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EFFECTS OF AIR VELOCITY AND TEMPERATURE ON MOISTURE PROFILE AND DRYING RATE OF EXTRUDED FISH FEEDS

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ABSTRACT

Drying is an important aspect of food processing and preservation. Fish feeds are dried to prolong the shelf life of the product. 2000 g of extruded fish feeds were dried in a continuous flow belt dryer for 270 minutes by using drying air temperature of 60 °C to 100 °C and drying air velocity of 0.8 m/s to 1.2m/s at a constant belt speed of 60 rpm. Variation in the moisture content and moisture ratio with time was recorded as the effect of temperature and air velocity on the moisture profile and drying rate of the feeds. Drying curves were obtained to show the drying behaviour of the feeds under the different machine operational conditions. The result obtained shows that the increase in the drying temperature led to an increase in the amount of moisture loss by the extrudate over the drying time while the drying rate gradually decreased with progress in drying time. Also, a rise in the drying air temperature reduces the time and both the drying air temperature and air velocity have a significant effect on the drying behaviour of the extruded fish feeds. Also, the moisture diffusivity ranges between 4.52 x 10^{-9} *m/s*^{2} *to 3.731 x* 10^{-9} *m/s*^{2} *while the activation energy is between 17.29 to 24.54 KJ/mol.*

KEYWORDS: Dehydrating temperature; dehydrating air velocity; dehydrating rate; moisture dissemination; activation energy.

INTRODUCTION

The estimated national annual demand for fish in Nigeria is 2.3 million tonnes out of which market research evidence shows that one in every 500 of this total demand represents the demand estimate (Adekunle et al., 2012). A high-quality nutritionally balanced diet is required by fish for growth and to attain market size within the shortest possible time. This is possible through the use of fish feeds. Fish feeds are commercially manufactured either as extruded (floating or buoyant) or pressure–pelleted (sinking) feeds. The technical quality of fish feeds is a multidimensional aspect which consists of feed composition, physical attributes and processing methods. The quality of feed including the sourcing, storage and handling significantly affects feed stability and nutrient bioavailability. Also, Kaushik and Seillies (2010) opined that physical characteristics such as pellet size, shape, density and water stability affect feeding behaviour and feed utilization. Furthermore, Haubjerg et al., (2014) reported that processing techniques such as extrusion, pelleting and drying impact feed quality. When an extrudates leaves the extruder, the temperature (65 to 85°C) and moisture content (18%) are usually high (Kurt, 2012) and for safe storage, the moisture has to be reduced to 10%. Dutta et al., (2012) reported that it is hard to lower the moisture content of products in which the liquid in the solid is bonded to the solid by sorption from higher moisture to a lower one. This is because the water present in the outer layer of the material evaporates much faster than that of the inner layers. Drying such product (fish feeds) at a higher temperature will create internal tension and produce tiny cracks which can lead to rapture of the product during subsequent treatments. It is therefore necessary to know the effect of the drying parameters in the moisture removal and temperature of which solid during the drying process to obtain the best drying conditions and to save energy. It has been reported by various researchers that most fish feeds produced in Nigeria are not floating and one of the major factors responsible for this is that most feeds are not properly dried. Thus, this research looks into the effects of drying air velocity and temperature on the drying rate of extruded fish feeds.

MATERIALS AND METHOD

Fish feed was formulated following the method proposed by Fagbenro and Adebayo (2005) for catfish feed production in Nigeria. The formulated feeds were extruded using a screw extruder and dried using a continuous flow belt dryer (Figure 1). The initial moisture content of the feeds was determined using AOCC method 44-19 (2000). 2500g of the wet feeds were introduced as a thin layer into the dryer. The machine operational conditions were varied by using air drying temperature from 60 °C to 100 °C at an interval of 10 °C (Kurt, 2012), drying air velocity of 0.8 m/s to 1.2 m/s at an interval of 0.1 m/s (Torres & Dincer, 2011) at a constant belt speed of 60 rpm. The drying curves were obtained by recording the moisture loss at every stage by using a specially developed weighing system with an accuracy of 0.01 g

Moisture content determination

The moisture content of the extrudate was determined using the method described by AOAC (2000). The moisture content was calculated using the following relationship (Eq. 1)

$$MC = \frac{W_x - W_y}{W_y} \text{ x } 100 \qquad (1)$$

Where MC is the moisture content (kg of water/kg of dry sample),

W_x is the weight of the sample (kg) and

W_y is the weight of the dry sample (kg).

