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Effect of Temperature and Composition on Thermal Properties of Catfish (Siluriforms Clarias)

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***Abstract*— The most important requirement in the design of storage and refrigeration equipment for food is the thermal properties of the food item concerned. The thermal properties will help in estimating the process time for refrigerating, freezing, heating or drying of the said food item. The objective of this study was to determine the compositional (moisture and fat contents), thermal conductivity, thermal diffusivity and volumetric heat capacity of catfish (S. Clarias) in the temperature range of 0°C to 30°C and to study their interactive effect on each other. Thermal properties (thermal conductivity, thermal diffusivity and volumetric heat capacity) were determined using the KD2 pro unsteady state method. The thermal conductivity ranged from 0.501 to 0.526W/mk, thermal diffusivity ranged from 0.162 to 0.204mm2/s and volumetric heat capacity ranged from 2.58 to 3.1mJ/m3kg. Moisture and fat contents were 52.58% and 13.88% respectively using the Association of Official Analytical Chemist (AOAC) standard of measurement. Based on the experimental results obtained, it was found that the thermal conductivity, thermal diffusivity and volumetric heat capacity of catfish is dependent on temperature while the compositional properties (moisture and fat contents) of the catfish are effective only on its volumetric heat capacity. This study through its findings has been able to present simpler models for predicting the thermal properties (thermal conductivity, thermal diffusivity and volumetric heat capacity) of the sample as a function of temperature as this information can be used by fish and food processors in the storage and design of fish kiln thereby saving both fish processors cost and fish farmers the problem usually associated with fish post harvesting farming.**

***Index Terms*— Catfish, KD2 Pro Device, Thermal properties, Quadratic Polynomial Equation.**

I. INTRODUCTION

Knowledge of the thermal properties of food is required to perform the various heat transfer calculations that are involved in the design of food storage and refrigeration equipment and estimating process time for refrigerating, freezing, heating or drying of foods. The thermal properties of foods are strongly dependent upon chemical composition and temperature, and there are a multitude of food items available [3]. According to [5], the world fish production from capture fisheries and aquaculture has reached 121million tons. In Africa, fish is an important source of animal protein needed for the maintenance of a healthy body and income. Although fishes when harvested, usually after some minutes begin to deteriorate and become putrid due to bacterial-enzyme action and the harsh weather conditions experienced in the tropics "Unpublished" [6]. A decline in fish availability will have a detrimental effect on the nutritional status of the citizenry particularly in places where fish contributes significantly to the protein intake of the people such as Nigeria with fish accounting for 40% of animal intake [7]. It has been reported that Nigeria needs about 3.2million metric tons of fish for its annual consumption [8]. Part of these annual fish consumption in Nigeria includes the fresh water catfish (*S. Clarias*). Efforts therefore should be geared towards increased fish production through improved resource management matched with effective post-harvest handling, preservation and processing to prevent spoilage. This study was designed to determine the thermal properties of catfish using an unsteady state method and its composition using [2] standard and to evaluate their relationship with temperature and composition for processors to know the nature of this fish and the best method of preservation (chilling, freezing, smoking or canning) to accurately apply.

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II. MATERIALS AND METHOD

Materials: Three fresh catfish samples of 18cm, 25cm and 30cm by length, were obtained from the popular catfish market in Abala-uno in Ndokwa East Local Government Area of Delta State, Nigeria and were gutted, washed and placed in a cold ice box for transportation to the laboratory before being used for analysis.

Method: The composition (Moisture and Fat Contents) of the test materials was analyzed using the method prescribed by the Association of Official Analytical Chemists [2]. Thermal properties (Thermal Conductivity, Diffusivity and Volumetric heat capacity) were obtained using the newly designed unsteady state device (KD2 pro) with measuring accuracy of ±10%, developed by Decagon Inc.

