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The effect of packed bed porous burner on drying kinetics of Nile tilapia

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Abstract. This paper aimed to study the effect of packed bed porous burner on drying kinetics of Nile tilapia. Drying kinetics were represented in form of drying rate (DR), drying specific energy consumption (SEC) and the dryer thermal efficiency (η_{th}). The pebbles were used as packed bed porous media having porosities of 0.31, 0.36 and 0.37, drying air velocities of 0.5, 1.0 and 1.5 m/s. and drying temperatures of 50, 60 and 70 °C, respectively. The results showed that the application of packed bed porous burner as heat source could improve the drying kinetics. Which the porosity of 0.37, drying temperature of 70 °C and air velocity of 1.5 m/s, the moisture ratio of the drying decreased rapidly, the highest drying rate was 220.43 g (water evap.)/hr., the lowest drying energy consumption was 141.35 MJ/kg (water evap.) and the thermal efficiency of the dryer increased by 23.91%.

1. Introduction

Hot air drying is the favourite food preservation method because it costs less than other methods. Besides, power sources of hot air dryer can be easily found i.e. heater element, heat from fuel burning, solar energy or heat from industrious processes in a factories etc. The most common power source of hot air dryer is heater element, but this source requires a power transformation from electricity to heat through heater element, causing more electricity consumption [1] and take a long time to dry products. In order to reduce drying cost and increase efficiency of hot air dryer, the heat from combustion of fuel is adopted to produce the hot air. Also, porous media is applied to support combustion and transfer the heat to the products for drying.

In the past, many researchers had developed a gas burner made from porous media in many different ways. [2-6]. The result of developing the gas burner appeared that the gas burner in which porous media was installed was more effective than the gas burner without porous media, that is the higher temperature and the less requirement of energy, this is because the porous media can absorb and diffuse heat wave. The benefit of the porous media as mentioned earlier is the main reason for deciding to use the packed bed porous burner to sustain combustion and transfer heat while drying. The given findings are useful approaches for developing the food processing technology by drying method.

2. Materials and Methods



The dried sample product of this experiment is Nile tilapia which was dried with the use of hot air from LPG fuel burning by implementing pebbles packed bed porous media to support the heat transferring. Equipment and processes are as follows.

2.1. Experimental equipment

There are several experimental equipment used in the experiment of drying Nile tilapia with the use of pebbles packed bed porous media to support the heat transferring, as shown in the figure 1.

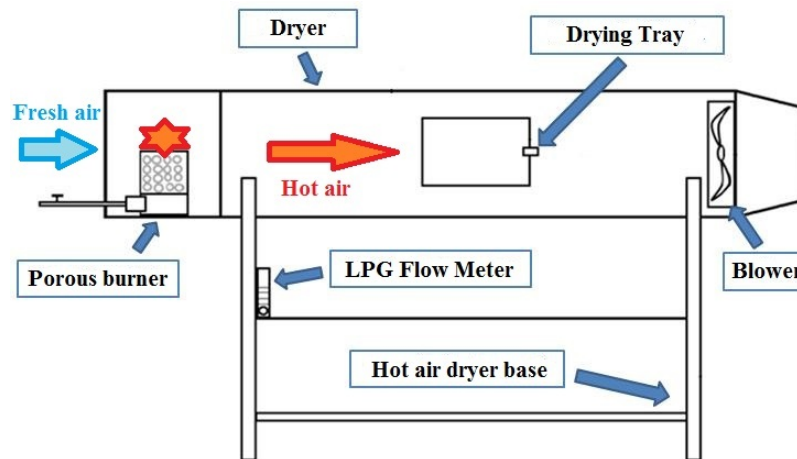


Figure 1. Hot air dryer with hot air flowing through packed bed porous burner

2.2. Analysis of drying kinetics

The analysis of drying kinetics in this research is analyzing the experimental result starting from the time when the initial moisture is around 400-450 % d.b.. The drying process is carried on drying condition and the water in product is evaporated until the moisture content is equal 160 % d.b. after that the drying experimental in each case is dried for another round, in this experiment and the reduction of product mass will be recorded every 5 minutes. Drying conditions consist of pebbled packed bed porosities of 0.31, 0.36 and 0.37, drying air velocities of 0.5, 1.0 and 1.5 m/s. and drying temperatures of 50, 60 and 70 °C, respectively. The study of drying kinetics of Nile tilapia will also be investigated in the form of drying rate (DR), drying specific energy consumption (SEC) and the dryer thermal efficiency (η_{th}) which can be shown in the equation (1)-equation (3), respectively.