Moisture ratio

The change in moisture content of the feed was recorded and converted to a dry basis. The moisture ratio of the extrudate was determined using Eq. 2 as reported by Saeed et al. (2010).

$$MR = \frac{M - M_e}{M_o - M_e} = \frac{M}{M_o} \qquad (2)$$

Where,

MR is the moisture ratio,

M is the moisture content at any drying time,

M_o is the initial moisture content (kg of water/kg of dry matter) and

M_e is the equilibrium moisture content. During the drying of the feeds,

M_e was relatively small compared with M and M_o.

Drying rate

The drying rate was determined by using Eq. 3 as reported by Meisami – asl et al., (2010).

$$DR = \frac{M_{t+dt} - M_t}{dt} \qquad (3)$$

Where,

DR is the drying rate,

M_{d+dt} is moisture content at t +dt, (kg of water/kg of dry matter),

M_t is moisture at t and t is drying time (min).

Estimation of moisture diffusivity

The moisture diffusivity of the extrudate was determined using the equation reported by Alibis (2014).

$$D_{eff} = -\frac{4L^2}{\pi^2} \, x \, (slope\ of\ line) \qquad (4)$$

Where,

D_{eff} is moisture diffusivity (m^2/s), k_1 is the slope obtained by plotting the graph of In MR verse time and

L is half the thickness of the feed (m).

Estimation of activation energy

To determine the activation energy of the extrudate, the effective moisture diffusivity was related to drying time and Eq. 5 was used to determine the moisture diffusivity.

$$D_{eff} = D_o \exp\left(\frac{-E_a}{RT_{abs}}\right) \qquad (5)$$

Where,

D_o is the Arrhenius constant to the diffusivity at infinitely high temperature (M^2/s),

R is the gas constant (8.134×10^{-3} Kj Mol^{-19} K^{-1}),

T_{abs} is the absolute temperature (^{o} K) and

E_a is the activation energy (Kj mol^{-1}).

The graph of In D_{eff} was plotted against 1/Tabs and its slope was used to determine the activation energy in Eq 6.

- (slope of line) x R = Ea (Beigi, 2015). (6)

RESULTS AND DISCUSSION

Results

The graphical representation of the moisture content versus drying time and moisture ratio versus drying time are shown in Fig 2 and 3 respectively for thin-layer drying of fish feed extrudate using continuous belt dryer. Figs 4 and 5 show the drying rate values versus drying time and moisture content respectively. Figs 6 and 7 show the moisture diffusivity and activation energy values respectively for the different machine operational conditions.

Discussion

Effect of drying air velocity and temperature on the moisture content and moisture ratio.

Figures 2 and 3 show the drying curves of moisture content versus drying time and moisture ratio versus the drying time. This result shows that, an increase in the air velocity of the drying air results in a decrease in the moisture loss at each drying time as a result of increasing convective heat and mass transfer between drying air and the fish feed extrudate. However, with any decrease in the air velocity, the circulation of the air temperature reduces and a low heat flow is delivered to the fish feed extrudate resulting in rapid breakdown in the temperature distribution and circulation in the continuous belt dryer towards the completion of the drying process causing a noticeable variation in the final moisture content obtained after 270 minutes.

Effect of air velocity on the drying rate.

Fig 4 and 5 depict the drying rate values versus drying time and moisture content respectively for the fish feed extrudate dried in a continuous belt dryer. The high initial drying rate recorded for the fish feed extrudate are about 0.23 ± 0.14, 0.27 ± 0.13, 0.35 ± 0.10, 0.40 ± 0.07 and 0.45 ± 0.06 $kg^{-1}min^{-1}$ increases with from the figures, it is noticed that drying time decreased as the air temperature and air velocity increased from 60 to 100 ^{O}C and 0.8 to 1.2 m/s respectively. Similar results have been reported in the literature for air temperature and air velocity influences on dehydration rate for chamomile (Motevali et al., 2014), native cassava starch (Aviara et al., 2014), and potato pulp waste (Carvalho et al., 2014). The drying duration of agricultural materials can be affected by some factors such as indigenous properties, initial and final moisture contents of the product, drying method and drying conditions. Higher temperatures and air velocity of drying air facilitate the heat transfer rate between the thermal source and the material leading to faster moisture evaporation and lower drying time. Also, it was observed that the drying rate increased with an increase in the temperature and this corroborates the results of some studies on milky mushrooms (Arumuganathan et al., 2009), on olive pomace (Meziane, 2011) and barberry (Gorjian et al., 2011).

