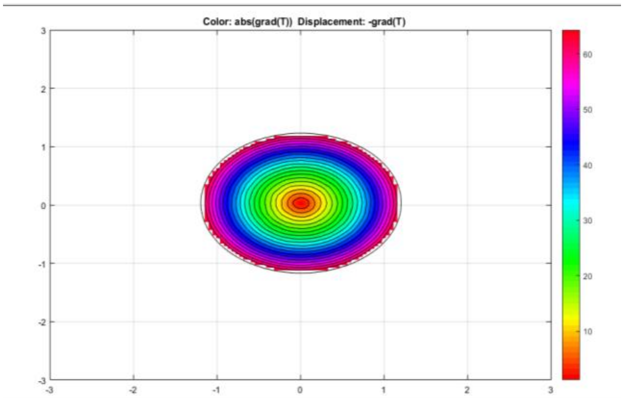

Figure 7: Temperature distribution for the Unblanched at 20℃

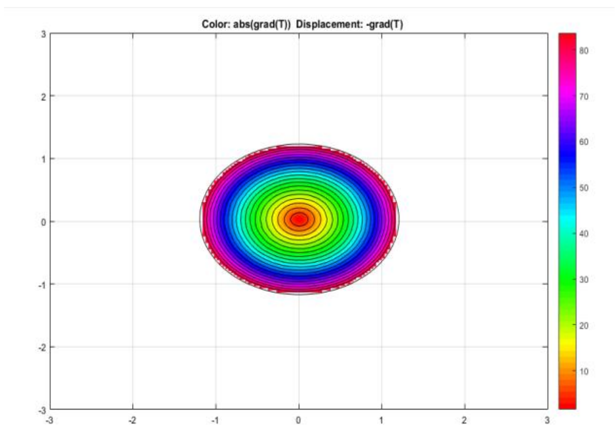

Figure 8: Temperature distribution for the Blanched at 20℃

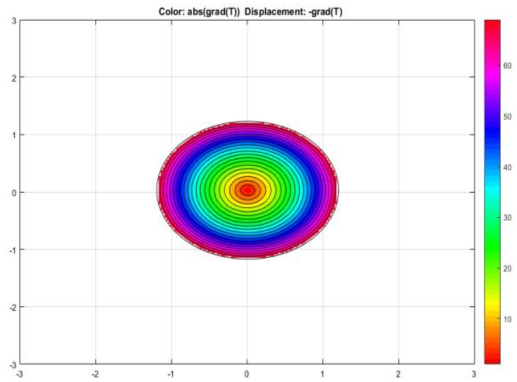

Figure9: Temperature distribution for the Peeled at 20℃

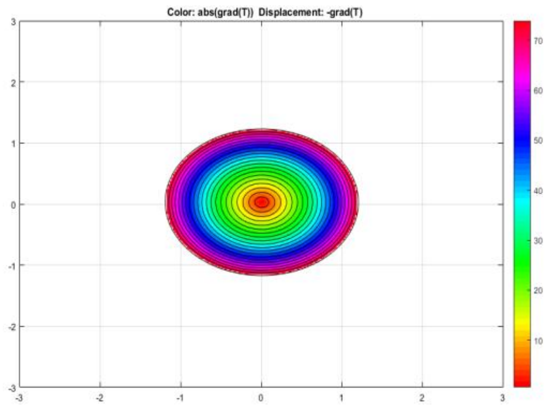

Figure10 Temperature distribution for the Unpeeled at 20℃

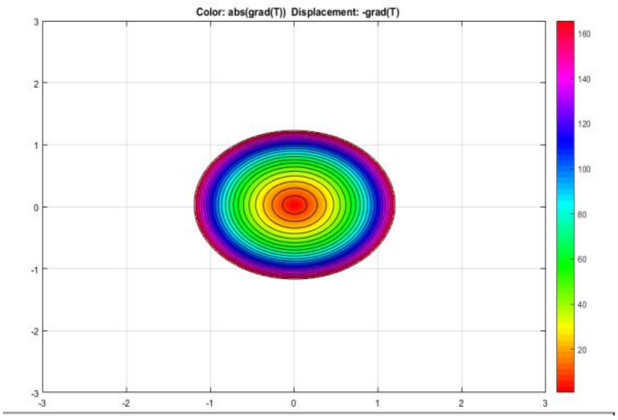

Figure 11: Temperature distribution for the unblanched at 30℃

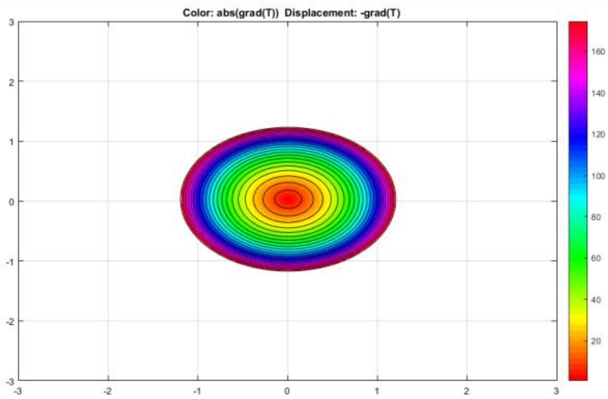

Figure 12: Temperature distribution for the Blanched at 30℃

