Drying Characteristic of Emulsified Gelatin Film

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Abstract*— Nowadays, the application of edible film is being increased. The biodegradable film is introduced as an alternative way to minimize the uses of the synthetic polymer because it can be eaten and degrade easily. The purpose of this study is to determine drying characteristic of emulsified edible film at different temperatures and to determine the optimum condition for drying. The method used to prepare the film is by casting method. The material or chemicals used to prepare the film are plasticizer (glycerol), protein (gelatin), distilled water and lipids (vegetable oil) which is sunflower oil. The film was dried at different temperature which were 45ºC, 50ºC, 55ºC and 60ºC. The drying of films also an effective ways of prolonging the shelf life by reducing the moisture content of the material that can reduced the microbial growth and enzymatic reaction. It also involved the heat transfer from heating the medium to the product surface. The drying data were fitted to the Newton model, Page model and Henderson and Pabis model. Then, the values of coefficient of determination (R^2), mean bias error (MBE) and root mean square error (RMSE) were used to determine the goodness or the quality of the data fitted. Therefore, the Page model showed a better fit to emulsified gelatin film compared to Newton and Page model with appropriate equation ln(-ln MR) = 2.1263 lnt - 4.8658. The optimum temperature of this research was 60ºC.

***Keywords*— Emulsified gelatin film, sunflower oil, oven, drying, moisture content, drying kinetics, drying modeling.**

1. INTRODUCTION

Drying process is the main role in preservation of agricultural products (Saeed et al., 2008). According to Ibrahim et al. (2009), the most frequently used dehydration operation in food and chemical industry is air drying. The awareness among customer regarding to the healthy lifestyle is increase. The research about the technique of prolonging shelf life of food product without necessity of preservatives needs to be improved. Therefore, the changing of mechanical and barrier properties depends on the main component in bio-polymer matrix that caused the increasing interest in composite structures, which enable to explore the complementary advantages of each component and to minimize the disadvantages.

Edible film is a primary packaging made from edible components and a thin layer that can directly coated as a food wrap without changing the original ingredients or processing methods. It is used to improve the gas and moisture barrier, mechanical properties, microbial protection and prolong the shelf life of various product.

The emulsified edible film is the combination of the emulsifier in the preparation of edible film. The emulsifier is the substance that stabilizes an emulsion by increasing the kinetic stability and known as surfactants. Emulsifier also contains of a water-loving hydrophilic head and oil-loving hydrophobic tail which are the hydrophilic head is more towards aqueous phase and hydrophobic tail to the oil phase. In emulsion, the position of emulsifier itself at oil/water or water/oil interface reduce the surface tension and has a stabilizing effect. Emulsion is a mixture of two or more liquids that are immiscible or unmixed.

Some types of emulsifier that mostly used are sunflower oil, olive oil, soybean oil, palm oil and etc. In this research, sunflower oil has been chosen. The application of lipid film can be seen in the packaging of fruits and vegetables where it can reduce the moisture losses. According to Hambleton et al. (2011) the addition of lipid can give a good effect on the moisture barrier properties.

Therefore, to find the effective ways of extending the shelf life drying method is the best options. It can reduce the moisture content of the material and also can decrease the microbial growth and enzymatic reaction. The film need to be dry at temperature of 45ºC, 50ºC, 55ºC and 60ºC. When the temperature increased, the moisture content in the film was decreased. It involved the heat transfer from heating medium to the product surface. While, moisture ratio is essential in determining the drying curve model. Drying kinetics is generally evaluated experimentally by measuring the weight of a drying material a function of time, while for drying curve it may be represented in three different type of plots that are moisture content versus time, drying rate versus time, and drying rate versus moisture content.

The objective of this research are to determine the drying characteristic of emulsified edible film at different temperature and to determine the optimum condition for drying.

II. METHODOLOGY

A) Materials

Gelatin, distilled water, glycerol (83% purity) and sunflower oil (emulsifier) purchased from Shah Alam, Selangor.

B) *Film preparation*

5.0 gram gelatin was dissolved with 75 mL distilled water at 500 rpm and 90ºC by using magnetic stirrer for 20 minutes. Then, 10 mL of glycerol was added and continuously mixed for 5 minutes. Next, 0.5 mL sunflower oil was added and mixed for another 25 minutes. The sample was poured into the petri dish and dried at 45ºC, 50ºC, 55ºC and 60ºC in an oven. The sample was weighted every 1 hour until constant weight was achieved.

