Effect of temperature by infrared thermal treatment on the rice bran qualities

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Abstract. The objective of this research was to study the effect of the infrared heat treatment on the qualities of the rice bran. The rice bran with the initial moisture content of 12.9 % water g⁻¹ dry matter was heated under the high temperature generated from infrared radiation at 60, 80, 100, 120 and 140°C respectively and the target moisture content of rice bran after being heated was 5 % water g⁻¹ dry matter. The optimum condition of thermal treatment of rice bran respect to the quality of extracted oil and the energy consumption was determined. The results showed that the rice bran oil was extracted more at 140°C heat treatment than other temperature; additionally, the free fatty acid in extracted rice bran oil was smallest in amount. Nevertheless, the concentration of gamma oryzanol was not different throughout the experiment. The mathematical model of drying kinetics was examined, and the appropriate model was the Logarithmic model which the R² of 0.9955 – 0.9994 and the RMSE of 1.5×10⁻⁵–6.3×10⁻⁵.

1. Introduction
Rice bran is the residual product of rice milling process which is generated from scrubbing the bran layer the outer layer of brown rice, producing the white rice or milled rice during the polishing process. Rice bran riches with nutrients and important substance, such as, fiber, vitamin E, gamma oryzanol and so on. These nourishments are not only natural supplements for maintaining human health, but also the anti-oxidant substance which decreasing the probability of generating the chronic disease, such as cancer, high cholesterol, coronary artery disease and so on [1]. With full of nutritive value, rice bran, therefore, is consumed in various forms, especially the rice bran oil (RBO).

RBO is segmented as the good quality oil as it contains high amount of unsaturated fatty acids and gamma oryzanol comparing with other vegetable oil [2]. It is given via the extraction of rice bran. There are several techniques applying for extracting of the RBO, but solvent extraction using hexane is the most commonly used as the conventional method for commercial extraction. The experiment of using RBO with the laboratory mice found that the level of cholesterol in laboratory mice was decreased [3]. Furthermore, following experiment of also found that RBO tends to resist the cancer cell development and to reduce the inflammation of human tissue as well [3].

The majority challenging of RBO production is the quality deterioration of rice bran before the process of extraction. Lipase activity plays the important roles with the rice bran quality deterioration. Lipase activity directs to get rancidity or odorless of rice bran which effect to the RBO quality.
Controlling the lipase activity is possibly slow down the rice bran deterioration. High level of water in rice bran is the main affect of accelerating the lipase activity. Reducing the amount of water (moisture content) of rice bran, then, decreases the lipase activity. However, the common approach to reduce lipase activity is applying high heat. Applying heat with steaming or hot air or roasting were commonly used for decreasing lipase activity. Infrared radiation heating is one of the heating sources that are easy to manage, save energy and provide high efficiency [4]. Infrared heating was combined with hot at 120°C to the palm fruits and the result found that the lipase activity was inhibited which leaded to reducing the content free fatty acid in palm oil [5]. Therefore, applying infrared radiation heating treatment for controlling lipase activity to achieve the better RBO quality was possibly to examine.

Thus, the objective of this research was to study the effect of the infrared heat treatment on the qualities of the rice bran.

2. Materials and methods

2.1. Material preparation

Rice bran samples from rice mills were collected and used as the raw materials throughout the experiment. Rice bran samples were dried at the temperature of 105°C for 24 hrs by hot air oven (Memmert 600, Germany) following [6]. Rice bran samples were weighted before and after drying for calculating the initial moisture content.

2.2. Infrared heating

In this research, using heating chamber with infrared radiation rod inside on top of drying tray. The ventilation fan was used for carrying the evaporated water from the material during heating process. The tray was under the infrared heater and connected with the digital scale for recording the changing weight during the heating process as shown in figure 1. The temperatures of infrared heater were set at 60, 80, 100, 120 and 140°C. The acquiring temperature generated from infrared heater was kept stable by controlling the input electrical current. Then the moisture ratio (MR) was calculated via equation (1).

\[
MR = \frac{M_t - M_e}{M_i - M_e}
\]

Where \(M_t\) is the moisture content at time, \(M_i\) is the initial moisture content, \(M_e\) is the equilibrium moisture content (\(M_e = 0\)) [7].