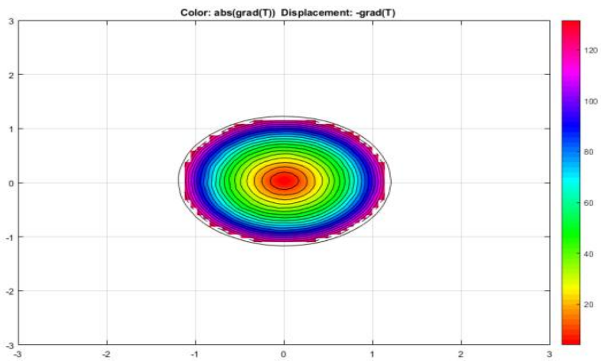

Figure 13: Temperature distribution for the Peeled at 30℃

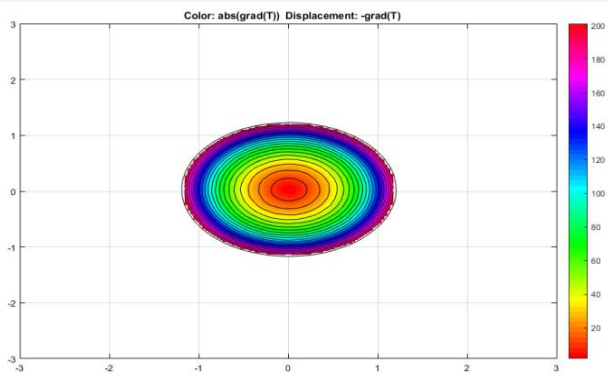

Figure 14: Temperature distribution for the unpeeled at 30℃

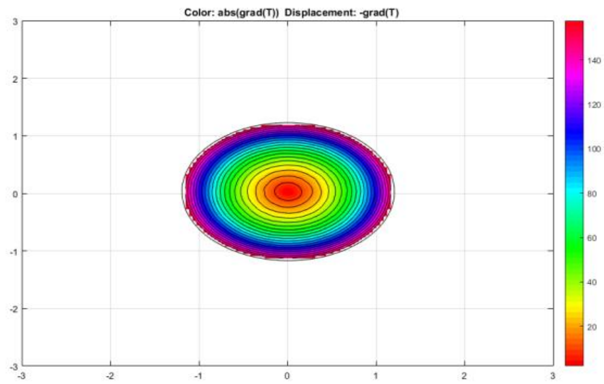

Figure 15 Temperature distribution for the unblanched at 40℃

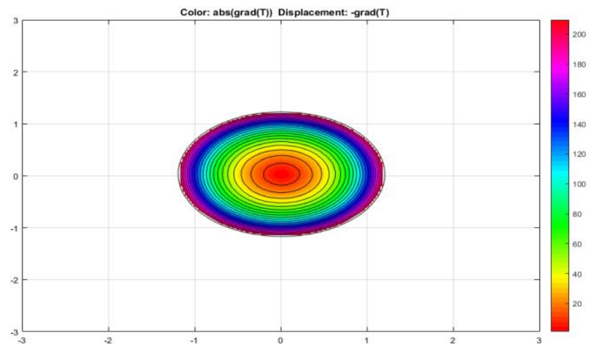

Figure16: Temperature distribution for the Blanched at 40℃

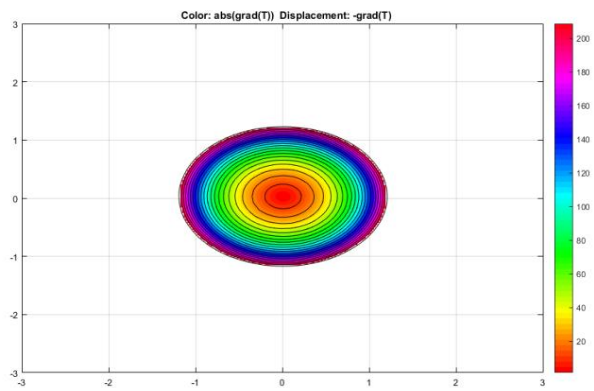

Figure 17: Temperature distribution for the Peeled at 40℃

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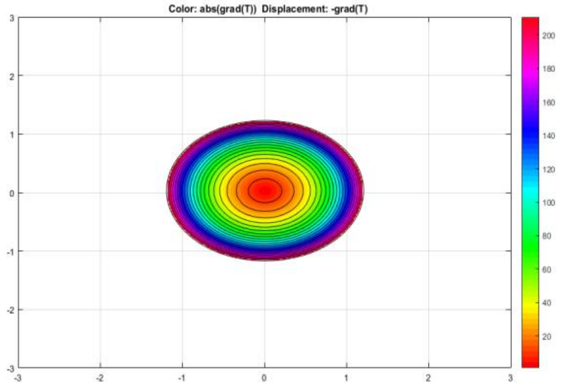