Data obtained were used to analyze the drying kinetic of the film formation. Moisture content of wet basis was calculated by equation:

$$M = \left(\frac{w-d}{w}\right)100\% \quad (1)$$

According to Dissa et al. (2009), the moisture content for dry basis is,

$$X = \left(\frac{w-d}{d}\right)100\% \quad (2)$$

Where,

w = mass of wet materials, g

d = mass of dry materials, g

C) *Drying Model*

Drying model is used to determine the drying kinetics of emulsified gelatin film. Table 1 shows the model that has been used to fit with the drying data.

Table 1. Several of drying models (Ibrahim et al. 2009; C.L. Hii *et al.* 2008)

No.	Model name	Model
1	Newton	MR= exp (-kt)
2	Page	MR= exp (-kt^n)
3	Henderson and Pabis	MR= a exp (-kt)

Referring to Ibrahim et al. (2009), the moisture ratio (MR) can be calculated as below,

$$MR = \frac{M - M_e}{M_o - M_e} \quad (3)$$

Where,

Me = Equilibrium moisture content

Mo = Initial moisture content

Since the value of Me was relatively small when compared with M and Mo, equation 3 can be simplified to M = M/Mo.

Therefore, to determine the quality of the drying model, the values of the coefficient of determination (R^2), mean bias error (MBE), and root mean square error (RMSE) is used. The highest values of R^2, and the lowest values of MBE and RMSE are selected to describe the best drying models and also determined the optimum condition of the drying emulsified gelatin film (Ibrahim et al. 2009).

The equation to calculate MBE and RMSE are as below:

Mean bias error, MBE

$$MBE = \frac{1}{N}\sum_{i=1}^{N}\left(MR_{pre,i} - MR_{\exp,i}\right)^2 \quad (4)$$

Root mean square error, RMSE

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}\left(MR_{pre,i} - MR_{\exp,i}\right)^2\right]^{\frac{1}{2}} \quad (5)$$

Where,

N = no. of observation

$MR_{\exp,i}$ = ith experiment data

$MR_{pre,i}$ = ith predicted data

III. RESULTS AND DISCUSSION

The result of the research of kinetic curves of drying emulsified film at 45ºC, 55ºC, 55ºC and 60ºC are shown in Fig. 1 to Fig. 14. It consists of three curves which are drying curve, drying rate curve and drying characteristic. For drying curve shows the profile change in moisture content versus drying time, while drying rate curve shows the drying rate profile versus drying time. Drying characteristic curves showed that the drying rate versus moisture content.

Therefore, in Fig. 1 shows a decreasing in moisture content wet basis of drying time for every different temperature. The moisture content was decrease when the drying temperature increased. It is because of the evaporation of water occurred. Fig. 2 show the drying rate profile versus drying time. From these graph, the drying rate was found higher in the high drying temperature. This means that the time required to dry the material to reach the equilibrium moisture content is shorter. The higher drying temperature, the lower the higher rate of evaporation of water from material (Yahya, 2007).

