Turkish Journal of Agricultural Engineering Research

https://dergipark.org.tr/en/pub/turkager
https://doi.org/10.46592/turkager.2021.v02i02.018

Turk J Agr Eng Res (TURKAGER)
ISSN: 2717-8420
2021, 2(2), 460-471

Research Article

Thermal Properties of New developed Nigerian Illa and Ekpoma Rice Flour Varieties as Effected with Moisture Content

Omenogor IKOKO[a] **Patrick Ejike IDE**[b*]

[a]*Departmet of Agricultural and Bioenvironmental Engineering, Delta State Polytechnic Ogwashi Uku, Delta State, NIGERIA*

[b]**Department of Agricultural and Bioresource Engineering, Enugu State University of Science and Technology, Enugu State, NIGERIA*

(*): Corresponding author, Patrick.ide@esut.edu.ng

ABSTRACT

Thermal parameters of food flour moisture content and temperature give an insight in the development and prediction of models that meet the needs of process design models, it also determine the thermal load of a particular product during handling. The bulk density (ρ), thermal conductivity (k), specific-heat capacity (Cp) and diffusivity (α) of Illa and Ekpoma rice flour were studied at varied (MC) moisture content (%) level. The results showed significance in thermal properties values at the different MC levels. The MC increased from 10.56 to 18.50%, increased the specific heat capacity (Cp) from 5.72 to 48.61kJ kg^{-1} $°C^{-1}$ and 6.84 to 29.41 kJ kg^{-1} $°C^{-1}$ for Illa and Ekpoma rice variety respectively and thermal conductivity(k) from 0.03 to 1.56 W/m^0C and 0.03 to 0.38 W m^{-1} $°C^{-1}$ for Illa and Ekpoma rice flour samples. Thermal diffusivity(α) and bulk density (ρ) of the processed Illa and Ekpoma rice flour samples decreased across the MC range of 10.56 to 18.50% (d.b). Thermal diffusivity(α) decreased from 4.38 to 1.25 x 10^{-4} m^2 s^{-1} and 3.42 to 1.30 x 10^{-4} m^2 s^{-1} for Illa and Ekpoma rice flour respectively while the values of bulk density (ρ) decreased from 697.72 to 676.34 kg m^{-3} and 687.49 to 664.26 kg m^{-3} for Illa and Ekpoma rice flour respectively.The developed model equations can be applied in estimation of thermal parameters of rice flour. Finally, Ekpoma and Illa rice flour sample displayed good thermal characteristics and it can be used as an alternative to imported wheat flour.
.

RESEARCH ARTICLE

Received: 04.09.2021
Accepted: 10.12.2021

Keywords:

- Thermal property,
- Moisture content,
- Rice varieties,
- Temperature,
- Rice flour

To cite: Ikoko O, Ide PE (2021). Thermal Properties of New Developed Nigerian Illa and Ekpoma Rice Flour Varieties as Effected with Moisture Content. Turkish Journal of Agricultural Engineering Research (TURKAGER), 2(2), 460-471. *https://doi.org/10.46592/turkager.2021.v02i02.018*

INTRODUCTION

Rice is the most food crop in the world with higher demand that feeds almost more than half of the world population (Pokhrel *et al.,* 2020; Danbaba *et al.,* 2019; Singh *et al.,* 2005). It is the second most beneficial cereal crop after wheat mostly in Nigeria that is cultivated throughout the world (Oko *et al.,* 2012). It belongs to the family of Poaceae and its origin was traced via ancient civilization native in Southeast Asia (Pokhrel *et al.,* 2020). Pokhrel *et al.* (2020) and Bandumula, (2018), reported that ninety percent (90%) consumed rice in Asia and eleven Asian countries contributed globally, 87% rice production in the world, while Nigeria is the number one importer in African and third importer in the whole world (Sowunmi *et al.,* 2014). Rice after proper cooking is consumed and it contains about 40% to 80% of the calorie intake (Thomas *et al.,* 2013). The rice landrace has played important role in livelihood and food security of the populace as it serves as food (Pokhrel *et al.,* 2020; Bhat and Riar, 2017). The rice breed has diverse agro-morphological properties, and some of the breeds do very well in terms of yield (Sharma *et al.,* 2020). According to Pokhrel *et al.* (2020), the traditional landraces have been adopted as a result of their higher nutritional value than the hybrid and also have been used medically for treatments of some different diseases like diarrhoea, vocal clarity, vomiting, fever improve eyesight, haemorrhage, burns, infertility (Pokhrel *et al.,* 2020). With ever growing population in Nigeria, the demand and consumption of rice equally expected to increase.

