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# Drying Behaviour of Mudskipper (*Periophthalmus gobiidae*)

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## ABSTRACT

The drying behaviour of Mudskipper (*Periophthalmus gobiidae*) was investigated using the oven method. Results show that the drying of mudskipper was influence by temperature and it was also observed that the falling rate period dominated the entire drying process. The effective moisture diffusivity was determined using Fick's second law and the values ranged from $5.178 \times 10^{-5} m^2/s$ to $1.005 \times 10^{-5} m^2/s$ for temperatures 60°C to 100°C respectively. The temperature dependence of effective moisture diffusivity obeyed the Arrhenius Law with activation energy of 27.44KJ/mol.

**Keywords: mudskipper, drying, moisture diffusivity, activation energy, moisture content**

## INTRODUCTION

Mudskippers (*Periophthalmus gobiidae*), otherwise called "Atula" in Ijaw and "Isla" in Kalabari languages, are amphibious fishes. These species of fishes uses their pectoral fins and pelvic fins to walk on land and also climb mangrove trees (Plate 1). They live mainly in intertidal habitats of the mangrove plantations and exhibit unique adaptations of this environment. Thus, mudskippers are in abundance in tropical, sub-tropical and temperate regions, especially in Africa (Jaafar and Larson, 2008).

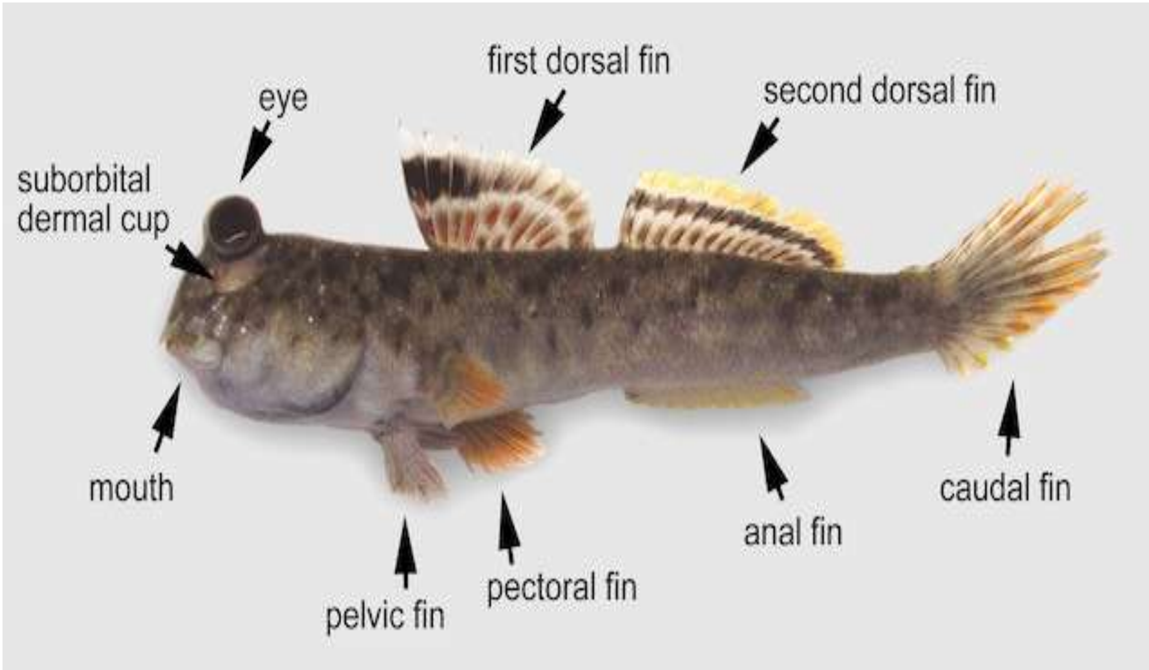


**Plate 1: Photograph of a Mudskipper**

In Nigeria, mudskippers are very common in the coastal areas of the Niger Delta region. They are highly nutritious and make the diet of many people in the coastal states of Nigeria (Bayelsa, Rivers, Delta, Akwa Ibom etc). Proximate analysis shows that mudskippers contains 55.2% proteins, 4.9% fats, 1.10% crude fibre, 17.9% ash content, 283.7% energy value, 1.88% carbohydrate and moisture content of 20.25% ( Andem and Ekpo, 2014). The mineral content of mudskipper was found to include calcium (2.2mg/g), phosphorus (0.89mg/g), sodium (0.38mg/g), potassium (0.22mg/g), magnesium (0.021mg/g) and zinc (0.0025mg/g) ( Andem and Ekpo, 2014). Literature also reveals that the vitamin composition of mudskipper has niacin (47.33mg/100g), panthetonic acid (10.49mcg/100g), vitamin B2 (3.22mg/100g) and vitamin E (2.0mcg/100g) as reported by Andem and Ekpo (2014). Thus, mudskipper is rich in protein, essential nutrients and vitamins and this makes mudskipper an excellent store house of high quality proteins which are superior to those of chicken and beef meat (FAO, 2004). Although, mudskippers are nutrient-packed in nature, these fish species are either not known or unavailable in markets in upland areas. Hence, can be made available in a market by preservation and the most common type of preservation is drying. But there is paucity of information on the drying characteristics of mudskippers. It is therefore the objective of this study to investigate the drying behaviour of mudskippers as influenced by temperature.