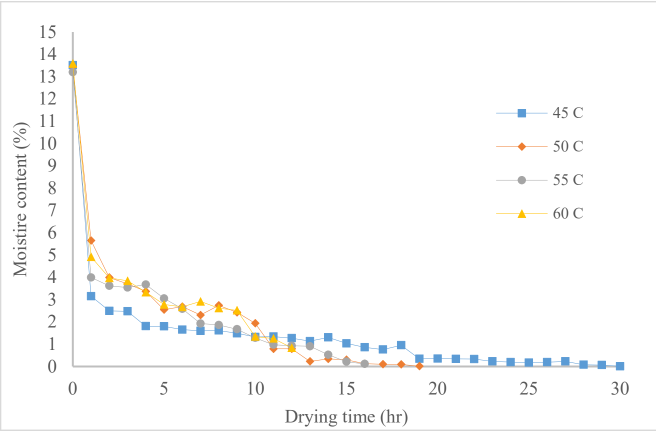

Fig. 1: Moisture content variation with drying time

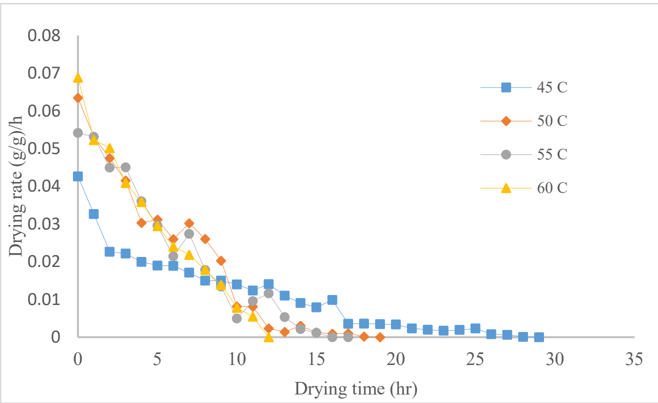

Fig. 2: Drying rate versus with drying time

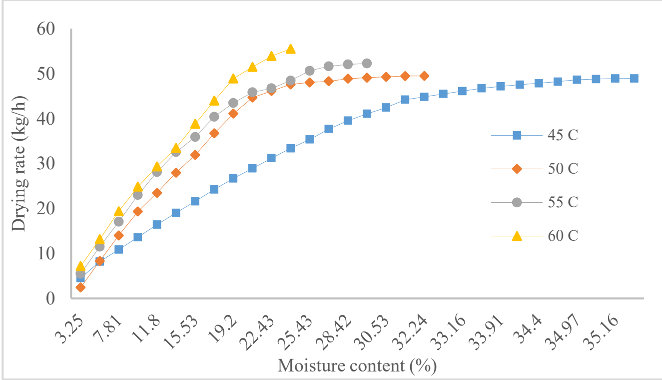

Fig. 3: Drying rate versus moisture content

In Fig. 3 shows that the drying rate was increased when the moisture content increased. It is because of the rate evaporation alters very much as the moisture content increase.

In addition, drying model are fitted with the experimental data using Newton model, Page model and Henderson and Pabis model. Fig. 4 to Fig. 7 shows plot of moisture content versus drying time at 45ºC to 60ºC for Newton model. The equation model can be seen in Table 1.

The equation of Newton model is,

$$MR = \exp(-kt) \quad (6)$$

The relationship of this equation is, MR versus with drying time.