The rice consumption rate in Nigeria have been estimated to 40kg rice per capita and it will continue to rise as long as the population rises (Adekoyeni *et al.,* 2018; Asiru *et al.,* 2018; Maji *et al.,* 2017; Nahemiah *et al.,* 2004). Among the 4.6million hectares of land readily available for cultivation, only 1.7 million hectares are utilized (GAIN, 2016 and Nwachukwu *et al.,* 2018). In 2016, globally, rice demand was approximately estimated to be 6.3 million metric tons while the short change in local supply was estimated to be 2.3 million metric tons (FMARD, 2016; Asiru *et al.,* 2018). The unsupplied 4 million metric tons were expected to be supplied by rice importation (Asuming-Brempong and Osei-Asare, 2007). The importation of rice (foreign) has caused a profuse effect on Nigeria's economy as it caused a severe danger in foreign exchange earnings and it also reduces nations' foreign reserve (Asiru *et al.,* 2018). As a result of all forgoing, there is a need to increase the landrace of rice with mind of improving quality and reducing the shortfall in rice and its based products supply.

This research work tends to in determination of the thermal properties of Illa and Ekpoma rice flour which will in due cause facilitate the thermal processing of the rice varieties. According to Mahapatra *et al.,* (2011) and Jica (2013) thermal treatments like drying, pasteurization, parboiling, cooling, sterilization, thawing, cooking are regularly in food handling and processing (Heldman, 2001). The information on thermal properties of agricultural materials like flour are vital for designing updated handling and storage systems (Lan *et al.,* 2000; Qi *et al.,* 2000; Kim *et al.,* 2003). The specific data of thermal properties of biomaterials are needed for both already existing food and newly developed products with their processes. In terms of processing and storage, thermal properties effects sensory and nutritional quality of food products. (Kamath *et al.,* 1994; Muramatsu *et al.,* 2005; Bozikova, 2003, Ide *et al.,* 2020). Despite that, thermal properties of rough rice have been reported in literatures, but the rice flour has limited literature to date. The growing demand for imported rice and high import demand have catalyzed the interest in the development of domestic rice varieties. Nigeria is the highest importer of rice in Africa, and the second highest in the World. Rice imports in Nigeria have represented a good proportion of total food imports overtime and there exists a threat to the Nigerian economy due to large volume of milled rice imports into Nigeria, with an import bill currently exceeding US$2 billion (Thomas *et al.*, 2013; Premium Time, 2017).

As a result of high demand for processed flour by food processors and industries. It is important to study their behavior of Illa and Ekpoma rice under different heat treatments. Therefore, the objectives of this research work was to investigate some thermal parameters of Illa and Ekpoma rice flour at different moisture content, and temperature using standard method.

MATERIALS and METHOD

Source of samples

Ekpoma rice was sourced from a local farm located Esan West, Local Government Area of Edo State while Illah rice was sourced from a local farm located in Oshimili North Local Government Area of Delta State both in Nigerian. Delta and Edo States are South-South part of Southern States in Nigeria. Delta State located within Latitude of 6.2059^{0}N and langitude of 6.6959^{0}E while Edo State is located 5.60^{0}N latitude and 6.32^{0}E longitude. Edo and Delta State are in tropical equatorial climate with mean annual temperature of 32.8^{0}C and annual rainfall ammount of 2673.8mm.

Preparation of the sample

The method reported by Jideani (2005) was used to prepare the rice sample into rice flour. The rice grains (1 kg) of Ekpoma and Illah rice species were selected and properly washed using warm distilled water at (65°C) water to remove unwanted materials attached on them from point of source capable of influencing the results. The partly processed samples were oven-dried (Multipurpose oven, with Model number OKH-HX-1A China) at 24 h for 50°C milled and sieved using locally fabricated attrition mill and sieved through 200 µm size respectively in order to obtain fine rice flour. The flour samples were further processed to three different moisture level 18.5, 12.50 and 10.56% (db), thereafter stored in a sealed plastic with appropriate labels and carried to the lab where the experiment was conducted.

Determination of the specific heat of rice flour

After the caloric values has been generated using bomb calorimeter, the specific heat capacity of rice flour was calculated using the method and equations reported by Association of Official Agricultural Chemists AOAC (2000) and Ide *et al.* (2020) on persimmon and horse-eye bean flour respectively.

$$Energy\ Content\ = \frac{E\Delta T - 2.3B - V}{g}\left(\frac{KJ}{kg}\right) \quad (1)$$

Where;

$E = Energy\ equivalent\ of\ the\ calorimeter = 13039$

$\Delta T = Temperature\ rise$

$B = Length\ of\ burnt\ wire$

$V = Titration\ volume$

$g = Weight\ of\ the\ sample$

Determination of the thermal conductivity of the rice flour

The thermal conductivity of rice flour was determined using the line heat source probe approach method on non-stable state heat conduction with equation reported by Ide *et al.* (2020); Bart-Plange *et al.* (2009); Mortaza *et al.* (2008); Sahin and Sumnu (2006).

$$K = \frac{Q}{4\pi\Delta T} \quad (2)$$

Where;

$K = Thermal\ conductivty$ ($Wm^{-1}\ {}^{0}C^{-1}$)

$Q = Power\ rating\ of\ the\ calorimeter\ (J)$

$\Delta T = Change\ in\ temperature\ (k)$

Determination of thermal diffussivity of the rice flour.