## MATERIALS AND METHODS

Fresh giant-sized mudskipper samples measuring about 25cm were purchased from Choba market in Port Harcourt and were immediately taken in plastic basins to the Food Processing Laboratory of the Niger Delta University, Bayelsa State for analysis. At the laboratory, samples were properly cleaned of foreign materials and part of the samples was then used to determine the initial moisture content using the oven method at 105°C. The initial moisture content of mudskippers was found to be 75% wet basis. The remaining samples were cut ….. , weighed and dried at temperatures 60°C, 80°C and 100°C. Periodic sampling was done, thus, samples were at intervals withdrawn, weighed and reintroduced into the oven until constant weight was achieved. This was replicated thrice for all temperature levels.

### Drying Curves

As drying time progresses, the moisture content in the sample will be reducing. Thus, a graphical plot of data on moisture content (X) against drying time (t) in polynomial fit yields

$$X = a_0 + a_1 t + a_2 t^2 \qquad (1)$$

Therefore, differentiating equation (1) with respect to time yields the drying rate at that condition as

$$Drying\ rate = -\frac{dX}{dt} = a_1 + 2a_2\, t \qquad (2)$$

This was repeated for all temperature levels (60°C, 80°C and 100°C) and the drying curves were respectively plotted between the drying rates and moisture contents to evaluate the drying behaviours (constant and falling rate periods).

For effective moisture diffusivity determination, the mudskipper fish samples were considered as infinite cylinders and the moisture diffusivity for infinite cylinder was obtained from the Crank (1975) equation as

$$MR = \frac{X-X_e}{X_o-X_e} = \sum_{n-1}^{\infty} \frac{4}{\lambda_n^2}\, exp\left[-\lambda_n^2\, D_{eff} t/r^2\right] \quad (3)$$

Where MR is moisture ratio, X is moisture at any time, $X_e$ is equilibrium moisture, $X_o$ is the initial moisture content and $\lambda_n$ are the roots of Bessel function (2.405, 5.520, 8.654,) of zero order. For n > 1, the second and subsequent terms of the equation become negligible. Hence $\lambda_1$ = 2.405 and therefore changing equation (3) to

$$MR = \frac{X-X_e}{X_o-X_e} = \sum_{n=1}^{\infty} \frac{4}{2.405}\, exp\left[-2.405^2 D_{eff} t/r^2\right] \quad (4)$$

Where for diffusion at the falling rate period in drying operations, the Fourier number ($F_O$) is

$$F_o = D_{eff} t/r^2 \quad (5)$$

Where r is the radius of the sample

$$MR = \frac{4}{\lambda_1^2} \exp( -\lambda_1^2 D_{eff} t /r^2 ) \quad (6)$$

Where $\lambda_1^2 = (2.405)^2 = 5.784$

Therefore,

$$MR = 0.6916\exp(-5.784\ D_{eff}t/r^2) \quad (7)$$

Taking log of both sides, we get

$$In\ MR = In(0.6916) - \frac{5.784D_{eff}t}{r^2} \quad (8)$$

Therefore, plotting ln(MR) against drying time, t gives a slope. The effective moisture diffusivity was then obtained from the slope of the plot as

$$D_{eff} = -slope\ (r^2)/5.784 \quad (9)$$

Furthermore, the temperature dependence of effective moisture diffusivity was indicated in an Arrhenius-type equation as

$$D_{eff} = D_o\exp(-E_a/RT) \quad (10)$$

Where $D_o$ is pre-exponential factor ($m^2/s$), Ea is activation energy (KJ/mol), R is universal constant and T is the absolute air temperature (°K).