The heat treatment process of rice bran was done when the moisture content was constant. The relationship between moisture ratio and drying time was plotted in graph as illustrated in figure 2. The kinetics drying model was also examined based on the model of Newton, Page, Henderson and Pabis and Logarithmic, respectively.

![Figure 1. Elements of infrared dryers used throughout the experiment.](image-url)
2.3. Analysis of RBO content
The amount of RBO in the sample was examined by extracting the rice bran with solvent extraction methods. (hexane was used as the solvent). The solution (RBO with hexane) were refined in Soxhlet with 90°C for 4 h by putting rice bran in thimble with the 100 ml of hexane [8]. Obtaining RBO from the extraction was weighted and calculated the amount of RBO from the equation (2).

\[
\text{RBO content} = \frac{\text{Weight of extracted RBO (g)}}{\text{Weight of rice bran (g}_{\text{dry matter}})}
\]  

(2)

2.4. Free fatty acid analysis
Determination of acidity can be done by titration analysis of RBO with KOH solution and using phenolphthalein solution as its indicator. During titration, the pH of titrate RBO was increased until stable which can be observe by changing of solution color from yellow to pink. Amount of KOH used in titration was records for calculating the free fatty acid via equation (3) [9].

\[
\text{Acid value} = \frac{5.61 \times \text{normality of KOH} \times \text{volume of KOH (ml)}}{\text{Weight of extracted RBO (g)}}
\]  

(3)

2.5. Analysis of gamma oryzanol content
The extracted RBO was diluted with hexane obtaining the appropriate concentration for measuring gamma oryzanol content (GABA) via the absorbance given by UV-spectrophotometer (Thermos Scientific GENESYS 10S UV-VIS, USA) at wavelength of 314nm [10]. The amount of gamma oryzanol was calculated in the unit of percentage of substance per RBO weight.

2.6. Analysis of energy transfer rates
Energy consumption for each heat treatment (60, 80, 100, 120 and 140°C) was measured individually throughout its experiment by using electric current meter (FLUKE 322 clamp meter). The energy consumption in unit of kW·hr·kg⁻¹_{dry matter} was calculated.

3. Results and discussion
Experimental finding for this experiment was aimed to focus on the suitable conditions for heating rice bran by infrared radiation heating method which giving high amount of extracted RBO, less amount of free fatty acid, high value of gamma oryzanol and low energy consumption. The results of this experiment were described as follow.

3.1. Effect of temperature on rice bran drying kinetics
Studying the drying time of infrared heating at the temperatures of 60, 80, 100, 120 and 140°C to reach the final moisture content of 5.0 %_{water}g⁻¹_{dry matter} were at 45.65, 21.68, 12.35, 9.60 and 7.58 minutes respectively. The applying higher temperature reduced more drying time; for instant, at 140°C used shorter drying time (shorter than 15 minutes) about 11.64 times faster than at 60°C, that made the graph was more steep than others as shown in figure 2 and was confirmed with the research of [11].

The drying kinetic models were also examined using the models of Newton, Page, Henderson and Pabis and Logarithmic, respectively. The study found that the model of Logarithmic was suitable model for explaining the data set as it gave the highest value of the coefficient of determination, R², which was between 0.9955-0.9994 and the values of root mean square error, RMSE, was between 1.48×10⁻⁵-6.3×10⁻⁵.
Table 1. statistical data of predictive drying kinetic models

| Model               | Equation          | $R^2$          | RMSE                  |
|---------------------|-------------------|----------------|-----------------------|
| Newton              | $MR = \exp(-kt)$  | 0.8269-0.9947  | $2.1 \times 10^{-4}$-$6.0 \times 10^{-3}$ |
| Page                | $MR = \exp(-kt_n)$| 0.9501-0.9973  | $1.0 \times 10^{-4}$-$9.0 \times 10^{-4}$ |
| Henderson and Pabis | $MR = a*\exp(-kt)$| 0.8379-0.9948  | $2.0 \times 10^{-4}$-$4.4 \times 10^{-3}$ |
| Logarithmic         | $MR = a*\exp(-kt) + c$ | 0.9955-0.9994  | $1.5 \times 10^{-5}$-$6.3 \times 10^{-5}$ |

