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A COMPARATIVE STUDY ON THERMAL PROPERTIES OF FIVE VARIETIES OF AFRICAN YAM BEAN SEED UNDER DIFFERENT MOISTURE CONTENTS

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ABSTRACT

A comparative study on thermal conductivity, specific heat capacity, and thermal diffusivity of five varieties of African yam bean that are cultivated in Ebonyi State Nigeria under different moisture contents was conducted. The result showed that thermal conductivity of the white, grey, brown, black, and speckled varieties ranged from 0.264 – 0.282 $Wm^{-1}K^{-1}$, 0.225 – 0.250 $Wm^{-1}K^{-1}$, 0.252 – 0.270 $Wm^{-1}K^{-1}$, 0.254 – 0.272 $Wm^{-1}K^{-1}$, and 0.263 – 0.280 $Wm^{-1}K^{-1}$ under moisture content range of 20 – 40 %. The specific heat capacity of the grey, white, brown, black, and speckled varieties ranged from 3.34 - 3.67 $kJkg^{-1}K^{-1}$, 3.16 – 3.38 $kJkg^{-1}K^{-1}$, 3.18 – 3.60 $kJkg^{-1}K^{-1}$, 3.19 – 3.46 $kJkg^{-1}K^{-1}$, and 3,12 – 3.50 $kJkg^{-1}K^{-1}$ under moisture content range of 20 – 40 %. The thermal diffusivity of the black, white, brown, grey, and speckled varieties ranged from 0.81 – 0.85 m^2s^{-1}, 0.802 – 0.834 m^2s^{-1}, 0.785 – 0.825 m^2s^{-1}, 0.795 – 0.830 m^2s^{-1}, and 0.816 – 0.840 m^2s^{-1} under moisture content range of 20 – 40 %. The white, grey, and black African yam bean varieties have higher thermal conductivity, specific heat capacity, and thermal diffusivity respectively than the other varieties under the different moisture contents. The findings indicated that thermal conductivity, specific heat capacity, and thermal diffusivity of the five varieties of African yam bean seed in Ebonyi State Nigeria increased with increase in moisture content.

KEYWORDS: *African yam bean, Thermal conductivity, Moisture content, Specific heat capacity, Thermal diffusivity*

INTRODUCTION

African yam bean (spenostylis stenocarpa) is a bean–shaped leguminous crop that could be black, brown, white, grey or speckled in appearance (Asoiro and Ani, 2011). The bean seeds are normally contained in a pod just like cowpea. The pods are generally borne on a climbing shoot, with broad heart-shaped leaves. It could be consumed in various forms. A good knowledge of the thermal properties of the yam bean could enhance the consumption power of the crop.

Thermal properties such as specific heat capacity, thermal conductivity, thermal diffusivity, and others indicate changes in the chemical composition and structural organization of foods ranging from the molecular to microscopic level (Barbosa-Cánovas *et al.* 2006). Computation of these properties can provide information about the macro structural effect of processing conditions in fresh and manufactured foods. Hydration and drying of seeds cause physical and physiological changes in the seed. Consequently, many researchers have determined thermal properties of various crops as a function of moisture content in the past (Ekinci *et al.*, 2010; Ahmadi *et al.*, 2009; Tavakoli *et al.*, 2009; Bamgboye and Adejumo, 2010; Aviara and Haque, 2001).

Kocabiyik *et al.* (2009) determined the specific heat, thermal conductivity and thermal diffusivity properties of pumpkin seeds in the moisture content range of 5.32 – 24.00 %. The specific heat, and thermal conductivity were determined using the method of mixtures, and the transient technique using the line heat source method assembled in a thermal conductivity probe respectively. The results showed that the specific heat of pumkin seeds was between 2.53 and 3.13 $kJkg^{-1}K^{-1}$, the thermal conductivity in the range of 0.113, and 0.135 $Wm^{-1}K^{-1}$, while the thermal diffusivity was between 9.954×10^{-8} and 1.289×10^{-7} m^2s^{-1}, under the moisture content range of 5.32 – 24.00 %. The findings indicated that specific heat and thermal conductivity of pumkin seeds varies directly with moisture content, while thermal diffusivity varies inversely with moisture content.