$$DR = \frac{m_{evap}}{t_{drying}} \quad (1)$$

Where, DR is drying rate (g/hr)
 m_{evap} is the mass of evaporated water from product (g)
 t_{drying} is drying time (hr)

$$SEC = \frac{m_{LPG} LHV_{LPG}}{m_{evap}} \quad (2)$$

Where, SEC is specific energy consumption (MJ/kg of water evaporated)
 m_{LPG} is the mass of LPG used (kg)
 LHV_{LPG} is lower heating value of LPG (46 MJ/kg)

$$\eta_{th} = \frac{\dot{m}_{air} C_{p,air} \Delta T_{air}}{\dot{m}_{LPG} LHV_{LPG}} \times 100 \quad (3)$$

Where, η_{th} is thermal efficiency (%)
 $\dot{m}_{air}$ is mass flow rate of air (kg/s)
 $C_{p,air}$ is specific heat value of air (1.008 kJ/kg.K)
 ΔT_{air} is differential temperature (K)
 $\dot{m}_{LPG}$ is mass flow rate of LPG (kg/s)

3. Results and Discussions

The study of the drying kinetics of Nile tilapia by experiment can be classified into 3 main cases that are, the influence of porosity effect on drying rate (DR), the influence of porosity effect on drying specific energy consumption (SEC) and the influence of porosity effect on dryer thermal efficiency (η_{th}), details are shown below.

3.1. Influence of porosity on drying rate

The influence of porosity that has caused the reduction of the product's mass of this experiment uses porosity which is 0.31, 0.36 and 0.37. The mass of the product reduced, after the increasing period of drying process, it is found that the DR tends to increase when porous burner porosity is increasing. At porosity equals 0.37, 70 °C drying temperature and 1.5 m/s drying air velocity the DR is 220.43 g (water evap.)/hr. that is the highest and DR tends to decrease when porosity equals 0.36 and 0.31 at the same drying temperature and drying air velocity, respectively. The comparison of DR between drying with porous burner and without porous burner found that DR of drying with porous burner is higher than without porous burner at the same drying temperature and drying air velocity too; details are shown in figure 2.