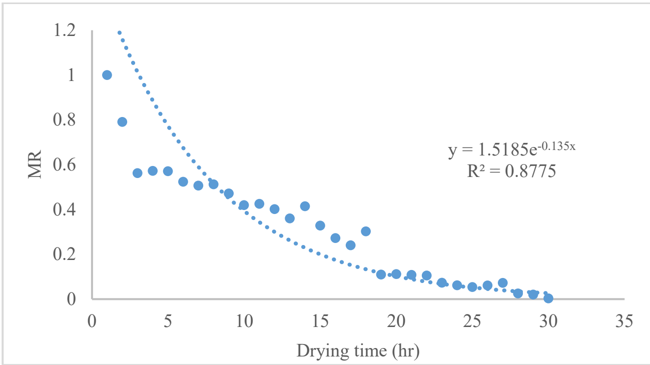

Fig. 4: Plot of MR versus drying time at 45ºC

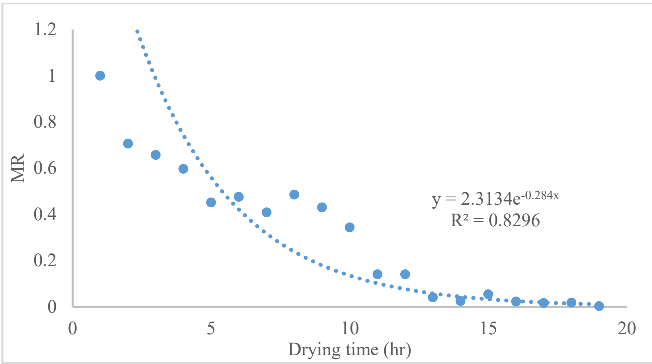

Fig. 5: Plot of MR versus drying time at 50ºC

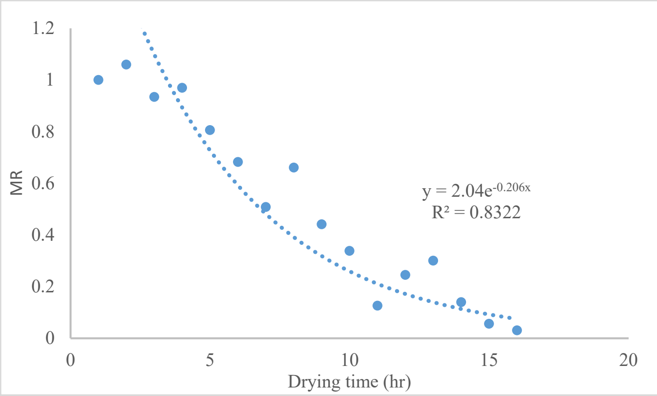

Fig. 6: Plot of MR versus drying time at 55ºC

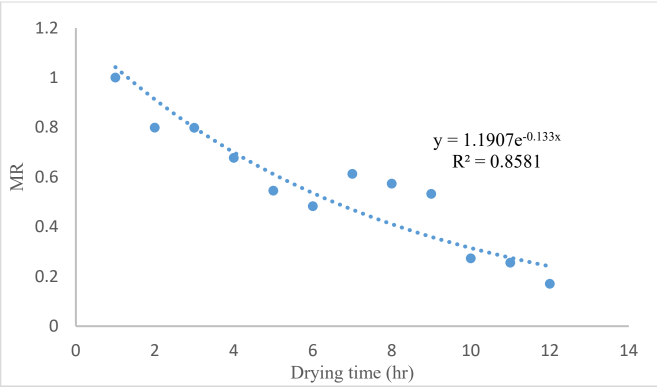

Figure 7. Plot of MR versus drying time at 60ºC

For Page model, the equation is given by,

$$\ln(-\ln MR) = \ln k + n \ln t \quad (7)$$

Equation 6 is the being modified into relationship of ln(-ln MR) versus ln t, is the curve of logarithmic equation, as shown in Fig. 8 to Fig. 11.