Ikegwu *et al.* (2016) evaluated the specific heat capacity, thermal conductivity and thermal diffusivity of African yam bean seeds at temperatures range of 30 to 50 ℃ and moisture content range of 9.6 to 30 %. The specific heat capacity, and the thermal conductivity were determined using the copper calorimeter, and the line heat source method respectively. The results showed increased of the specific heat from 2.035 to 2.816 $KJkg^{-1}k^{-1}$ under the changing temperature and moisture content. The thermal conductivity and the thermal diffusivity varied from 0.267 to 0.374 $Wm^{-1}k^{-1}$, and 9.38×10^{-8} to 8.63×10^{-8} m^2s^{-1}. The findings indicated that the African yam bean could retain heat when processed.

Onyeike and Omubo-Dede (2002) studied the effects of heat treatments on the proximate composition, energy content, and levels of some anti-nutritional factors in brown and marble-coloured African yam bean seed flours. The results showed that autoclaving and cooking increased the moisture level slightly, and decreased crude protein, crude fat, ash contents, and level of toxicants. The findings suggest that the trypsin inhibitor is the most heat-labile toxicant, and cooking to tenderness is the most recommended heat treatment methods.

Although researchers have studied the thermal properties of Africam yam bean seeds in the past, yet the association of thermal properties of different varieties of African yam bean seeds is still under-studied. Therefore, the present study seeks to compare the specific heat capacity, thermal conductivity, and thermal diffusivity properties of five varieties of African yam bean seeds under different moisture content in Abakaliki town of Ebonyi State Nigeria.

MATERIALS AND METHODS

The test programme for the determination of the thermal properties of African yam bean seeds is shown in Figure 1. The grey, brown, black, white, and speckled varieties of African yam bean seeds were sourced from Abakaliki in Ebonyi State Nigeria.