Moisture diffusivity of the exudates

Fig 6 shows the graph of moisture diffusivity versus time for different temperatures at a conveyor speed of 60 rpm. The obtained values of D_{eff} range between 1.658×10^{-9} m^2/s and 3.958×10^{-9} for the conveyor speed of 60 rpm. The reported D_{eff} values were within the general range of 10^{-11} to 10^{-9} m^2/s for food materials (Doymaz, 2011). However, it was observed that D_{eff} values increased greatly with increasing drying temperature. When fish feed extrudates were dried at higher temperatures, an increase in heating energy would increase the kinetic energy of water molecules leading to higher moisture diffusivity (Xiao et al., 2010). The values of D_{eff} are comparable with the reported values of 1.19 to 4.27×10^{-9} m^2/s for pumpkin fruits at 40 – 80 ^{O}C (Tunde-Akintunde & Ogunlakin, 2011), 1.015 to 2.650×10^{-9} m^2/s for tomato leathers at 60 – 100 ^{O}C (Demiray & Tulek, 2012) and 1.1×10^{-10} to 1.26×10^{-9} m^2/s for the drying of terebinth in the temperature range of 40 – 80 ^{O}C (Amiri-Chayjan & Kaveh, 2014).

Activation Energy

The activation energy was determined using the linearization of the Arrhenius-type equation as approached by Chen et al., (2012), Rodriguez et al., (2014) and Lee & Zuo (2013). Fig 7 shows the graph of activation energy versus temperature for different air velocities. The values of energy of activation for the fish feed extrudate are in close range with the value reported of 12.7-110 kJ/mol by Aghbashlo et al., (2009) for most food, fruit, and vegetable materials. The activation energy (Ea) for fish feed extrudates varied from 6.47 to 24.58 kJ/mol.

CONCLUSIONS AND RECOMMENDATIONS

The drying air velocity significantly influences the moisture profile during the drying process. Higher drying air velocity leads to more rapid moisture removal from the surface of the feeds and this can lead to non-uniform drying of the materials. Whereas, lower air velocity, promote more even drying of the feed. Also, the drying rate increases with an increase in the drying temperature leading to faster drying of the feeds. It is recommended that the optimal drying temperature of the feeds should be investigated to strike a balance between moisture removal and maintenance of the desired characteristics of the dried feeds.

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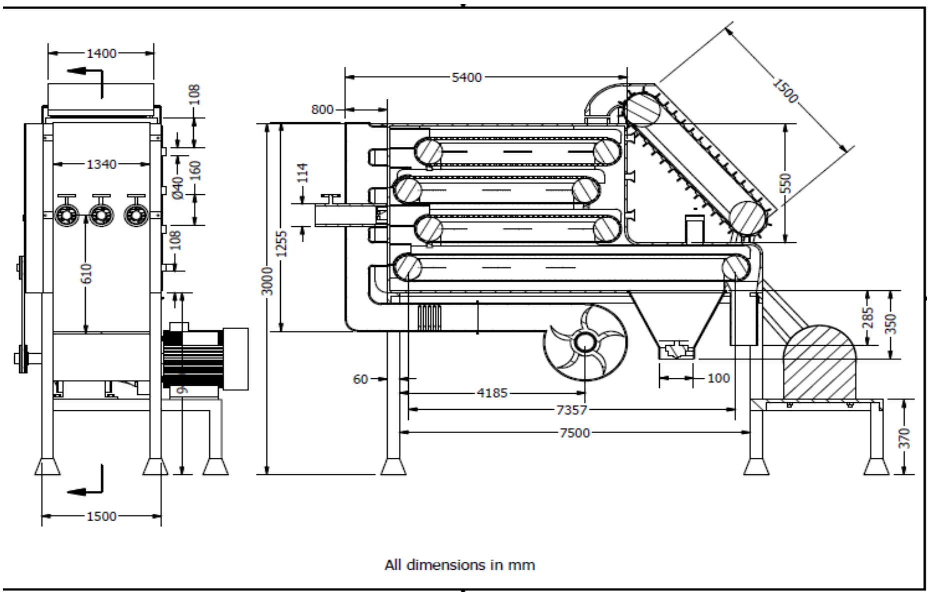