Figure 18: Temperature distribution for the unpeeled at 40℃

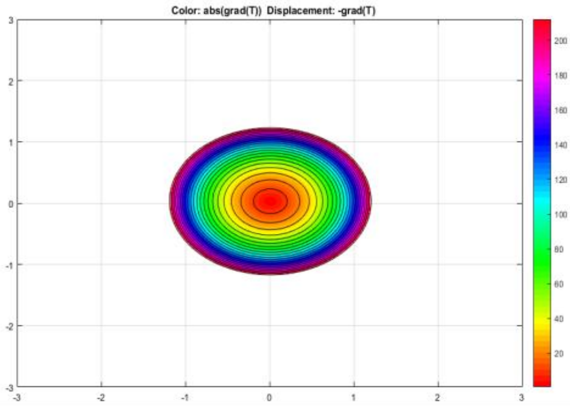

Figure 19: Temperature distribution for the unblanched at 50℃

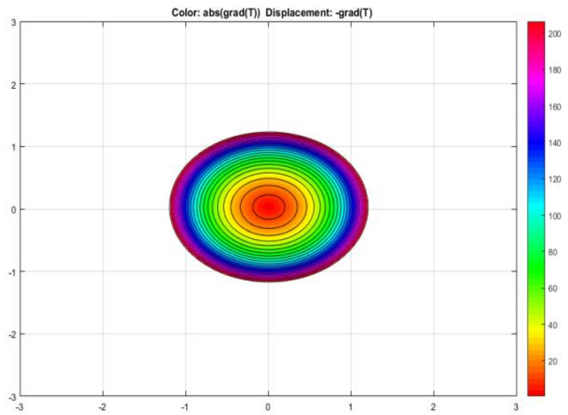

Figure 20: Temperature distribution for the Blanched at 50℃

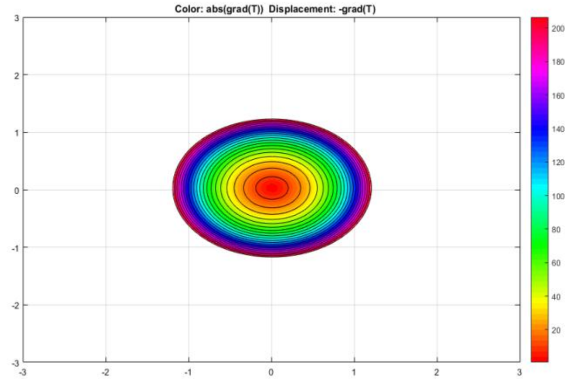

Figure 21: Temperature distribution for the Peeled at 50℃

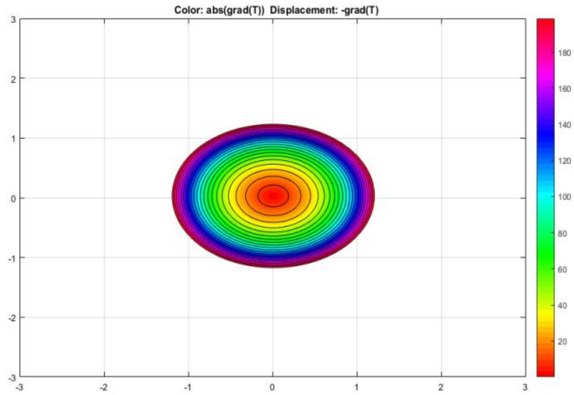

Figure 22: Temperature distribution for the unpeeled at 50℃

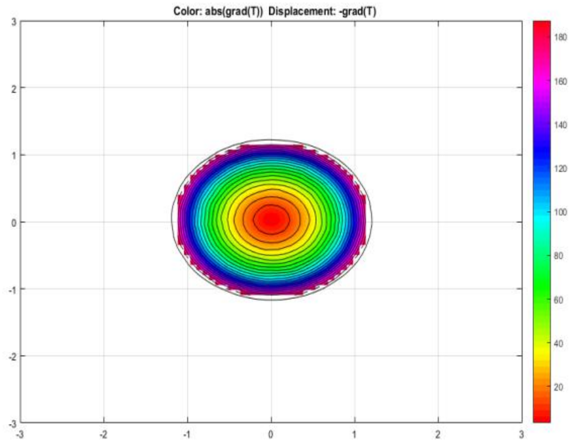

Figure 23: Temperature distribution for the unblanched at 60℃

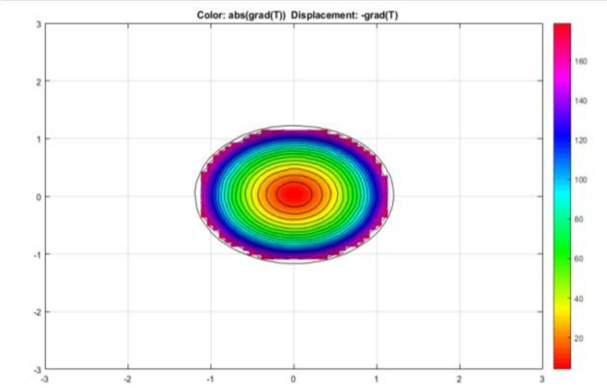

Figure 24: Temperature distribution for the blanched at 60℃

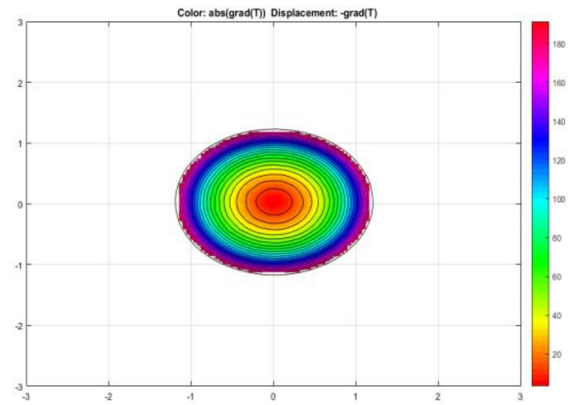

Figure 25: Temperature distribution for the Peeled at 60℃

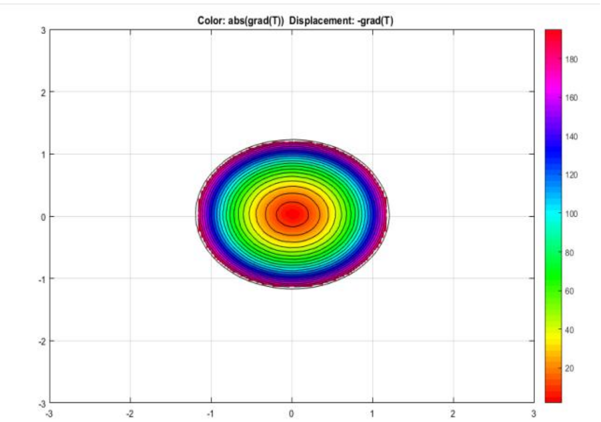

Figure 26: Temperature distribution for the unpeeled at 60℃

Table 1: 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	
Time (Hour)	2	24	2	24	2	24
Final Moisture Content (%)						
Unblanched	88.84	49.55	86.55	47.81	87.34	39.55
Blanched	84.58	41.13	86.29	34.26	86.65	17.48
Peeled	88.74	55.91	87.85	37.49	87.95	27.76
Unpeeled	91.08	62.22	86.17	48.36	87.71	31.15
Thermal Conductivity (W/m. K)						
Unblanched	0.406	0.161	0.406	0.149	0.107	0.068
Blanched	0.329	0.140	0.292	0.131	0.1006	0.069
Peeled	0.377	0.143	0.377	0.139	0.1459	0.065
Unpeeled	0.340	0.171	0.345	0.171	0.1126	0.061

Temperature	40°C		50°C		60°C	
Time (Hour)	2	24	2	24	2	24