Taking log of both sides gives

$$In(D_{eff}) = In\ (D_o) - \frac{E_a}{R}\left(\frac{1}{T}\right) \quad (11)$$

Therefore, plotting $\ln(D_{eff})$ on y-axis and (1/T) on x-axis we obtain the slope and intercept as

$$Slope = -\frac{E_a}{R} \quad (12)$$

The activation energy is therefore calculated from equation (12) as

$$E_a = -slope\ (R) \quad (13)$$

And

$$Intercept = In\ (D_o) \quad (13)$$

This implies that,

$$D_0 = \exp(intercept) \quad (14)$$

## RESULTS AND DISCUSSIONS

The data for drying of Mudskipper samples at the desired temperatures were collected with respect to drying time. Figure 1 shows the plots of moisture content and drying time for the selected drying temperatures and the attendant polynomial fit equations generated. Results show that moisture content decreases with increase in drying temperature and time. It was also observed that like other biomaterials, the drying of mudskippers falls under the falling rate period, signifying that the drying rate was controlled by capillary action and internal diffusion. These findings agree with reports of other researchers on different biomaterials (Sacilic, 2007; Omodara and Olaniyan, 2012; Burubai and Etekpe, 2014).

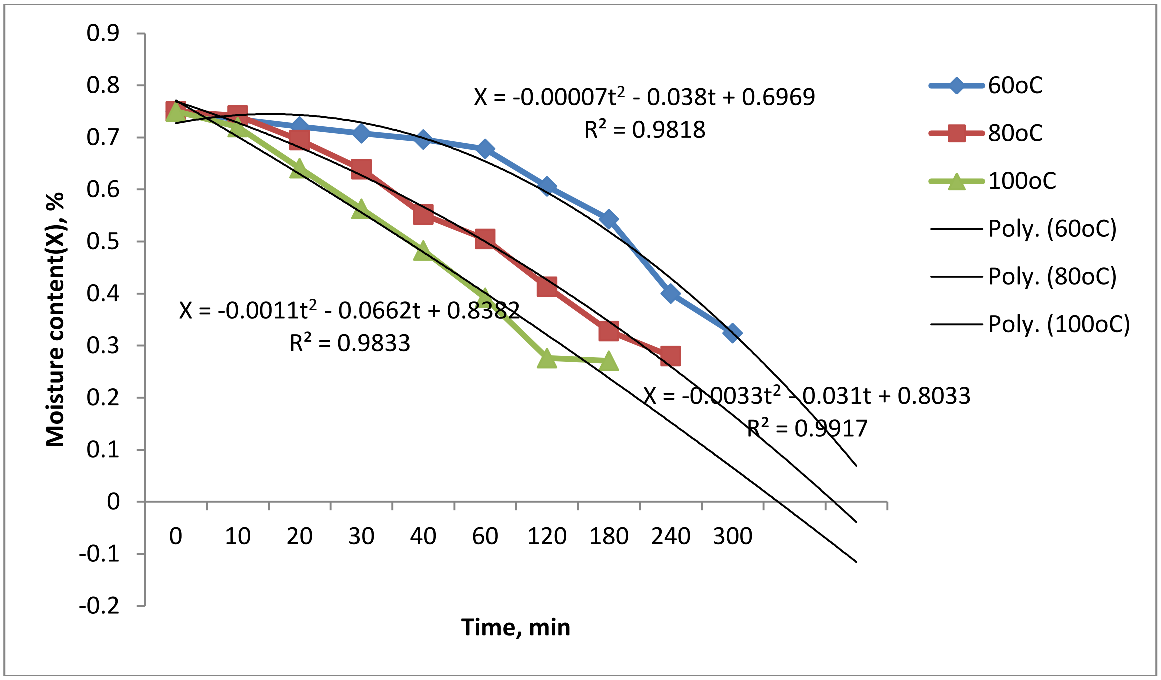


**Fig 1Relationship between moisture content and drying time**

**Analysis**

At 60°C, the polynomial equation generated from the drying curve is

$$\boldsymbol{X = -0.00007t^2 + 0.038t + 0.696} \qquad (15)$$

Where X is moisture content (%) and t is drying time (min). Differentiating equation (15) with respect to time yields the drying rate equation at 60°C as