All dimensions in mm

Figure 1. Schematic diagram of the dryer

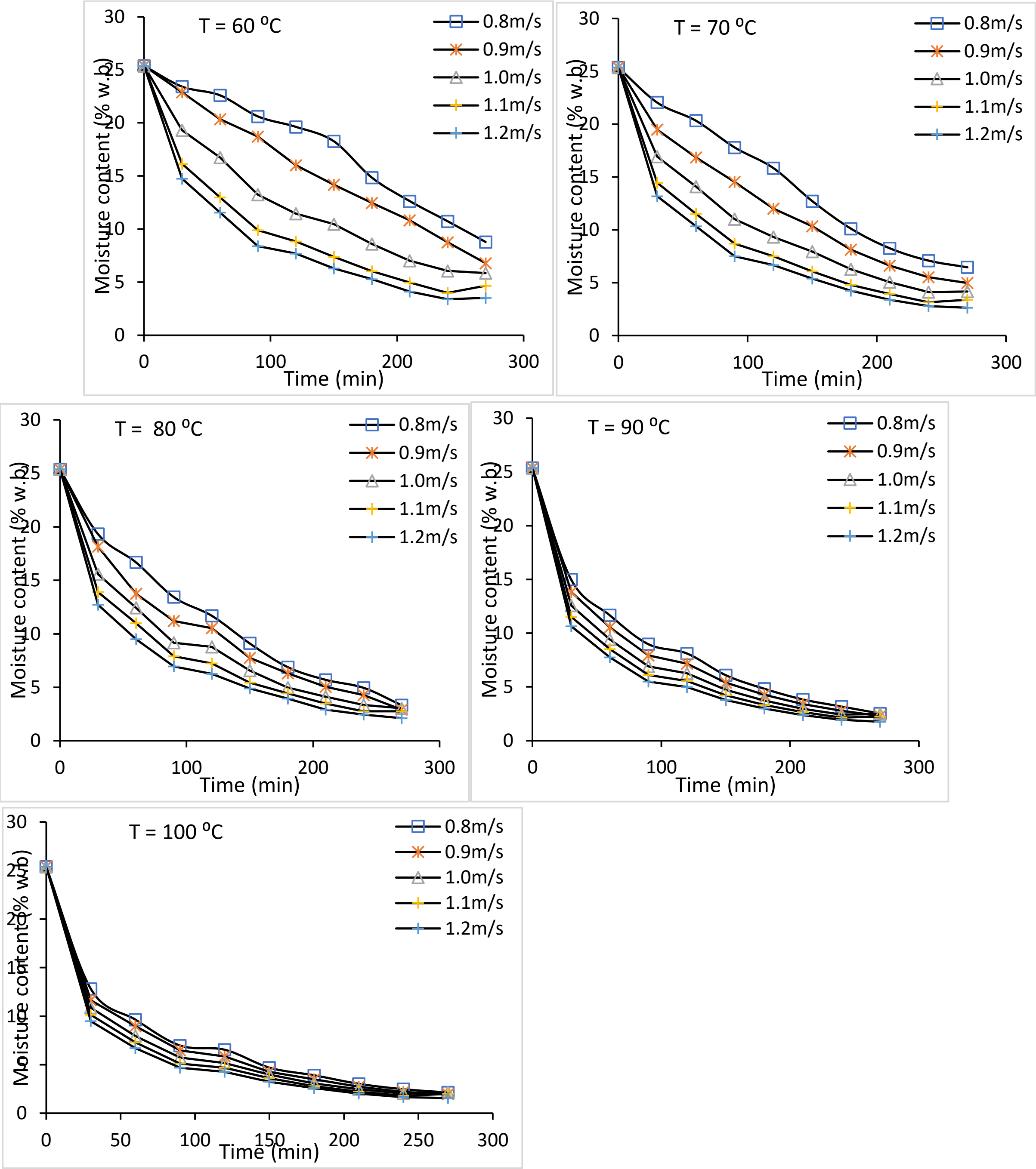

Figure 2. Influence of air velocity on moisture content vs. drying time at different temperatures for 60 rpm conveyor speed