The thermal diffusivity (α) of the rice flour samples were determined by adopting bulk density, specific heat capacity and thermal conductivity values of the rice flour. The equation reported by Ide *et al.* (2020); Bart *et al.*, (2009) on determination of thermal parameters of Horse-eye bean and maize and cowpea flour respectively was used to calculate thermal diffusivity of rice flour.

$$\alpha = \frac{K}{\rho_b\, c_P} \quad (3)$$

Where;

$\propto = thermal\ diffusivity$ ($m^2\ s^{-1}$)

$k = thermal\ conductivity$ ($Wm^{-1}\ {}^{0}C^{-1}$)

$\rho b = bulk\ density$ ($kg\ m^{-3}$)

$Cp = specific\ heat\ capacvity\ (J/K(KG))$

Determination of the moisture content of rice flour

This is the quality of water contains in the sample. The experiment was conducted under the influence of three (3) different moisture contents 10.56%, 12.50%, and 18.5% under wet base. The method reported by Ide *et al.* (2019) on effect of moisture content on the thermal properties of Horse-Eye Bean was adopted in determining the moisture content of the samples. The hydrated samples and the moisture content of the samples were measured using determined weight of wet sample and weight of dried sample using the following equation reported by Ide *et al.* (2019).

$$Mc = \frac{Ww - WD}{WD}\ x\ 100\% \quad (4)$$

Where;

Mc = moisture content, %; Ww = wet samples; and WD = dried samples.

Determination of the bulk density of rice flour

The method described by Sadiku and Bamgboye (2014) was used to determine the bulk density of the rice flour at various conditions.

$$p_b = \frac{M_s}{V_s} \tag{5}$$

Where;
$\rho b = bulk\ density\ of\ the\ rice\ flour$ (kg m^{-3})
$Vs = volume\ of\ the\ rice\ flour$ (m^3)
$Ms = mass\ of\ the\ flour\ sample\ (kg)$

Analysis of Variance

The data generated from this research work were subjected to analysis of variance (ANOVA), with the means compared by Duncan's test at 5% of significance. All results were expressed as the mean value standard error (SE). Statistical analyses were performed using SPSS for Windows 8.0 SAS 1988 version. The best fit regression equations were generated using excel world application package

RESULTS and DISCUSSION

The summary of results of the determined thermal parameters of Illa and Ekpoma rice flour are presented in the Table 1.

Table 1. Effect of moisture content on the thermal properties of milled rice flour at temperature range of 50 to 350˚C.

Samples	Moisture content (%)	Bulk density (BD) kg m^{-3}	Specific heat Capacity (kJ kg^{-1} ^{0}C^{-1})	Thermal conductivity (W m^{-1} ^{0}C^{-1})	Thermal diffusivity (x10^{-4} m^2 s^{-1})
ILLA	18.50	676.34(1.05)	48.61(2.-5)	1.56(2.04)	1.25(3.08)
	12.50	692.67(3.05)	7.34(1.07)	0.069(3.23)	1.57(3.05)
	10.56	697.72(3.24)	5.72(3.06)	0.036(0.95)	4.38(2.03)
Mean value	***13.85***	***688.91***	***20.55***	***0.55***	***2.40***
EKPOMA	18.50	664.26(1.32)	29.41(0.45)	0.386(0.93)	1.305(3.05)
	12.50	681.29(3.90)	9.31(2.04)	0.068(2.04)	1.488(1.23)
	10.56	687.49(3.01)	6.84(2.06)	0.033(3.12)	3.428(0.33)
Mean value	***13.85***	***677.68***	***15.18***	***0.15***	***2.06***

The values in brackets are the standard deviation of the replicated data.

The bulk density of processed Illa and Ekpoma rice flour samples presented in Figure 1 showed that the bulk density of Illa and Ekpoma rice flour sample were 697.72, 692.67 and 676.34 kg m^{-3} for Illa rice flour and 687.49, 681.29, 664.26 kg m^{-3} for Ekpoma rice samples at MC range of 10.56, 12.50 and 18.50% respectively. It was observed that, the increase in MC from 10.56 to 18.50% of rice flour samples decreased the bulk densities of both Illa and Ekpoma rice flour from 697.72 to 676.43 kg m^{-3} and 687.49 to 664.26 kg m^{-3} respectively (Anita *et al.*, 2019; Mahapatra *et al.*, 2011).