$$\boldsymbol{\frac{-\,dX}{dt} = 0.00014t + 0.038} \qquad (16)$$

At 80°C, the polynomial equation obtained from the drying curve is

$$\boldsymbol{X = -0.0033t^2 - 0.031t + 0.803} \qquad (17)$$

Differentiating equation (17) with respect to time yields the drying rate equation at 80°C as

$$\boldsymbol{-\frac{dX}{dt} = 0.0066t + 0.031} \qquad (18)$$

At 100°C of drying, the polynomial equation generated is

$$\boldsymbol{X = -0.0011t^2 - 0.0662t + 0.838} \qquad (19)$$

Differentiating equation (19) with respect to time yields the drying rate profile at 100°C as

$$\boldsymbol{-\frac{dX}{dt} = 0.022t + 0.0662} \qquad (20)$$

Therefore, substituting the drying time intervals into equations (16), (18) and (20) gives the drying rates as presented in Table 1.

**Table 1: Drying rates at different temperatures**

| Drying Time, min | Drying rates $\left(-\frac{dX}{dt}\right)$, min$^{-1}$ | | |
|---|---|---|---|
| | 60°C | 80°C | 100°C |
| 0 | 0.0380 | 0.031 | 0.0662 |
| 10 | 0.0394 | 0.0376 | 0.0882 |
| 20 | 0.0408 | 0.0442 | 0.1102 |
| 30 | 0.0422 | 0.0508 | 0.1322 |
| 40 | 0.0436 | 0.0574 | 0.1542 |
| 60 | 0.0464 | 0.0706 | 0.1982 |
| 120 | 0.0548 | 0.1102 | 0.3302 |
| 180 | 0.0632 | 0.1498 | 0.4622 |
| 240 | 0.0716 | 0.1874 | 0.5942 |
| 300 | 0.0800 | 0.229 | 0.7262 |

Plotting the drying rate values above against moisture content reveals the drying behaviour of Mudskipper as shown in Fig 2.