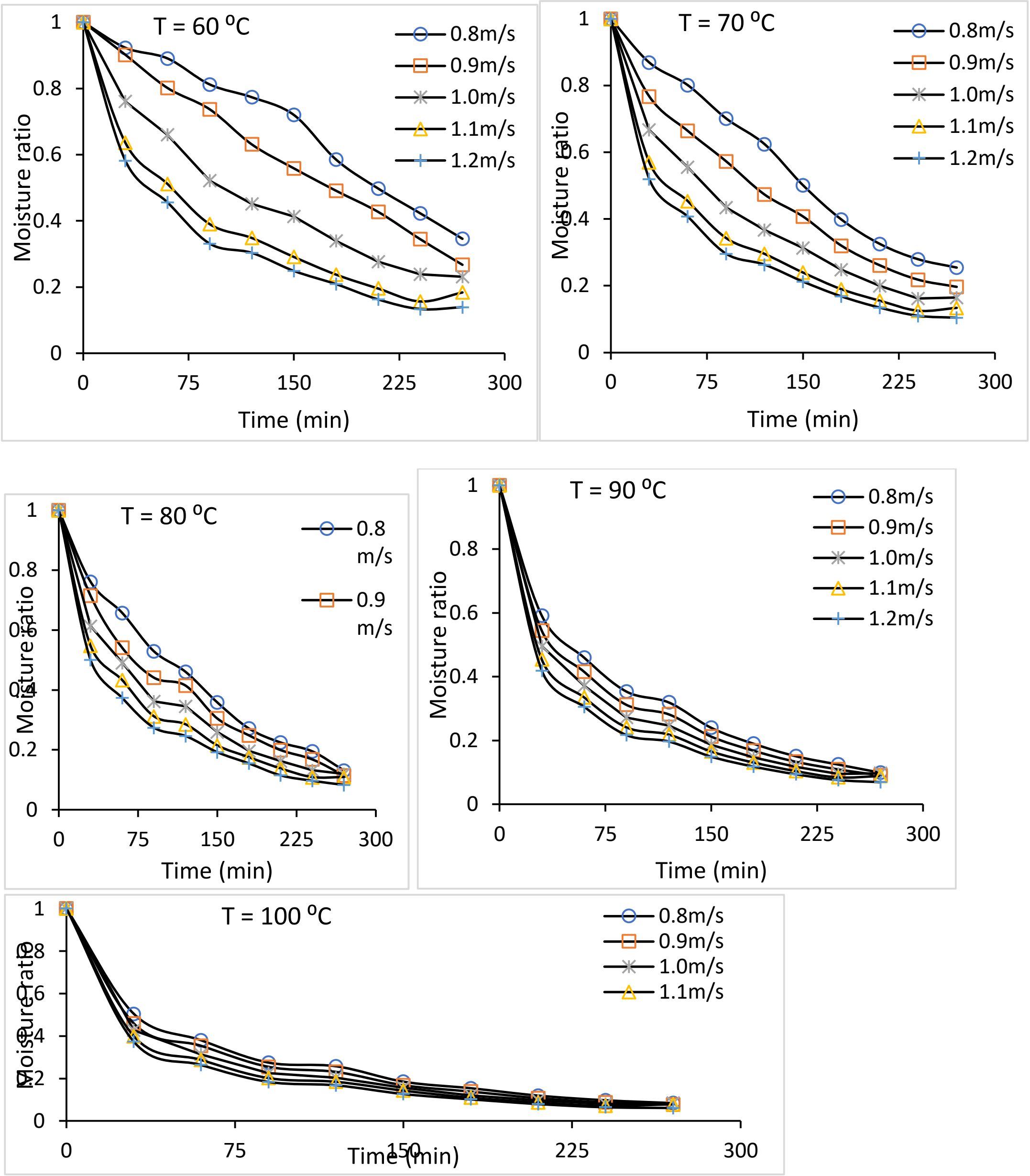

Figure 3. Effect of air velocity on moisture ratio vs. drying time at different temperatures for 60 rpm conveyor speed