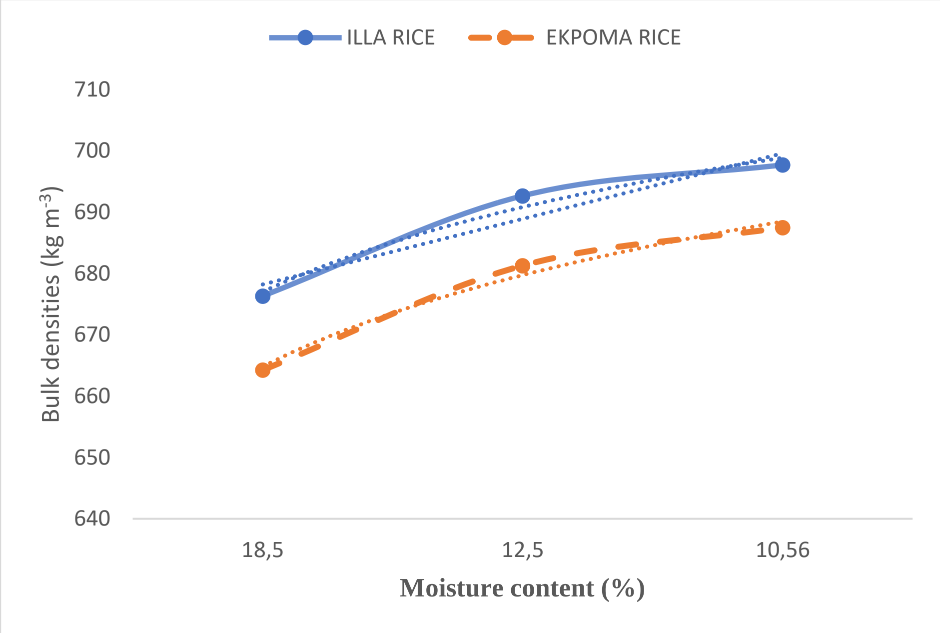

Figure 1. Moisture content effect on the bulk density of Milled ILLA and EKPOMA rice flour.

The observed different in bulk density and varieties were significant in MC ($p < 0.05$). This finding could be attributed to the fact that bulk density of the flour sample depends on thermal diffusivity. Bulk density effects both packing and transportation of food materials, the Illa rice flour sample with higher bulk density at 10.56% moisture content are known to exhibit better packaging factor and transportation advantages than those with low bulk density, based on this fact as the moisture content decreases the packing factor and transportation advantages increases *(*Arinola and Jeje, 2017*).* The relationship that existed between the bulk density and moisture content were best described in the following Equations (6) and (7).

$$BD = 19.902 \ln(MC) + 677.02T \quad R^2 = 0.9789 \tag{6}$$

$$BD = 21.514 \ln(MC) + 664.83T \quad R^2 = 0.9873 \tag{7}$$

for Illa and Ekpoma rice flour respectively. The trend of the bulk density graph of both sample exhibited logarithmic trend of best fit modelling equation on the effect of MC on the bulk density of processed rice flour samples (Table 2).

Table 2. Relationships of thermal properties with rice varieties, moisture content and temperature.

Thermal properties	Illa rice	R^2	Ekpoma rice	R^2
Bulk density (kg m^{-3})	$BD = 19.902\ln(MC) + 677.02T$	0.9789	$BD = 21.514\ln(MC) + 664.83T$	0.9873
Specific heat capacity (kJ kg^{-3} °C^{-1})	$Cp = 42.685(MC)^{-2.032T}$	0.9305	$Cp = 27.827(mc)^{-1.363T}$	0.9708
Thermal conductivity (W m^{-1}°C^{-1})	$K = 1.3421(MC)^{-3.694T}$	0.9706	$K = 0.3693(MC)^{-2.33T}$	0.9973
Thermal diffusivity (x10^{-4} m^2 s^{-1})	$\alpha = 4.1394(MC)^{-1.178T}$	0.9597	$\alpha = 3.2422(MC)^{-0.915T}$	0.9415

BD=Bulk density, *Cp*= specific heat capacity, *k*= thermal conductivity, *α*=thermal diffusivity, R^2= R squared value.

The specific heat capacity of agricultural flour determines the quantity of thermal energy a unit of the food flour retains at every unite increase in temperature (Sandra and Bernarda 2015). It is basically important in thermal analysis of packaged food products. From the table and figure 1, it was observed that specific-heat capacity was measured with respect to changes in moisture content and temperature. It was noticed that specific-heat-capacity of the rice flour samples showed that Illa rice flour samples increased from 5.72, 7.34 and 48.61 kJ kg^{-3} ˚C^{-1} while Ekpoma rice flour samples increased from 6.84, 9.31 and 29.41 kJ kg^{-3} ˚C^{-1} as MC increased from 10.56, 12.50 and 18.50%, respectively.

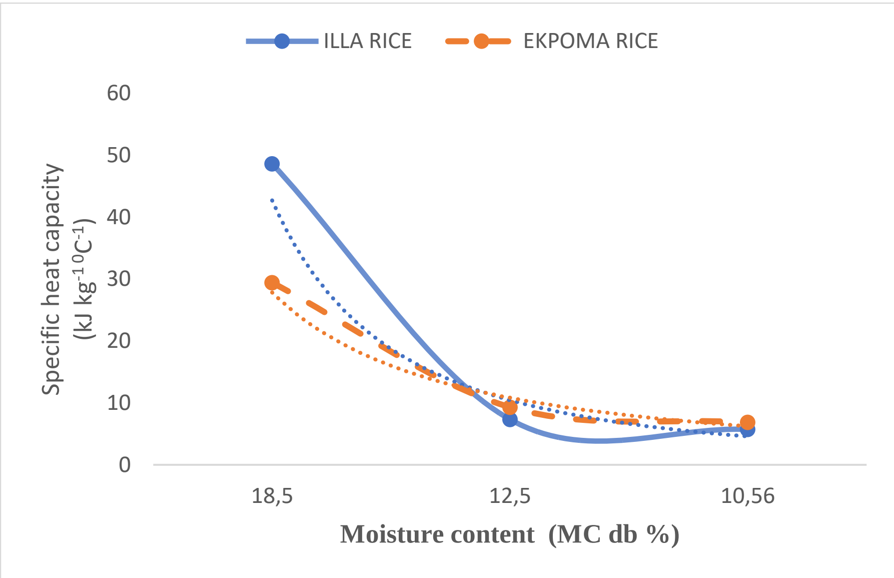

Figure 2. Moisture content effect on the specific heat capacity of Milled ILLA and EKPOMA rice flour.