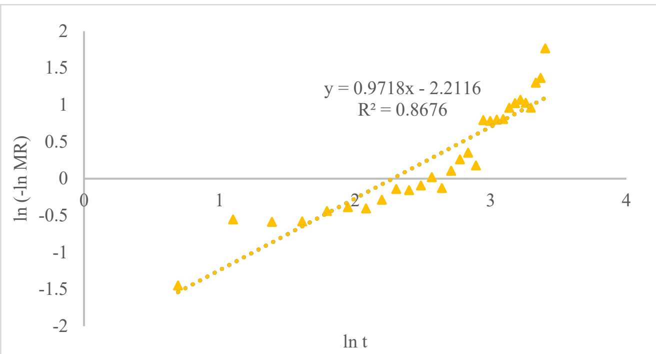

Fig. 8: Plot of ln (-ln MR) versus ln t at 45ºC

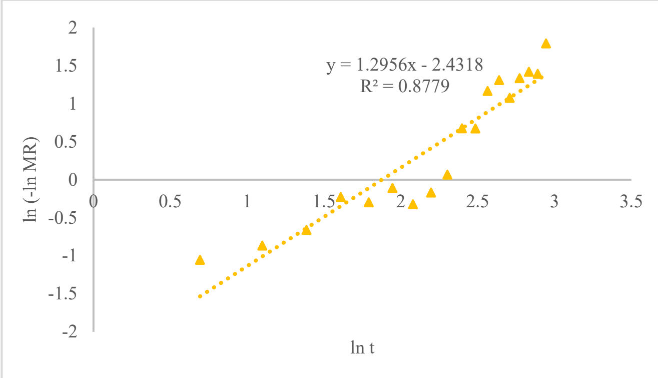

Fig. 9: Plot of ln (-ln MR) versus ln t at 50ºC

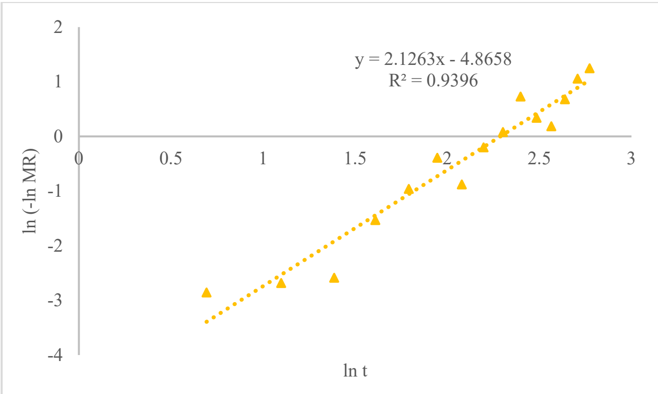

Fig. 10: Plot of ln (-ln MR) versus ln t at 55ºC

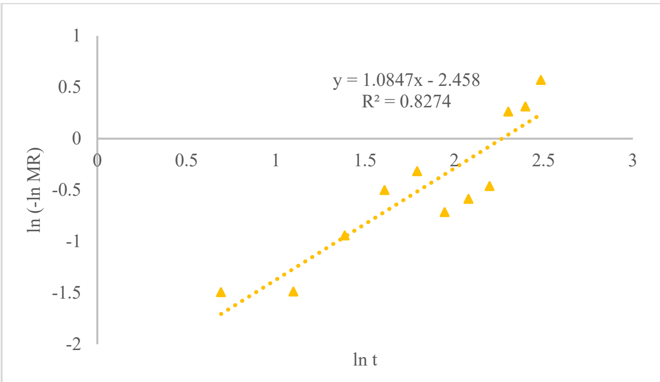

Fig. 11: Plot of ln (-ln MR) versus ln t at 60ºC

For Henderson and Pabis model, the equation give,

$$\ln MR = -kt + \ln a \quad (8)$$

In this equation, a plot of ln MR versus drying time gives a straight line with intercept = ln a and slope = k. As shown in Fig. 12 to Fig 15, the graph have been plotted.