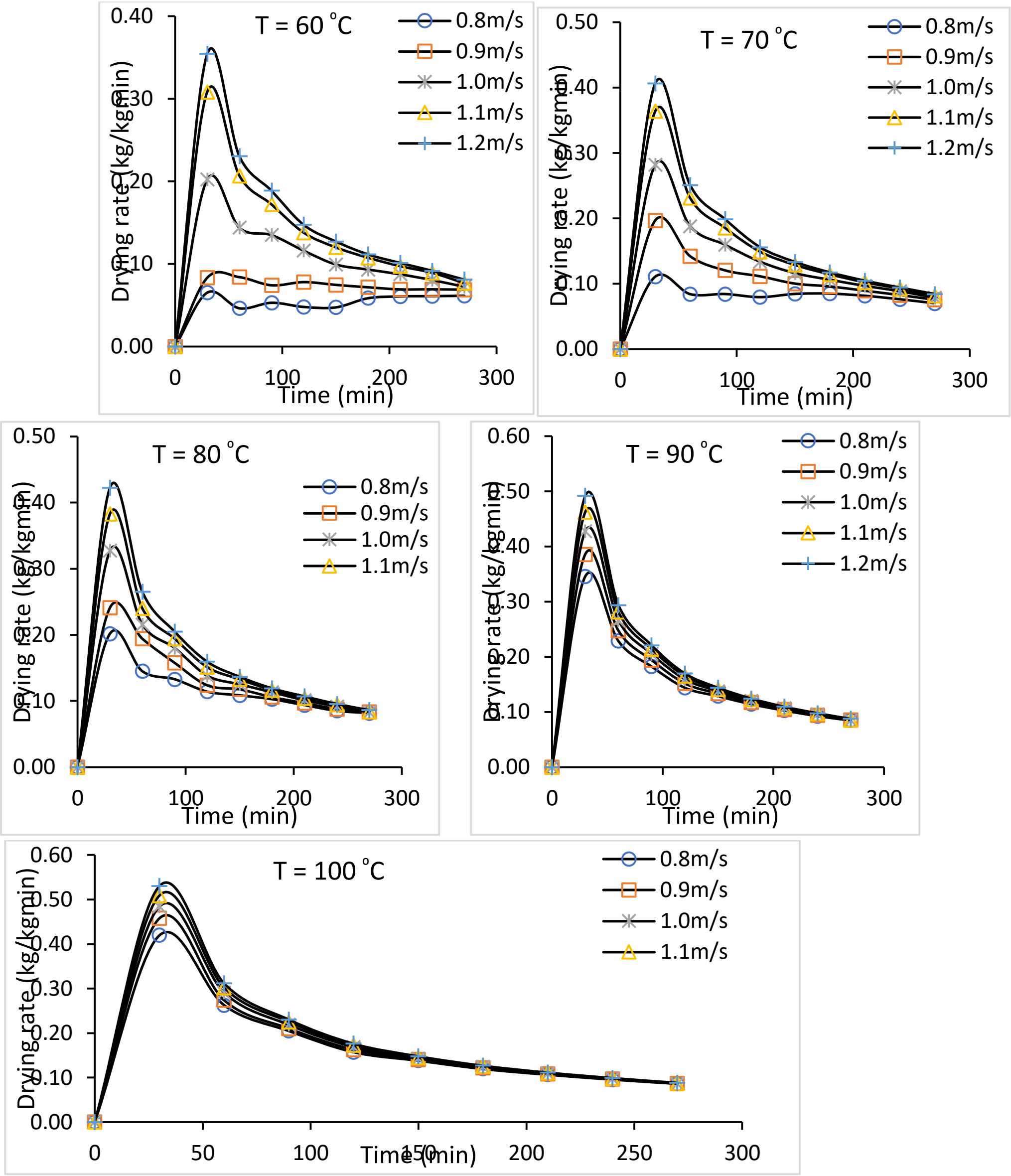

Figure 4. Effect of air velocity on drying rate vs. drying time at different temperatures for 60rpm conveyor speed.