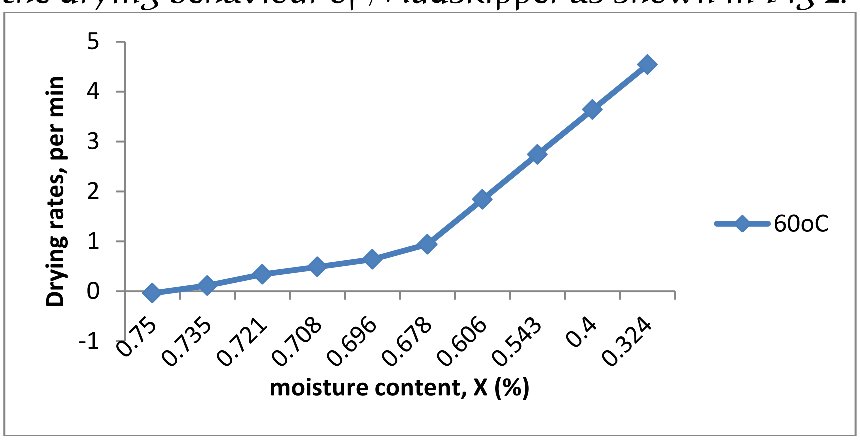


**Fig 2: Drying rate curve for mudskipper at 60°C**

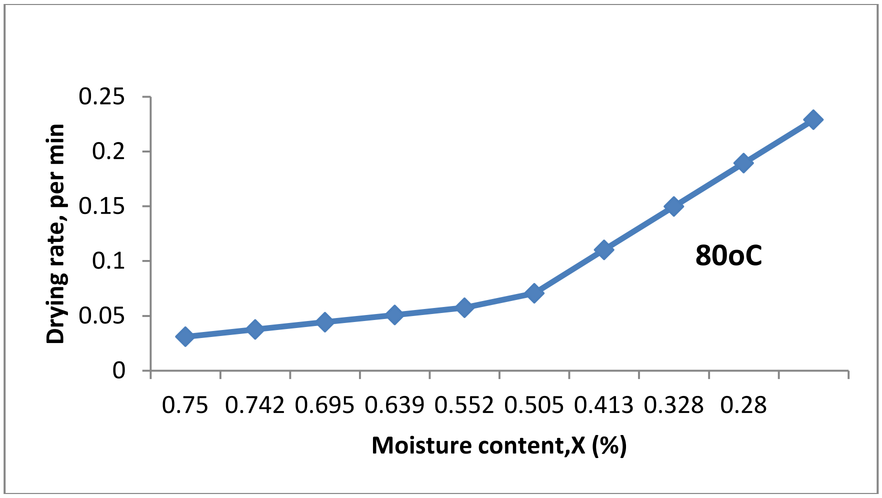


Fig 3: Drying rate curve for mudskipper at 80°C

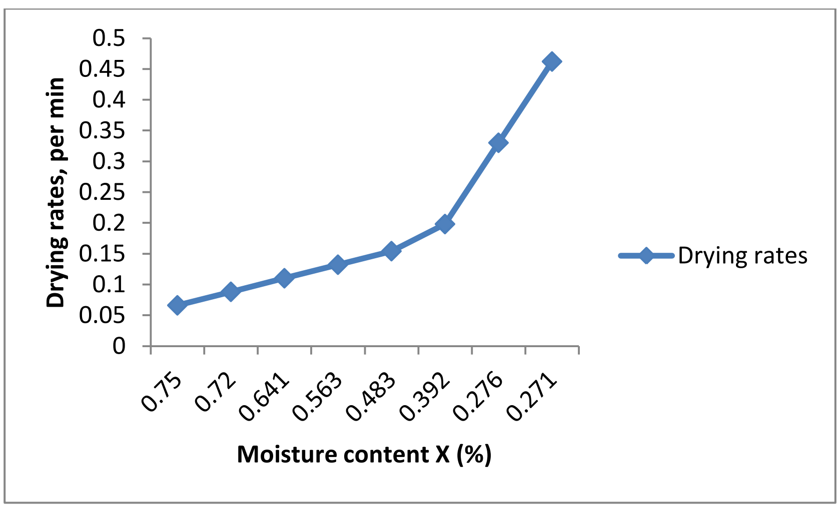


Fig 4: Drying rate curve for mudskipper at 100°C

From Figures 2, 3 and 4, it is obvious that irrespective of temperature variations, the drying rate of mudskipper is basically in the falling rate period. However, two zones were noticeable: namely the constant or first falling rate period which is controlled by capillary forces and the second falling rate period purely controlled by liquid diffusion.

## Effective Moisture Diffusivity and Activation Energy

The effective moisture diffusivity was calculated using the slope method (equation 9) as was also applied by Robert et al, 2008 and Jittanit, 2011. Table 2 shows that effective moisture diffusivity of mudskipper fish increases with increase in temperature. At 60°c, moisture diffusivity value of $5.178 \times 10^{-5}$ m²/s was recorded but increased to $1.005 \times 10^{-4}$ m²/s. The explanation is that, at higher temperatures, the activity of water molecules increases which, perhaps, causes higher moisture diffusion. Similar reports were made by Doymaz (2004) and Jittanit(2011). Table 2 also reveals the activation energy needed to dry mudskipper as 27.44 KJ/mol. This is the energy required to initiate moisture diffusion from mudskipper during drying at the falling rate period. This energy value is far lower than that of freshwater frog (45.6KJ/mol) as reported by Burubai and Bratua(2015) . A plot of In $D_{eff}$ against 1/T is as shown in Fig 5 and the mathematical relationship between moisture diffusivity and temperature is given in equation 21 below.

**Table 2 Moisture Diffusivity values and Activation energy of mudskipper**

| Temp(°C) | Moisture Diffusivity (m²/s) | $D_o$(m²/s) | Activation energy $E_a$(KJ/mol) | $R^2$ |
|---|---|---|---|---|
| 60 | $5.178 \times 10^{-5}$ | $3.83 \times 10^{-5}$ | 27.44 | 0.975 |
| 80 | $7.905 \times 10^{-5}$ | | | |
| 100 | $1.005 \times 10^{-4}$ | | | |