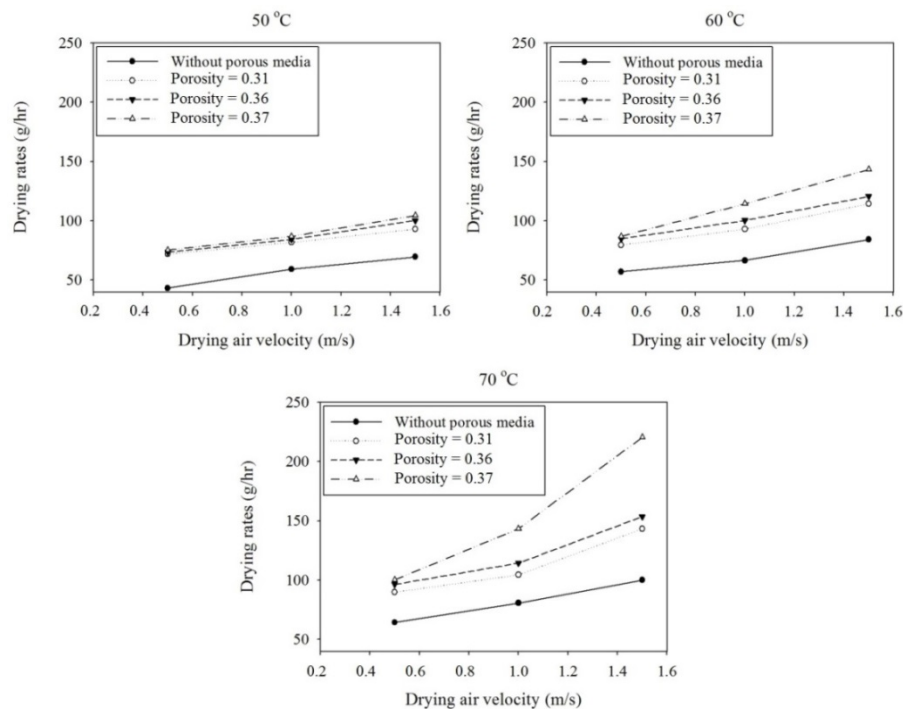


Figure 2. Drying rate at different drying temperatures

From figure 2, it shows that the increasing of drying rate when porosity of porous burner is increased and drying rate of drying with porous burner is higher than without porous burner at the same drying temperature and drying air velocity. The reason of this effect is when porous media is applied to burner in drying process, the heat transfer area of burner is increased that means heat convection, heat conduction and heat radiation of the dryer heat source are improved [4, 5] and higher than dryer without porous burner. So at porosity equals 0.37 which is higher porosity than porosity equals 0.36 and 0.31, the burner will has more heat transfer area than porosity equals 0.36 and 0.31, respectively and the drying rate is highest as well.

3.2. Influence of porosity on drying specific energy consumption

The drying SEC decreased when porosity is increasing. At porosity equals 0.37, 70 °C drying temperature and 1.5 m/s drying air velocity the drying SEC is 141.35 MJ/kg that is lowest and tends to increase when porosity is decreasing. This drying SEC results are related to the DR results that when DR increase the mass of evaporated water from product will increase at the same drying time, moreover when porous media is applied to the burner it makes the combustion of burner is completely than burner without porous media because when porous burner is lit, porous media will absorb the heat from combustion process and radiate heat to preheat the intake air and intake fuel at the mixing chamber under the flame holder of the burner so the dryer that using porous burner as heat source will use less energy than dryer without porous burner due to drying process, details are shown in figure 3.