The observed moisture content increase of the samples showed that, the moisture content and specific heat capacity varied significantly at ($p>0.005$) interval and this in line with the report of Anita *et al.* (2019) and Akbari and Chayjan (2017) reported on the effect of dry basis moisture content (MC) on African Walnut and persimmon for modelling of thermal properties of the samples. The relationship that existed between Cp (specific heat capacity) of the rice flour varieties as it was influenced by dry basis MC and heating temperature was stated via the quadratic regression equation with their *R* squared values as a drying constant as $Cp = 42.685(MC)^{-2.032T}$ $R^2 = 0.9305$ and $Cp = 27.827(mc)^{-1.363T}$ $R^2 = 0.9708$ (Table 2) for Illa and Ekpoma rice flour samples respectively. Almost in all cases, there was no relationship in the specific heat values of two rice varieties, the specific heat increased with increase in both moisture and temperature (Azadbakht *et al.*, 2013) and this is in line with Shrivastava and Datta (1999) and Singh and Goswami (2000) reported on thermal properties of mushrooms and cumin-seed revealed that the moisture content when correlate with the temperature it had a highly valid significant effect on Cp tested. The thermal conductivity of the processed rice flour samples was presented in the Figure 3.

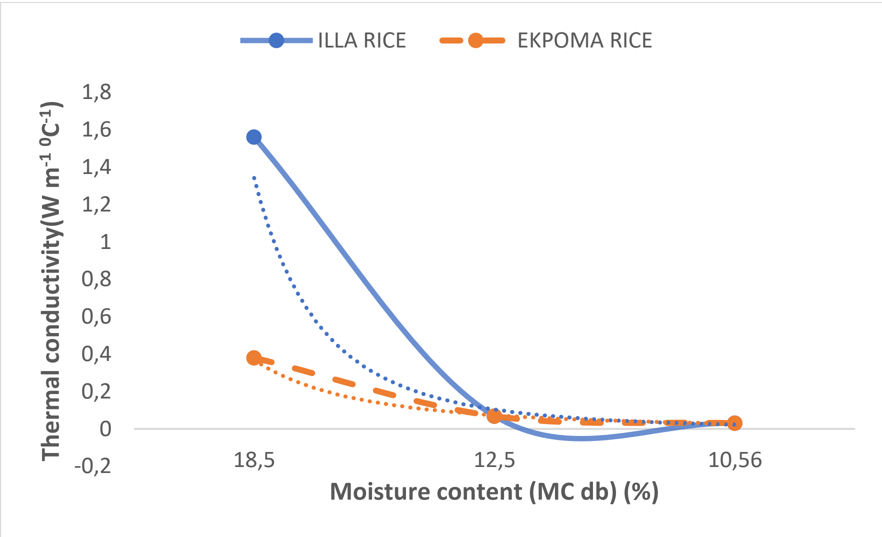

Figure 3. Moisture content and thermal conductivity relationship of Milled ILLA and EKPOMA rice flour.

The thermal conductivity of a food material measures the magnitude of thermal energy that transferred during thermal processing of the food material (Sandra and Bernarda, 2015). Thermal conductivity of both samples species was observed to be varied as moisture content (MC) increases. The corresponding increase in MC from 10.56 to 1.50% (db) caused the thermal conductivity (k) of the Illa and Ekpoma rice flour samples to be noticeably-increased from 0.036 to 1.56 W m^{-1} $^0C^{-1}$ and 0.03 to 0.38 W m^{-1} $^\circ C^{-1}$ at MC range of 10.56 to 18.50% respectively. It implies that thermal conductivity (k) determined at three (MC) level were differently significant at ($p < 0.05$). This increase in thermal conductivity of rice flour with increase in MC is due to magnitude of heat transferred in the flour and this is preferred when the sample is wet than when it is dried (Jibril *et al.*, 2016). The relationship of thermal conductivity of rice flour varieties and its moisture content is best expressed in the equations below, $K = 1.3421(MC)^{-3.694T}$ $R^2 = 0.9706$ and $K = 0.3693(MC)^{-2.33T}$ $R^2 = 0.9973$ for Illa and Ekpoma rice flour respectively (Table 2). This is very similar with what Aviara and Haque *(2001)* on thermal-properties of Guna seed and Mahapatra *et al.* (2013) on thermal-properties of Cowpea flour.