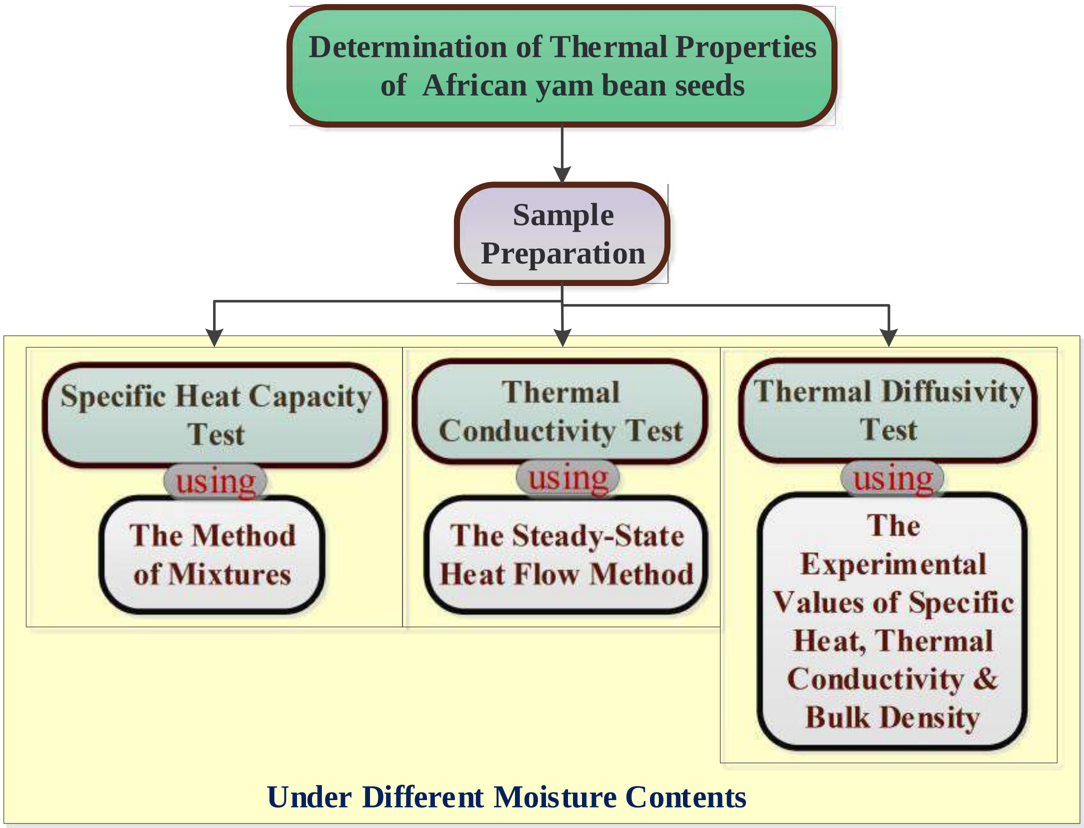

Figure 1: Test program for determining thermal properties of African yam bean seeds under different moisture contents

The seeds were cleansed manually to remove all foreign matters. The initial moisture content of the seeds was determined by the oven method (Tabataeefar, 2003). Twenty seeds of the African yam bean were weighed using a sensitive electronic balance and the weights were recorded. The weight of an empty washed and dried petri dish was weighed and recorded as W1. The sample and the petri dish were weighed together and were recorded as W2. The seeds and the petri dish were dried in an oven at a set temperature of 105 °C for 3 hours. The Petri dish and the dried seeds were removed from the oven with a crucible tong into a dessicator to cool for 10 minutes. The petri dish and the sample were re-weighed in a weighing balance to get the weight W3. The percentage moisture content was calculated thus:

$$\%\text{ moisture content } = \frac{W2-W3}{W2-W1} \text{ x } 100$$

Where W1 = weight of dried petri dish (g), W2 = weight of the sample + petri dish before drying (g), W3 = weight of the sample + petri dish after drying (g).

The study was carried out within the moisture content range of 20 – 40 % dried basis (d.b) at the intervals of 5 %. The amount of water that were added (Q) to condition the seeds to the desire moisture content was determined using the equation given by Tunde-Akintunde and Akintunde (2007).

$$Q = \frac{A\,(b-a)}{100-b}$$

Where Q = mass of water added in g, A = total mass of the seeds in g, a = initial moisture content of sample in % d.b, b = final moisture content of sample in % d.b.

The specific heat capacity was determined using the method mixture described in Aviara and Haque (2001). The thermal conductivity was determined using the steady-state heat flow method adopted in Kraemer and Chen (2014). The thermal diffusivity was calculated using experimental values of specific heat, thermal conductivity, and bulk density.

RESULTS AND DISCUSSION

The results of the thermal conductivity of five varieties of African yam bean seed under different moisture content are presented in Figure 2. The results showed that the white African yam bean variety has higher thermal conductivity than the other varieties under the varying moisture content. The thermal conductivity of the white variety ranged from 0.264 – 0.282 $Wm^{-1}K^{-1}$ under moisture content range of 20 – 40 %. The thermal conductivity of the grey, brown, black, and speckled varieties ranged from 0.225 – 0.250 $Wm^{-1}K^{-1}$, 0.252 – 0.270 $Wm^{-1}K^{-1}$, 0.254 – 0.272 $Wm^{-1}K^{-1}$, and 0.263 – 0.280 $Wm^{-1}K^{-1}$ under moisture content range of 20 – 40 %. The grey variety has the lowest thermal conductivity among the varieties under the different moisture content values. The findings indicated that thermal conductivity of African yam bean varies directly with moisture content. The increase of thermal conductivity with moisture content increase could be attributed to the fact that an increase in moisture content increases the amount of water molecules to fill the pores within the sample, thus increasing the ability of the sample to conduct more heat. The finding is in line with the submission of other researchers (Yang *et al.*, 2002; Muramatsu *et al.*, 2006; Aviara *et al.*, 2008; Bart-Plange *et al.*, 2009).