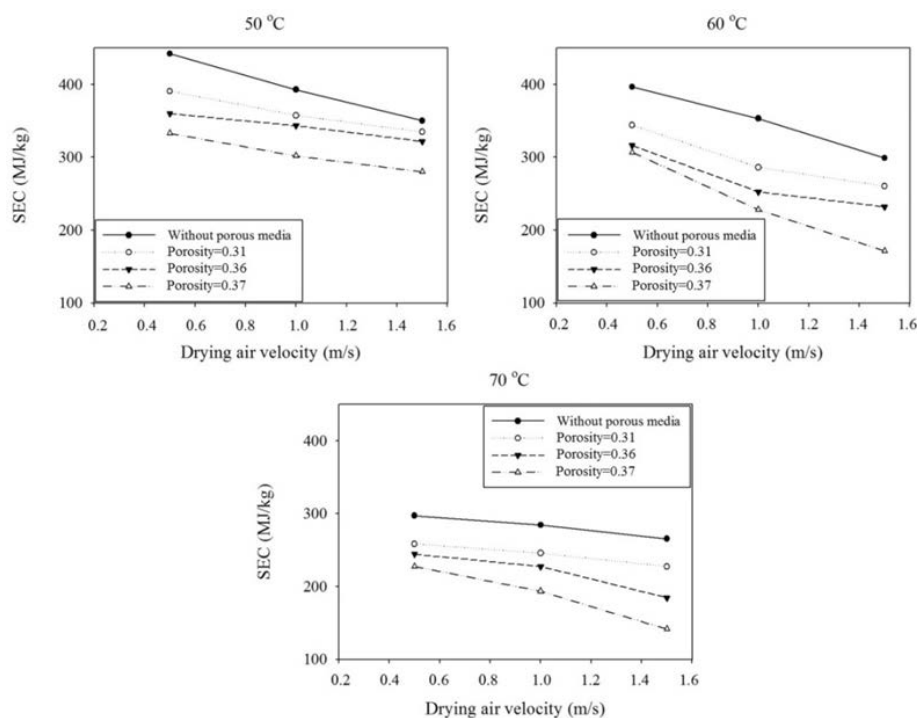


Figure 3. Drying SEC at different drying temperatures

3.3. Influence of porosity on dryer thermal efficiency

The results of dryer thermal efficiency show that the dryer thermal efficiency is increased when porosity is increasing and tends to decrease when porosity is decreasing these results are related to SEC results that means when heat input is reduced that has cause the dryer thermal efficiency is increased at the same drying temperature. The comparison of dryer thermal efficiency between dryer with porous burner and without porous burner shows that dryer thermal efficiency of dryer with porous burner is higher than without porous burner at all of drying conditions. At porosity equals 0.37, 70 °C drying temperature and 1.5 m/s drying air velocity the dryer thermal efficiency is 60.76% that is

highest which is 23.91% increased when comparing to dryer thermal efficiency of dryer without porous burner at the same drying conditions, details are shown in figure 4.

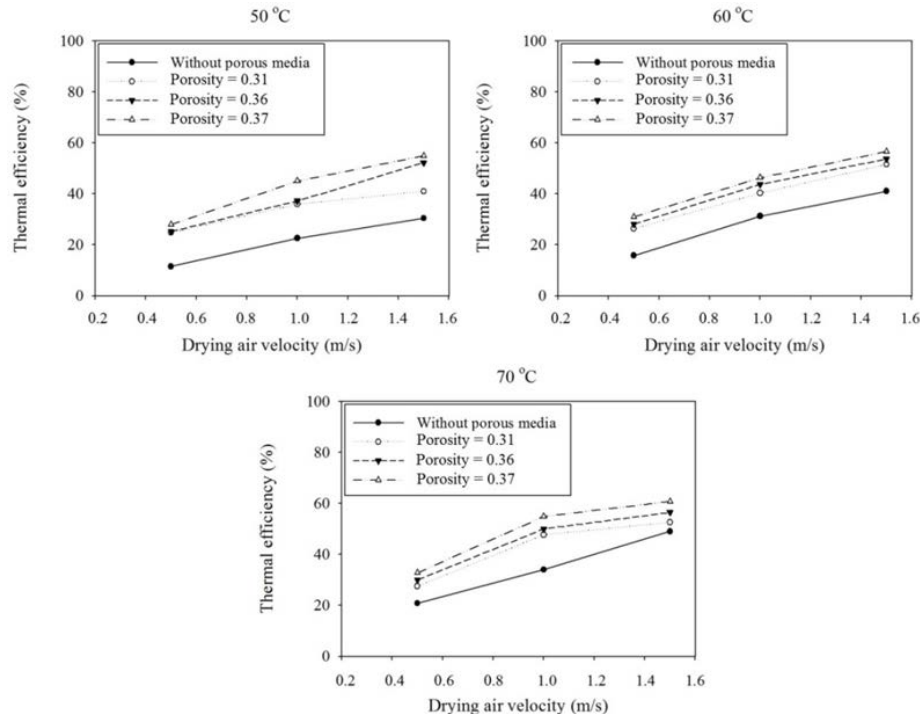


Figure 4. Dryer thermal efficiency at different drying temperatures

4. Conclusions

The results from the study on the effect of packed bed porous burner on drying kinetics of Nile tilapia drying using pebbles packed bed porous burner as heat source can be concluded as followed.

The application of packed bed porous burner as heat source on hot air dryer can improve the drying rate of drying. The drying specific energy consumption in case of using porous burner as heat source is lower than without using porous burner at all of drying conditions and the dryer thermal efficiency is improved when using porous burner as heat source which highest drying rate is 220.43 g (water evap.)/hr., lowest drying specific energy consumption is 141.35 MJ/kg and the highest dryer thermal efficiency is 60.76% that is 23.91% increased at drying conditions are porous burner porosity 0.37, 70 °C drying temperature and 1.5 m/s drying air velocity

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