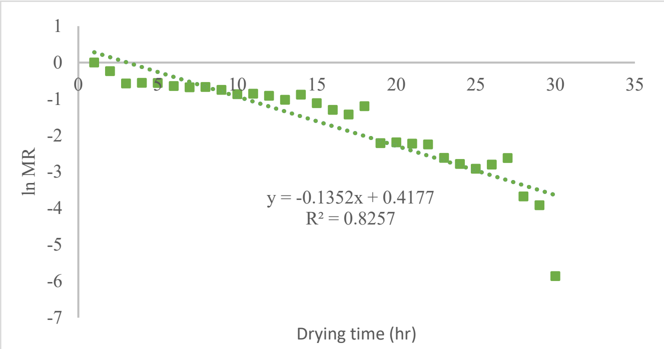

Fig. 12: Plot of ln MR versus t at 45ºC

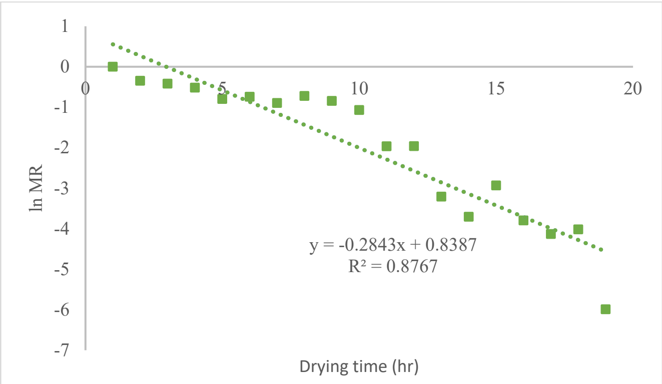

Fig. 13: Plot of ln MR versus t at 50ºC

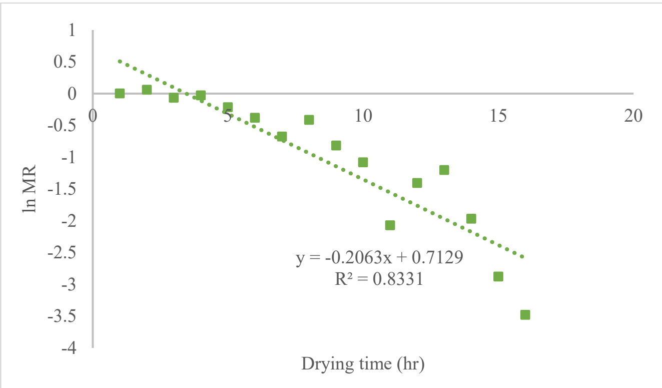

Fig. 14: Plot of ln MR versus t at 55ºC

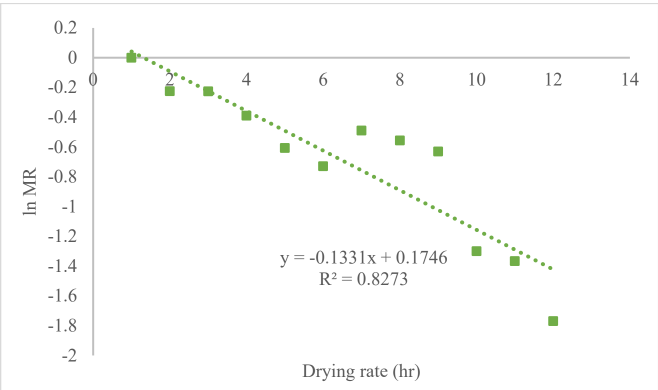

Figure 15. Plot of ln MR versus t at 60ºC

Therefore, the result of the modeling drying for the Newton model, Page model and Henderson & Pabis model were tabulated as below,

Table 2. Constant value fitting of Newton model

T(ºC)	k	R^2	MBE	RMSE
45	0.135	0.8257	0.0382	0.1956
50	0.284	0.8767	0.0343	0.1853
55	0.206	0.8331	0.0046	0.0685
60	0.133	0.8273	0.0406	0.2015
Ave.		0.8407	0.0294	0.1627

Table 3. Constant value fitting of Page model

T (ºC)	k	n	R^2	MBE	RMSE
45	0.1095	0.9718	0.8676	0.0071	0.0846
50	0.0878	1.2956	0.8779	0.0001	0.0083
55	0.0077	2.1263	0.9396	0.0026	0.0515
60	0.0856	1.0847	0.8274	0.0005	0.0235
Ave.			0.8781	0.0026	0.0419

Table 4. Constant value fitting of Henderson and Pabis model

T(ºC)	k	a	R2	MBE	RMSE
45	0.1352	1.5185	0.8257	0.0276	0.1956
50	0.2843	2.3134	0.8767	0.0004	0.0197
55	0.2063	2.0398	0.8331	0.0023	0.0489
60	0.1331	1.1908	0.8273	0.0001	0.0010
Ave.			0.8407	0.0076	0.0785

Based on the results in Table 2 to Table 4, it shows that the Page model was the best result that have the highest value of R^2, and the lowest value of MBE and RMSE compared to Newton model and Henderson and Pabis model. Therefore, the suitable drying model of emulsified gelatin film was Page model with appropriate equation $\ln(-\ln MR)=2.1263 \ln t - 4.8658$. Because of the highest R^2 and the lowest MBE and RMSE which are 0.9396, 0.0026 and 0.0515 in that model. The optimum temperature that more suitable in the gelatin film is 60ºC

IV. CONCLUSION

The emulsified gelatin film was dried at varying temperature of 45ºC, 50ºC, 55ºC and 60ºC until the weight of the film was constant. The emulsified gelatin film was prepared by using casting method. The materials that used in preparation of film were gelatin, glycerol, distilled water and sunflower oil. Sunflower oil acts as a lipid and emulsifier that required to mix with the other components, then from the homogenization technique, it applied and need to dry in different temperature. From that, the drying characteristic was investigated.

The result shows that when the drying temperature was increasing, the time for drying was decreasing as shown in Fig 1. In Fig. 2, it showed graph of drying rate versus drying time. When the drying rate increase, the drying time was decreased. At the high temperature, the rate of evaporation was higher. In addition, in Fig. 3 it shows the drying rate curves versus with moisture content. At constant exchange rates, free moisture on the surface and continuous evaporation rate of change very little as to reduce the moisture content. During this period, the drying rate is high, and the intake air temperature is higher than in the subsequent drying stage can be used without the detrimental effects of the product. While for the decreasing of drying rate, the transition of moisture content at which the departure from constant rate drying is noticed as termed of the critical moisture content. At this point shows that insufficient water on the surface that required to maintain a continuous film of water. The higher the drying temperature the moisture content will be rapidly reduced.

Other than that, analyses were carried out to select the thin layer model that best described the drying kinetics and also optimum condition of the emulsified gelatin film. Therefore, results showed that the best model that able described the drying kinetic of this film was Page model with $R^2 = 0.9396$, MBE = 0.0026 and RMSE = 0.0515 respectively. Then, the best optimum temperature for this film is 60^{o}C.

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