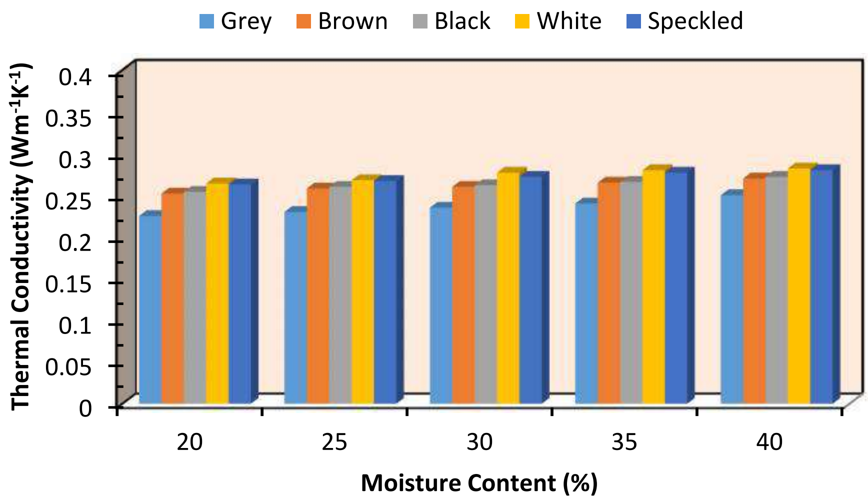

Figure 2: Thermal conductivity of African yam bean seeds under different moisture contents

The results of the specific heat capacity of five varieties of African yam bean seed under different moisture content are presented in Figure 3. The results showed that the grey African yam bean seed variety has higher specific heat capacity than the other varieties under the different moisture content. The specific heat capacity of the grey variety ranged from 3.34 - 3.67 $kJkg^{-1}K^{-1}$ under moisture content range of 20 – 40 %. The specific heat capacity of the white, brown, black, and speckled varieties ranged from 3.16 – 3.38 $kJkg^{-1}K^{-1}$, 3.18 – 3.60 $kJkg^{-1}K^{-1}$, 3.19 – 3.46 $kJkg^{-1}K^{-1}$, and 3,12 – 3.50 $kJkg^{-1}K^{-1}$ under moisture content range of 20 – 40 %. The findings indicated that the specific heat capacity of African yam bean varies linearly with moisture content. The linear relationship of the specific heat capacity and moisture content could be due to the increase in the amount of heat storage, which is a consequence of high surface area. The finding is in conformity with the assertion of other researchers that studied the effects of moisture content on specific heat capacity of cashew nut (Nathakaranakule and Prachayawarakom, 1998), and pistachios (Hsu et al., 1991).