3.2. Effect of infrared heating on extracted RBO content.

The RBO extracted from rice bran samples were treated from difference of Infrared heating temperatures and from difference of drying time (longer drying time gave less moisture content). The results showed that various of temperature during heating rice bran with infrared radiation affected the amount of receiving RBO from extraction process as the results shown in figure 3. With the higher temperature and the lower moisture content, the obtaining percentage of RBO content increased. Therefore, treating sample with the temperature of 140°C gave 8.29% of RBO content than the initial condition (no heat treatment). From this experiment, it could be assumed that heating with infrared radiation changed some physical and/or chemical properties of rice bran which the rice bran could release the oil easily.

Similarly, the study of amount of extracted curcumin from curcuma longa was increased when it was heated by infrared radiation [12].

3.3. Effect of infrared heating on obtaining free fatty acid values in RBO

RBO samples were tested to quantify the percentage of free fatty acid and the results illustrated in figure 4. It showed that decreasing the moisture content (effected from increasing the drying time) decreased the percentage of free fatty acid in RBO samples which were treated at the varied temperatures. The higher temperature applied to the rice bran, the lower percentage of free fatty acid. Furthermore, the ratio of decreasing of the percentage of free fatty acid at higher treated temperature was increased which these results confirmed from previous studies [13, 14]. The heated rice bran at 140°C and at the final moisture content (5 %g water \textsuperscript{1}g\textsuperscript{-1} dry matter) gave the lowest percentage of free fatty acid which was 14.3% lower than the initial condition of rice bran (no heat treatment) which the this showed in Figure 4.

3.4. Effect of infrared heating on obtaining gamma oryzanol content in RBO

Gamma oryzanol content in RBO was quantified consecutively from the RBO samples which were heated at different temperature until their moisture contents approached 5 %g water \textsuperscript{1}g\textsuperscript{-1} dry matter

Statistically, the results were not significantly different($p<0.05$) as their values of gamma oryzanol obtained results. They showed that the data were distributed and vauged to be explained as well as to be set the relationship with the heating temperature and with the moisture content. These behaviour of obtained gamma oryzanol content were reported from another research [15].
3.5. Energy consumption rate

From understanding, the results of energy usage of heating at lower temperatures were lower energy consumption.

Nevertheless, the relative using energy on the unit of kW per weight of dry matter were contrasted as shown in table 2. The results showed that using lower temperature required longer time of drying; therefore, the energy consumption was not lower as expected. The temperature of 60°C, then, was required energy of 3.39 kW·hr·kg\(^{-1}\)\(_{dry\ matter}\) and the temperature of 140°C, then, was 1.27 kW·hr·kg\(^{-1}\)\(_{dry\ matter}\).
Table 2. Energy consumption of thermal treatment of rice barn levels for 5% $g_{\text{water}}$ g$^{-1}$ dry matter.

| Temperature (ºC) | Time of drying (min) | Energy (kW·hr·kg$^{-1}$ dry matter) |
|------------------|----------------------|-------------------------------------|
| 60               | 45.65                | 3.39                                |
| 80               | 21.68                | 2.23                                |
| 100              | 12.35                | 1.54                                |
| 120              | 9.60                 | 1.46                                |
| 140              | 7.58                 | 1.27                                |

4. Conclusions
The suitable mathematical model to explain the drying kinetic model was the Logarithmic model which gave the coefficient of determination, of 0.9955-0.9994 and the values of root mean square error of $1.48 \times 10^{-5}$ - $6.3 \times 10^{-5}$. Heating rice bran at 140°C with infrared radiation heating until the moisture content reached 5% $g_{\text{water}}$ g$^{-1}$ dry matter gave shorter drying time (shorter than 15 minutes). Additionally, at this temperature, the amount of extracted RBO was 8.29% higher than non heated condition and the percentage of free fatty acid in RBO was 14.3% lower than non heated condition, while, the percentage of grammar oryzanol from RBO was not statically difference from non heated condition. Furthermore, the energy consumption of heating rice bran at 140°C was 1.27 kW·hr·kg$^{-1}$ dry matter.

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