The thermal diffusivity of Illa and Ekpoma rice flour were presented Figure 4, showed that the thermal diffusivity of Ekpoma were 1.30, 1.48 and 3.42 x10^{-4} m^2 s^{-1} and for Illa were1.25, 1.57 and 4.38 x10^{-4} m^2 s^{-1} at moisture content range of 18.50, 12.50 and 10.56%, respectively.

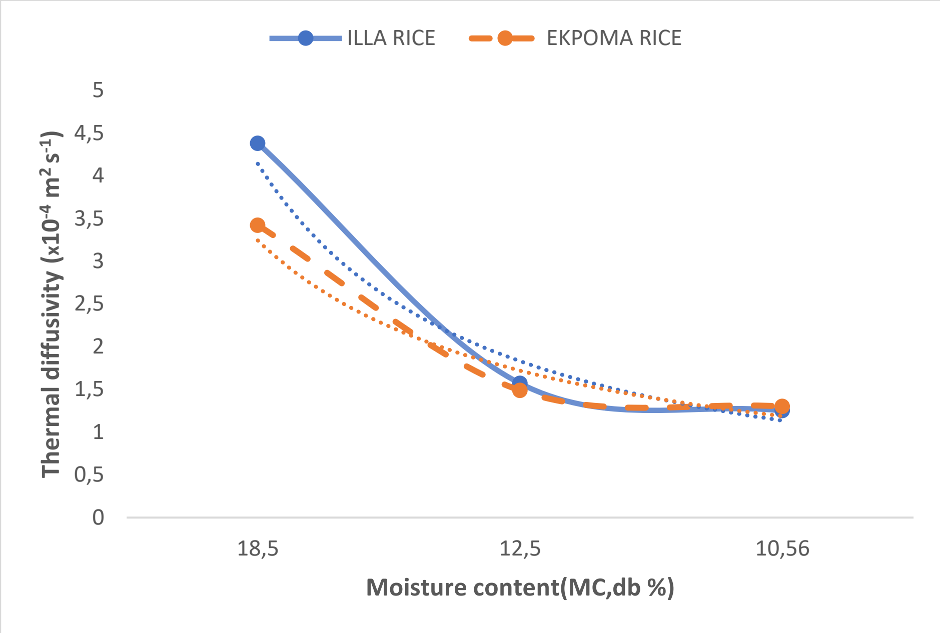

Figure 3. Moisture content effect on thermal diffusivity of Milled ILLA and EKPOMA rice flour.

It was observed that, the MC of rice flour- showed decreased in the thermal diffusivity of the processed samples. Thermal diffusivity reveals the extent at which food material retain heat either under storage or during thermal processing, it was therefore indicated that the Illa rice flour sample displayed higher rate of heat energy circulation among the particles of the flour than the Ekpoma rice flour. This is because the Illa rice flour recorded higher thermal diffusivity value of 4.38 x 10^{-4} m^2 s^{-1} at 10.56% (db) moisture content and have the tendency of retaining much heat than Ekpoma rice sample. The findings were not similar with what Opoku *et al.* (2006) reported on hay timothy, where increase in moisture in the range of 7.7% to 17.1% will cause increase in their thermal properties (thermal conductivity and diffusivity) from 0.284 to 0.0605 W m^{-1} °C^{-1} and 1.024 to 3.031×10-7 m^2 s^{-1}. The observed different in MC and thermal diffusivity were validly significant ($p < 0.05$). This is attributed to the fact that thermal diffusivity of the flour sample depends on bulk density of food samples as they decreased with increase in moisture content. The relationship between the thermal diffusivity and MC was best described in the following equations below $\alpha = 4.1394(MC)^{-1.178T}$ $R^2 = 0.9597$ and $\alpha = 3.2422(MC)^{-0.915T}$ $R^2 = 0.9415$ for Illa and Ekpoma rice flour samples respectively (Table 2).

CONCLUSION

The thermal parameters of rice flour of Illa and Ekpoma rice varieties were determined at different moisture levels. The research results showed that the validly significant variation in thermal parameters values were varied per respect to different moisture content levels. The observed increase in MC from 10.56 to 18.50 %, had same correspond increased the specific heat capacity from 5.72 to 48.61 kJ kg^{-3} ˚C^{-1} and 6.84 to

29.41 kJ kg^{-3} $^{\circ}$C^{-1} for Illa and Ekpoma rice variety respectively and thermal conductivity from 0.03 to 1.56 W m^{-1} ^{0}C^{-1} and 0.03 to 0.38 W m^{-1} ^{0}C^{-1} for Illa and Ekpoma rice flour samples. Thermal diffusivity and bulk density of the processed Illa and Ekpoma rice flour samples decreased across the MC range of 10.56 to 18.50% (db). Thermal diffusivity decreased from 4.38 to 1.25 x10^{-4} m^{2} s^{-1} and 3.42 to 1.30 x10^{-4} m^{2} s^{-1} for Illa and Ekpoma rice flour respectively while the bulk density also decreased from 697.72 to 676.34 kg m^{-3} and 687.49 to 664.26 kg m^{-3} for Illa and Ekpoma rice flour, respectively. The developed model equations from the Figure 1 to Figure 4 can be applied in the estimation the thermal processing parameters of rice flour around the range treatments.