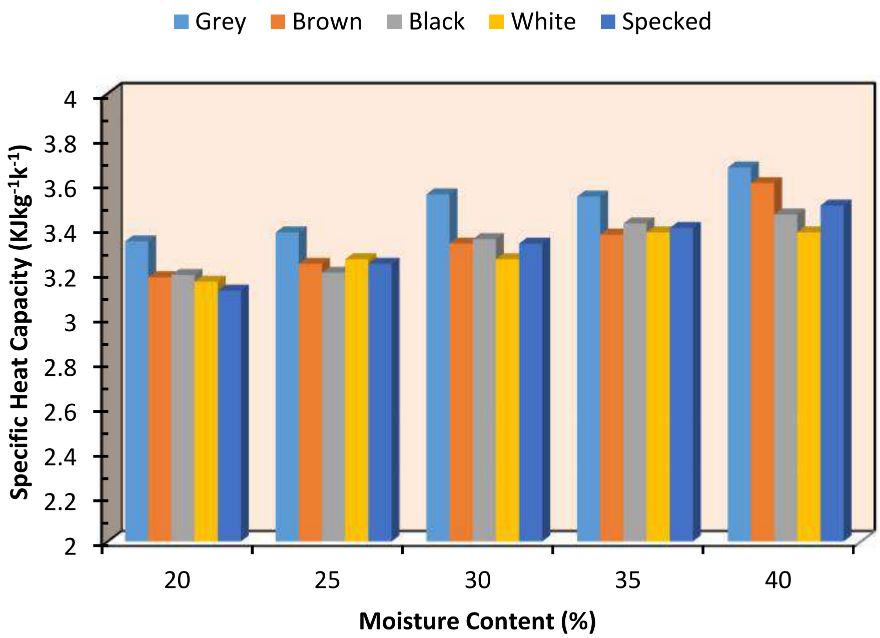

Figure 3: Specific heat capacity of African yam bean seeds under different moisture contents

The results of the thermal diffusivity of five varieties of African yam bean seed under different moisture content are presented in Figure 4. The results showed that the black African yam bean seed variety has higher thermal diffusivity than the other varieties under the different moisture content.

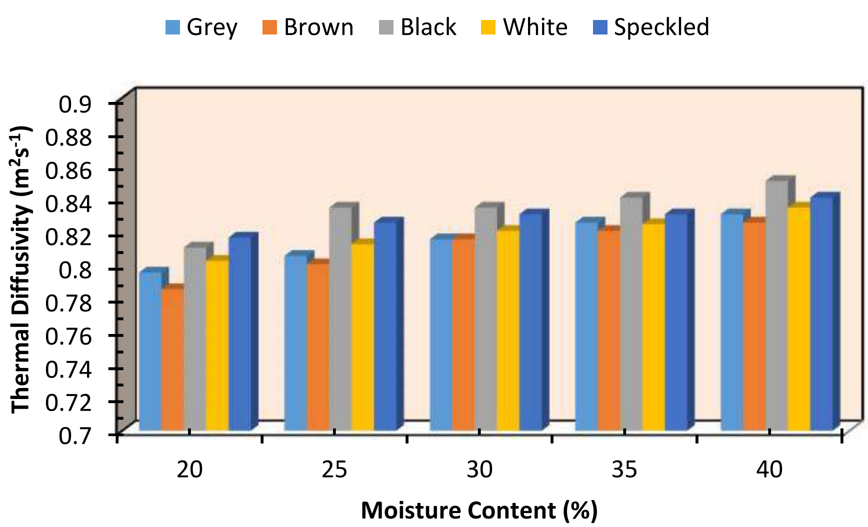

Figure 4: Thermal diffusivity of African yam bean seeds under different moisture contents

The thermal diffusivity of the black variety ranged from 0.81 – 0.85 m^2s^{-1} under moisture content range of 20 – 40 %. The thermal diffusivity of the white, brown, grey, and speckled varieties ranged from 0.802 – 0.834 m^2s^{-1}, 0.785 – 0.825 m^2s^{-1}, 0.795 – 0.830 m^2s^{-1}, and 0.816 – 0.840 m^2s^{-1} under moisture content range of 20 – 40 %. The findings indicated that thermal diffusivity of African yam bean increases with increase in moisture content. As the moisture content increased, the pores and capillaries of the African yam bean seed varieties that were initially filled with air were gradually filled up by the adsorbing water. The heat released due to the water adsorption resulted to the increased thermal diffusivity (Kostaropoulos and Saravacos, 1997).

CONCLUSIONS

This paper compares the specific heat capacity, thermal conductivity, and thermal diffusivity properties of five varieties of African yam bean seeds under different moisture content in Abakaliki town of

Ebonyi State Nigeria. The results showed that the white African yam bean variety has higher thermal conductivity than the other varieties under the varying moisture content. The grey variety and the black variety have higher specific heat capacity and thermal diffusivity respectively, than the other varieties under the different moisture content. The findings indicated that thermal conductivity, specific heat capacity, and thermal diffusivity of the five varieties of African yam bean seed in Ebonyi State Nigeria increased with increase in moisture content.

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