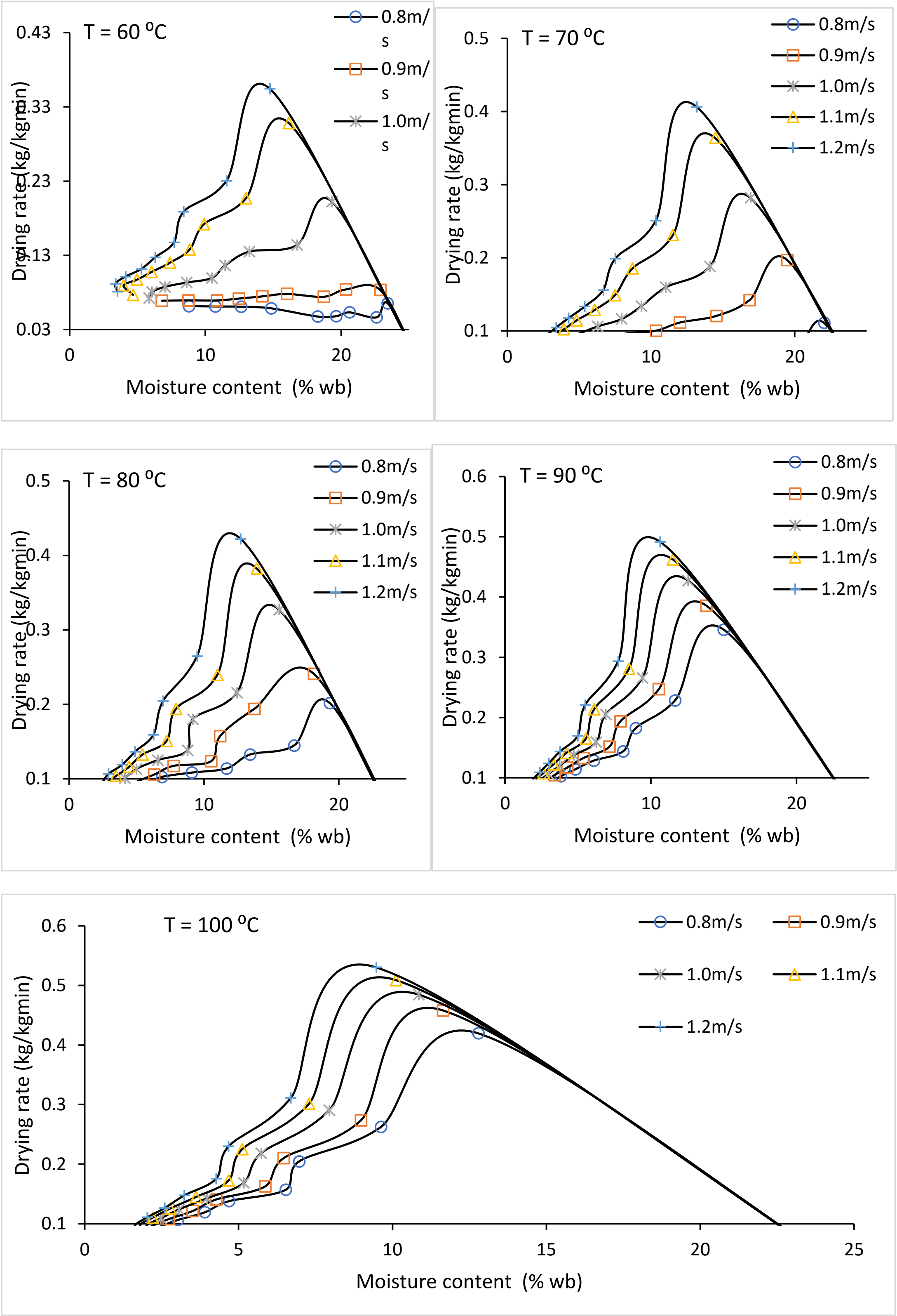

Figure 5. Effect of air velocity on drying rate vs. moisture content at different temperatures for 60 rpm conveyor speed

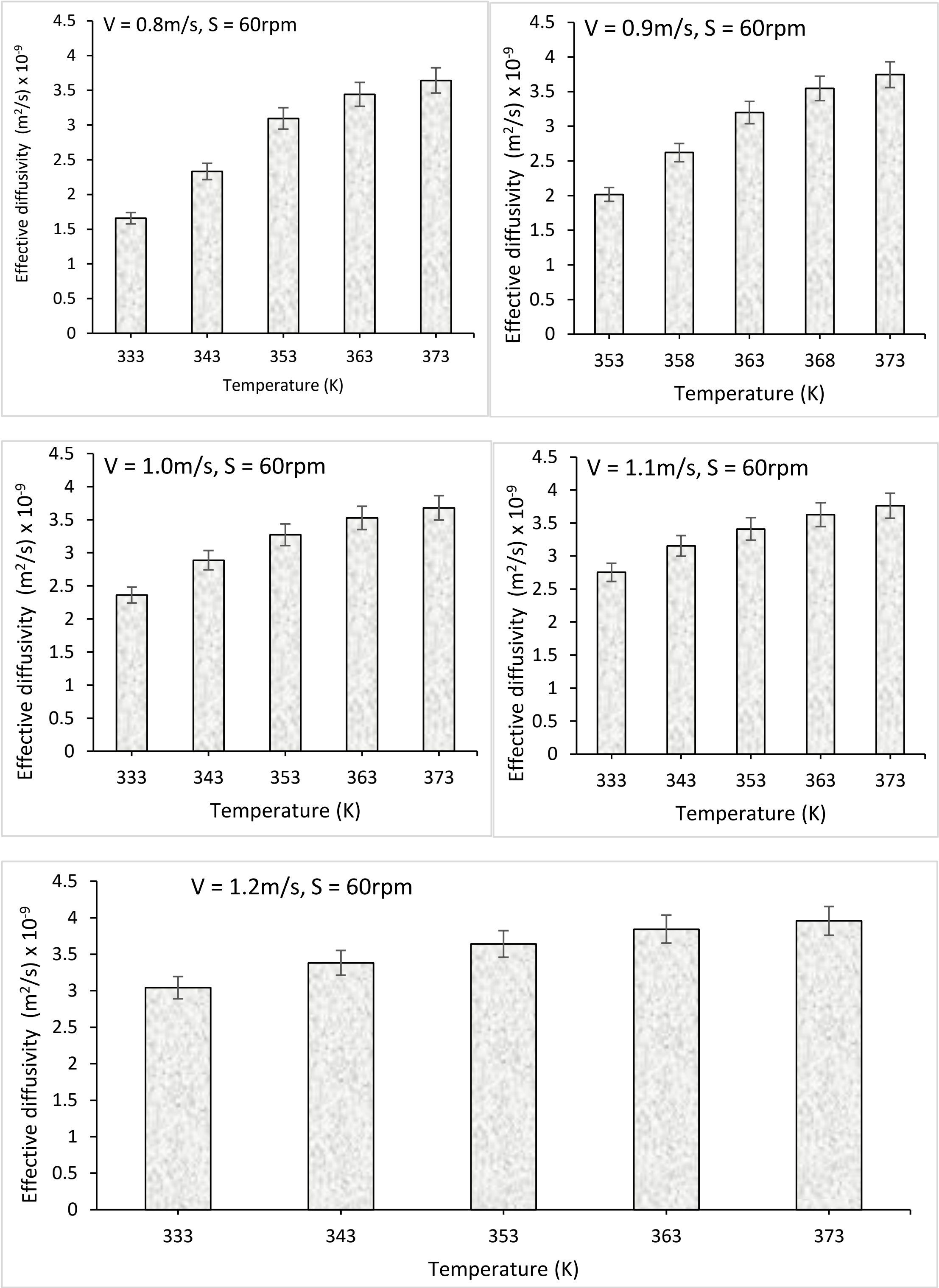

Figure 6. The graph of moisture diffusivity versus Time for different temperatures at a conveyor speed of 60 rpm.