REFERENCES

Adekoyeni OO, Fagbemi SA and Ismaila AR (2018). Ofada rice identity, physical qualities and processing technology options for upgrading:A review. *Annual Research & Review in Biology 23(2): 1-9. Article no. ARRB.38938*

Akbari S and Chayjan RA (2017): Moisture content modelling of thermal properties of persimmon (cv. 'Kaki'). *Research Agricultural Engineering, 63: 71-78.*

Anita C, Ezeagba, Ike S. Oluka and Ejike PI (2019). Effect of moisture content and drying methods on the thermal properties of African walnut flour. *The Pacific Journal of Science and Technology,* 217.

AOAC (2000). Official Methods of Analysis 16 Ed. Association of Official Analysis Chemist. Washington DC.USA.

Arinola SO and Jeje OA (2017). Drying characteristics and thermalproperties of two local varieties of unripe plantain. *American Journal of Science and Technology, 4(5): 74-79.*

Asiru MA, Agada IG and Kolade O (2018). Impacts of rice importation on Nigeria's economy. *Journal of Scientific Agriculture, 2: 71-75..*

Asuming-Brempong S and Osei-Asare Y (2007). *Has imported rice crowded-out domestic rice production in Ghana? What has been the role of policy?* African Association of Agricultural Economists (AAAE) Conference Proceedings.

Aviara NA and Haque MA (2001). Moisture dependence of thermal properties of shea nut kernel. *Journal of Food Engineering, 47: 109-113.*

Azadbakht M, Khoshtaghaza MH, Ghobadian B and Minaei S (2013). Thermal properties of soybean pod as a function of moisture content and temperature. *American Journal of Food Science and Technology, 1(2): 9-13.*

Bandumula N (2018). Rice production in Asia: Key to global food security. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences*, *88(4): 1323-1328.*

Bart-Plange A, Asare V and Addo A (2009). Thermal conductivity of maize and cowpea. *Journal of Engineering and Technology, 2(3): 6-11.*

Bhat FM and Riar CS (2017). Physicochemical, cooking, and textural characteristics of grains of different rice (*Oryza sativa* L.) cultivars of temperate region of India and their interrelationships. *Journal of Texture Studies, 48(2): 160-170.*

Božiková M (2003). Thermophysical parameters of corn and wheat flour. *Research in Agricultural Engineering, 49(4): 157-160.*

Danbaba N, Idakwo PY, Kassum AL, Bristone C, Bakare SO, Aliyu U, Kolo IN, Abo ME, Mohammed A, Abdulkadir AN, Nkama I, Badau MH, Kabaraini MA, Shehu H, Abosede AO and Danbaba MK (2019). rice postharvest technology in Nigeria: An overview of current status, constraints and potentials for sustainable development. *Open Access Library Journal, 6: e5509.*
emefiele.html. 2015; accessed 17.04.2017

Federal Ministry of Agriculture and Rural Development (2016). The agriculture promotion policy (2016-2020). Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria.

Global Agricultural Information Network (2016). Nigeria's grain and feed annual report. https://gain fas. usda.gov/Recent%20GAIN%20Publications/Grain%20and%20Feed%20Annual_Lagos_Nigeria_4-21-2016. pdf. 2016; Accessed 22.02.2021.

Heldman DR (2001). Prediction models for thermophysical properties of foods. In food processing operations modeling, design, and analysis; Irudayaraj, J., Ed.; Marcel Dekker, Inc.: *New York*, 2001; 1-24.

Ide PE, Eze PC and Offor BC (2019). Effect of moisture content on the physicomechanical properties of *Mucuna sloanei. International Journal of Scientific Engineering and Research (IJSER), 7(2): 91-96.*

Ide PE, Ike O and Eze PC (2020) Effect of moisture content on the thermal properties of horse-eye bean seeds relevant to its processing. University of Belgrade Faculty of Agriculture Institute of Agricultural Engineering. *Scientific* Journal *Agricultural Engineering, Year XLV No. 4, pp: 71 – 80.*

JICA (2013). Status of NRDS Implementation in Nigeria, Presentation at the Fifth General Meeting of CARD, 5-6 February 2013, Dakar, Senegal. JICA 2013 Status of NRDS Implementation in Nigeria, Presentation at the Fifth General Meeting of CARD, 5-6 February 2013, Dakar, Senegal.