Experimental procedure and calculation: The unsteady state thermal property measurement of the fish sample was carried out using the KD2 Pro device. The SH-1 dual needle which comes with the KD2 pro device was inserted parallel to each other all the way through the catfish to make for an accurate reading, after having been verified using the SH-1 Derlin block standard of Verification. With the inserted SH-1 probe in the fish sample, the KD2 pro device was turned ON. The various characteristic properties of the fish sample were displayed on the visual screen of the device. A processing bar shown at the bottom of the screen indicated the time taken for the completion of the various measurements, a thermometer

icon displaying the heat application from the probe to the sample and at the completion of the measurements, the entire thermal properties (thermal conductivity, thermal diffusivity and volumetric heat capacity) of the fish samples were then recorded. The test material, whose thermal properties have been recorded, was used to determine the composition (moisture and fat content) using the method prescribed by the Association of Official Analytical Chemists [2] with the applied formula on a percentage bases:

$$Moisture\,(\%) = \frac{Predry - Postdry}{Predry} \times 100 \quad (1)$$

Statistical analysis: statistical analysis was done using the Microsoft Excel 2008 version and data were analyzed using ANOVA ($p<0.05$).

III. RESULTS AND DISCUSSION

Table I: Thermal properties and composition of catfish

S/N	Tem. (^{0}c)	Thermal cond. (W/m^{0}c)	Thermal diff. (mm^2/s)	Vol. Heat cap. (mJ/m^{3}K)	Moist. (%)	Fat (%)
1	14.39	0.501	0.162	3.1		
2	18.15	0.518	0.178	2.93		
3	21.91	0.534	0.193	2.76	52.57	13.88
4	23.01	0.53	0.199	2.66		
5	24.1	0.526	0.204	2.58		

Results are mean triplicate values of measurements.

Table 1 summarizes the thermal properties and compositions of the catfish. The thermal conductivity values ranged from 0.501 to 0.526W/m^{0}c, thermal diffusivity values ranged from 0.162 to 0.204mm^2/s, volumetric heat capacity ranged from 3.1 to 2.58mJ/m^{3}k, moisture content was 52.57% and fat content 13.88%. Both the moisture and fat contents of the catfish are well within the range obtained by [1].

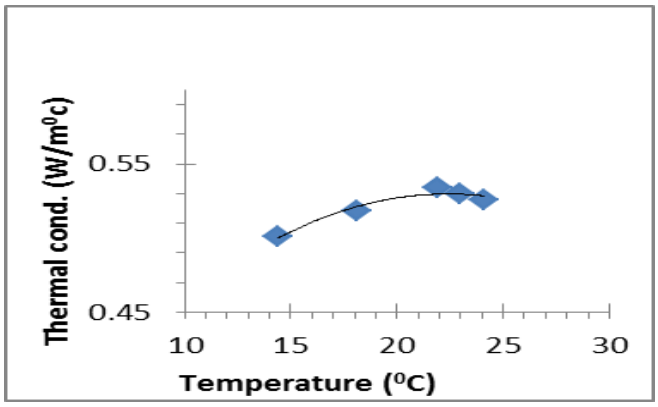

Fig. 1: Thermal conductivity of catfish as a function of temperature

Figure 1 shows the graphical presentation of thermal conductivity against temperature in the temperature range of 0 to 30^{0}C, thermal conductivity of catfish first started slowly with temperature and later increased, then slightly increased to maximum value at 23.01^{0}C before a slight fall which could be due to some external factors from the surrounding.

Similarly, statistical analysis was carried out to study the actual effect of temperature on the thermal conductivity of the sample using ANOVA to validate the result at a significance level of 5% and confidence level of 95%. It was observed from the regression summary that R-square was 82% with a significance F value of 0.034 which is lower than (α-0.05) thus indicating that temperature has a significant effect on the thermal conductivity of the sample. Also, thermal diffusivity was plotted against temperature and as can be observed in figure 2, thermal diffusivity of catfish increased with increase in temperature at the range of 0 to 30^{0}C.