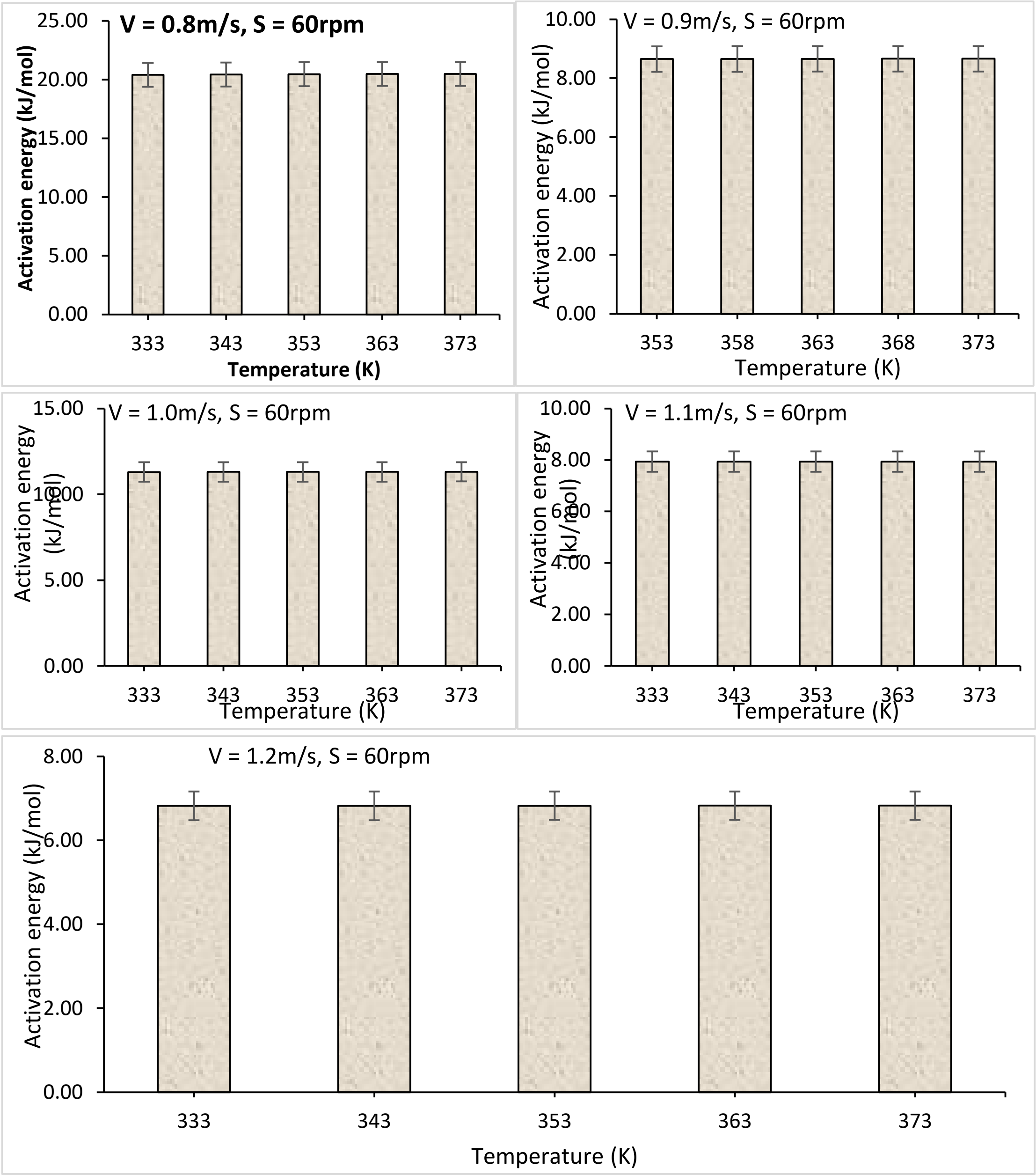

Figure 7. The graph of activation energy versus temperature for different air velocities at a conveyor speed of 60 rpm