Jibril N, Yadav KC, Binni MI and Kabir MH (2016). Study on effect of moisture content on thermal properties of bambara groundnut (*Vigna subterranea l.* Verdc.) seed. *Report and Opinion, 4(6): 52-58.*

Jideani VA (2005). Characteristics of local pearl millet *(Pennisetum glaucum)* grains. *Nigerian Food Journal, 23(1): 193-204.*

Kamath S, Puri VM and Manbeck HB (1994). Flow property measurement using the Jenike cell for wheat flour at various moisture contents and consolidation times. *Powder Technology, 81: 293-297.*

Kim YS, Flores RA, Chung OK and Bechtel DB (2003). Physical, chemical, and thermal characteristics of wheat flour milling coproducts. *Journal of Food Process Engineering, 26(5): 469-488.*

Lan Y, Fang Q, Kocher M and Hanna MA (2000). Thermal properties of tapioca starch. *International Journal of Food Properties, 3(1): 105-116.*

Mahapatra AK, Lan Y and Harris DL (2011). Influence of moisture content and temperature on thermal conductivity and thermal diffusivity of rice flours. *International Journal of Food Properties, 14(3): 675-683.*

Mahapatra AK, Melton SL and Isang EM (2013). Effect of moisture content on thermal properties of cowpea flours. *Agricultural Engineering International: The CIGR Journal. 15(2): 251-255.*

Maji AT, Ukwungwu MN, Danbaba N, Abo ME and Bakare SO (2017). Rice: History, Research and Development in Nigeria. In: Nahemiah, D., Nkama, I., Maji, A.T. and Ukwungwu, M.N., Eds., Rice in Nigeria, Traditional Recipes & Research Needs, *Ronab Graphix Print*, Bida, Nigeria, 65-84.

Mortaza A, Mohammad HK and Seyed RH (2008). Specific heat and thermal conductivity of berberis fruit (*Berberis vulgaris*). *American Journal of Agricultural and Biological Sciences, 3(1); 330-336.*

Muramatsu Y, Tagawa, A, Kasai, T. (2005). Effective thermal conductivity of rice flour and whole and skim milk powder. *Journal of Food Science, 70(4): 279-287.*

Nahemiah D, Alabi MO, Nkama I and Abo ME (2004). Utilization of rice and rice by-products in Nigeria. In: Abo, M.E. and Abdullahi, A.S., Eds., Nigerian Rice Memorabilia, *Project Synergy Limited*, Abuja, Nigeria, 343-349.

Nwachukwu IM, Agwu NM and Ezeh CI (2008). *Comparative study of consumer purchase attitude of local and foreign rice in Abia State*. Proceedings of 42nd meeting of Agricultural Society of Nigeria held at Ebonyi State University, Abakaliki, 19-23 October 2008; pp.764-767.

Oko AO, Ubi BE and Dambaba N (2012). Rice cooking quality and physico-chemical characteristics: A comparative analysis of selected local and newly introduced rice varieties in Ebonyi State, Nigeria. *Food and Public Health, 2(1): 43-49.*

Opoku A, Tabil LG, Crerar B and Shaw MD (2006). Thermal conductivity and thermal diffusivity of timothy hay. *Canadian Biosystems Engineering. 48: 31-37.*

Pokhrel A, Dhakal A, Sharma S and Poudel A (2020) Evaluation of physicochemical and cooking characteristics of rice (Oryza sativa L.) landraces of Lamjung and Tanahun districts, Nepal. *Hindawi International Journal of Food Science, Volume 2020, Article ID 1589150, 11 pages.*

Premium Times (2017). Nigeria spends $2.41b on rice importation in 3 y–Emefiele.

Qi F, Lan Y, Kocher MF and Hanna MA (2000). Thermal conductivity of granular rice starches. *International Journal of Food Properties, 3(2): 283-293.*

Sadiku AO and Bamgboye I (2014). Moisture dependent mechanical and thermal properties of Locust bean (*Parkia biglobosa*). *Agricultural Engineering International: CIGR Journal 16(1): 99-106.*

Sahin S and Sumnu SG (2006). Physical properties of foods. *Springer Science Business Media*, LLC., 233 Spring Street, New York, NY 10013.

Sandra Budžaki and Bernarda Šeruga (2015) Specific heat and thermal conductivity of the croatian unleavened dough, *International Journal of Food Properties, 18:10, 2300-2311.*

SAS (1988). SAS/STAT users guide, release 6.03, SAS institute Inc.,Carey NC.

Sharma S, Pokhrel A, Dhakal A and Poudel A (2020). Agro-morphological characterization of rice (*Oryza sativa* L.) landraces of Lamjung and Tanahun District, Nepal. *Annals of Plant Sciences, 9(2): 3731-3741.*

Shrivastava M and Datta AK (1999). Determination of specific heat and thermal conductivity of mushrooms (*Pleurotus- florida*). *Journal of Food Engineering, 39: 255-260.*

Singh KK and Goswami TK (2000) Thermal properties of cumin seed. *Journal of Food Engineering, 45: 181-187.*

Singh, N, Kaur L, Sodhi NS and Sekhon KS (2005). Physicochemical, cooking and textural properties of milled rice from different Indian rice cultivars. *Food Chemistry, 89(2): 253-259.*

Sowunmi FA, Omigie OC and Daniel DT (2014). Consumers' perception on Ofada rice in Ibadan North Local Government Area of Oyo State, Nigeria. *Journal of Economics and Sustainable Development, 5(16):78.*

Thomas R, Wan-Nadiah WA and Bhat R (2013). Physiochemical properties, proximate composition, and cooking qualities of locally grown and imported rice varieties marketed in Penang, Malaysia. *International Food Research Journal, 20(3): 1345-1351.*