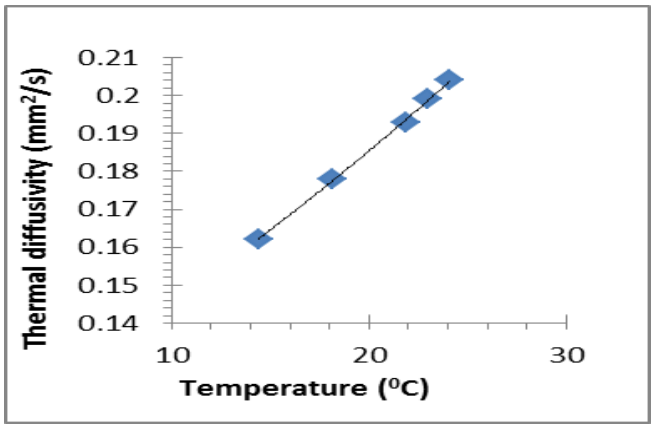

Fig. 2: Thermal diffusivity of catfish as a function of temperature

Statistical analysis was done to study the effect of temperature on thermal diffusivity of catfish and the regression summary result showed R-square to be 99.8% with a significance F value of 0.04.

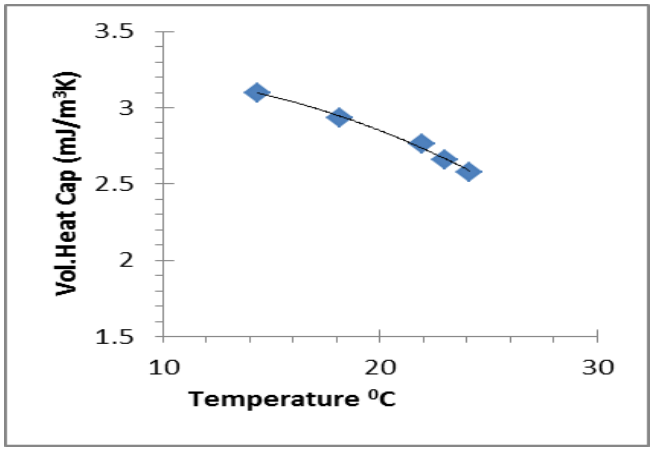

Fig. 3: Volumetric heat capacity of catfish as a function of temperature

Figure 3 shows the graphical presentation of the measured volumetric heat capacity value with temperature as observed from the plots, volumetric specific heat decreased with increasing temperature at a range of 0 to 30^{0}C. As was the case with thermal conductivity and diffusivity, regression analysis was carried out to also study the effect of temperature on the volumetric heat capacity of the sample and the summary result showed R-square to be 98.5% and Significance F value of 0.001.

Table II: Regression summary of thermal properties with temperature

Regression Statistics	Catfish		
	Thermal conductivity (W/mk)	Thermal diffusivity (mm^2/s)	Vol. Heat Cap. (mJ/m^3kg)
R Squared	0.82	0.998	0.985
Significance F	0.034	0.04	0.001
Standard Error	0.006	0.007	0.03
Observation	5	5	5

In same vein, the effect of moisture and fat content on the thermal properties of catfish was done by regression analysis since the values could not be plotted directly because of a unified measurement. A combined regression analysis of both moisture and fat content effect on the thermal properties of the sample showed moisture and fat content to be insignificant on thermal conductivity and diffusivity with significant F values of 0.414 and 0.455 respectively but have effect on the volumetric heat capacity of the sample with Significance F value of 0.044 and R-square of 95%. The experimental values of the catfish could not be compared with the additional equation found in literature which is based on the water, protein, carbohydrate, fat, fiber and ash contents as a function of temperature [4]. Since the compositional properties measured were moisture and fat contents only. Based on the experimental thermal conductivity, thermal diffusivity and volumetric heat capacity values of catfish at various temperatures so obtained, polynomial equation of the form ($k = a + bt + ct^2$) was developed for the temperature range from 0 to 30^0C for all thermal properties measured. The parameters and coefficients of correlations (R^2) for the equations are shown in Table III. The R-square ranged from 0.945 to 0.999.

Table III: Thermal Properties equation form ($k = a + bt + ct^2$) for catfish

Thermal Property	Catfish				
	Temp (^{0}C)	a	B	C	R^2
K(W/mK)	0-30	0.2967	0.0208	-0.0005	0.945
D(mm^2/s)	0-30	0.1124	0.003	3.00E-05	0.999
V(mJ/m^3Kg)	0-30	3.1676	0.023	-0.0019	0.994

Where; K = thermal conductivity (W/mk),
D = thermal diffusivity (mm^2/s),
V = Volumetric heat capacity (mJ/m^3kg

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