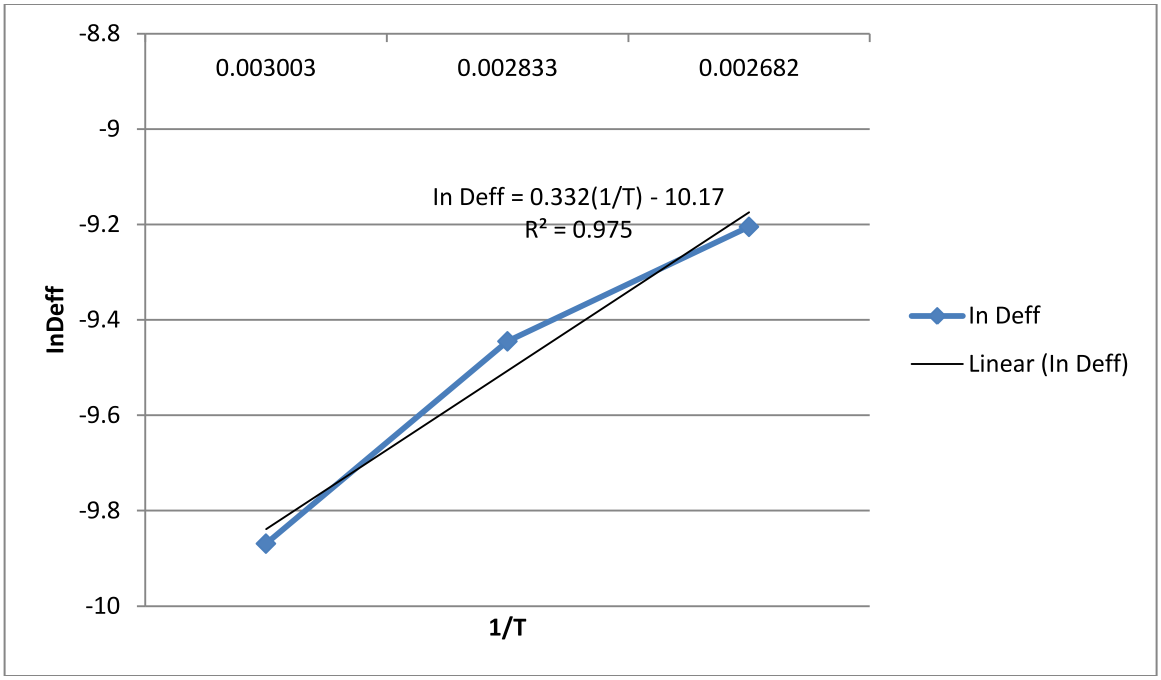


**Fig 5 Arrhenius-type relationship between effective moisture diffusivities and reciprocal absolute temperatures**

$$D_{eff} = 3.83 \times 10^{-5} \exp\left(-\frac{3300.5}{T + 273.2}\right);\ R^2(0.975) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (21)$$

## CONCLUSION

The drying behaviour of mudskipper fish was studied in this work. Results show that, the drying rate of mudskipper responded positively to increase in drying temperature. The drying process was also dominated by the falling rate period like other biological materials. The effective moisture diffusivity values varied between 5.178 x $10^{-5}m^2/s$ and 1.005 x $10^{-5}m^2/s$ for the temperatures used.

## REFERENCES

Andem, A.B and Ekpo, P.B (2014) Proximate and Mineral Composition of Mudskipper Fish in the Mangrove Swamp of Calabar River. *The International Journal of Science and Technology*, 2(3): 72-76.

Burubai,W. and Bratua, I (2016) Drying kinetics of pre-osmosed fresh water frog. *Nigerian Journal of Technology,* 35(4): 935- 939.

Burubai, W and Etekpe, G. W (2014) Microwave-Drying Behaviour of African Nutmeg (*Monodora myristica*) and Ogbono (*Irvinga gabonensis*) kernels. *Advanced Journal of Agricultural Research,* 2(12) 189-196.

Crank J (1975). The mathematics of diffusion 2nd ed, Oxford University Press. London, UK. 414 pp.

Doymaz I. (2004) Convective air drying characteristics of thin layer carrots. *J. Food Eng.,* 61:359-364.

Food and Agricultural Organization (FAO) (2004). The composition of fish. Available fromhttp://www.fao.org/wairdoes/tx5916e/×5916c01.htm., Pp: 1-80.

Jaafar, Z. E and Larson, H. L (2008). A New species of mudskipper, Teleostei, Gobiidiae, Oxudercinae from Australia, with a key to the Genus. *Zoolo. Sci.,* 25:946 -952.

Jittanit W (2011). Kinetics and temperature dependent moisture diffusivity of pumpkin seeds during drying. *Kasetsart J. (Nat. Sci.)* 45:147 – 158.

Omodara, M.A. and Olaniyan, A.M.(2012) Effect of pretreatment and drying temperatures on drying rate and quality of African catfish. *Journal of Biology, Agriculture and Healthcare,* 2(4): 1-10.

Robert, J. S., David R. K., Olga, P (2008) Drying kinetics of grape seeds. *J. Food Eng.*, 89:460 – 465

Sacilik, K (2007) Effect of drying methods on thin-layer drying characteristics of hull-less seed pumpkin. *J. Food Eng.*, 79:23 – 30.