Final Moisture Content (%)						
Unblanched	79.32	30.12	71.65	17.95	74.16	6.63
Blanched	70.11	17.00	66.64	10.25	63.11	9.04
Peeled	75.93	23.92	65.50	13.21	70.75	8.56
Unpeeled	81.46	26.30	67.85	15.49	74.36	5.98
Thermal Conductivity (W/m. K)						
Unblanched	0.076	0.056	0.072	0.054	0.076	0.055
Blanched	0.071	0.056	0.073	0.0556	0.084	0.052
Peeled	0.072	0.052	0.076	0.0519	0.079	0.048
Unpeeled	0.072	0.054	0.078	0.0460	0.078	0.046

III 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 past and bacterial infections, but when dried at high temperature say 60.c will drastically reduced the effects of pest and bacterial infecting associated with moist ginger rhizomes
- The drying rate at higher drying times (24 hours) was 0.889/°C and 0.4437/°C for 2 hours drying, giving 50% in 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 of drying, as expected. In Afolayan M.O et al (2014)
- The result of this study shows that the lowest moisture content (5.98%) is obtained for unpeeled ginger while the highest is the blanched (9.04%) all for 24 hour-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% as expected in Eze, J and Agbo, K (2011) This is better than the result of 22.54% obtained at 50°C under blanched condition drying for 32 hours (Hoque *et al.*, 2013).

- At higher temperatures ginger shrinkages and surface decolouration may occur. good results are achievable at temperature of 60°C to sustain the quality of the products for preservation .
- The thermal conductivity for 24 hour-dried ginger at 60°C approximates to the thermal conductivity of dried ginger and it is 0.050 W/mK on the average, with unpeeled ginger giving the lowest value of 0.046 W/mK and unblanched ginger giving the highest value of 0.055 W/mK.
- MATLAB gave good approximations by Finite Element method the temperature distributions within the ginger rhizomes at different drying temperatures.
- The essence of testing for thermal conductivities of samples is to gain proper understanding of their thermal behaviours. They are also utilized for the modelling and development of processes such as drying and freezing as mass and energy are exchanged. Other thermal properties such as thermal diffusivity and specific heat were not included in this research.
- The drying curve for the Nigerian ginger rhizomes under all conditions of temperature and time shows that increasing rate of drying behaviours clearly shows that maximum drying takes place at a higher temperature and time such as when external factors such as moisture barriers and air/mass movement influencing the drying process. The drying process is relatively slow at lower temperatures of 10°C - 20°C (Figures 3-26) and increases from 30°C - 60°C with an increase of drying time from 14 – 24 hours.
- Temperature distribution of discretized elements applied on the dried ginger rhizomes using MATLAB PDES for optimal preservation of ginger rhizomes.

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