MATHEMATICAL MODELING AND EXPERIMENTAL STUDY ON THIN LAYER HALOGEN DRYER OF STRAWBERRY AND STUDY IT'S EFFECT ON ANTIOXIDANT ACTIVITY

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ABSTRACT

The halogen drying characteristics of strawberry (*Fragaria ananassa Duch*) slices were investigated. Drying experiments were carried out a three different drying temperatures (60, 70 and 80°C). The effect of drying temperature on the drying rate, drying coefficient, efficiency, effective diffusivity of the strawberry and antioxidant activity were evaluated. The best model for describing the halogen drying process was chosen by fitting nine commonly used drying models. The effective moisture diffusivity and activation energy were calculated using an infinite series solution of Fick's diffusion equation. The results showed that increasing drying temperature accelerate the halogen drying process. As well as, increasing of drying rate, drying rate constant, drying coefficient and effective diffusivity. All drying experiments had only falling rate period. The goodness of fit tests indicated that the proposed modified page model gave the best fit to experimental results at 70 and 80°C, but page model gave the best fit to experiment results at temperature of 60°C. The effective diffusivity varied from 7.53×10^{-9} -2.52×10^{-8} m^2/sec. Effective diffusivity was satisfactorily by an Arrhenius type relationship with activation energy with in 60-80°C temperature range. The ability of reducing power of the ferrous ion can taken as an indicator for the ability or antioxidant power for strawberry extracted.

Keywords: Strawberry, Dehydration, Halogen Dryer

1. INTRODUCTION

Strawberries are popular fruits grown in Iraq and many other countries. Strawberries could be consumed fresh or in many others forms, such as juice, concentrate jam, jelly, dried rehydrated with yogurt, bakery products, alcoholic beverage and marmalades (Pallauf *et al*., 2008). Strawberries have been used in the Spain and Morocco as a traditional medicine (Tahraoui *et al*., 2007). Natural sun drying is the most common method used to preserve agriculture products in most tropical and sub tropical countries. But natural sun drying isn't possible as a drying method for the Strawberries, because this fruit appears in clusters and ripen in autumn and winter months. In addition hard being unprotected from rain, wind carry dirt, dust, infestation by insects, rodent and other

animal (El-Beltagy *et al*., 2007; Orak *et al*., 2011). On the other hand natural sun drying application is restricted by the long drying time and need to for favorable weather (Arora, 2006).

There are many methods are used for Strawberries drying, such as the vacuum drying may allow to obtain high quality products, microwave and air drying Evans *et al*. (2002); Shishehgarha *et al*. (2002); Taiwo *et al*. (2003); Askari *et al*. (2006) and Muthukumaran *et al*. (2008). As well as freeze drying method is used for drying Strawberries Asami *et al*. (2003). Evans *et al*. (2002) stated that the Strawberries is one of the most delicate and highly perishable fruits due to respiration, weight loss and susceptibility to fungal contaminations. Orak *et al*. (2011) concluded that Strawberries tree fruit is assessable in food industry by drying due to rich

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nutritional components, antioxidant activity and attractive color of the fruit. Strawberries are a good source of antioxidants, which may help reduce the risk of a variety of chronic disease (Marquest *et al.*, 2010). Al-Hilphy *et al.* (2011) found that the moisture content of the carrot, okra, green peppers and cauliflower has decreased with the increase drying time. There also appeared a constant drying rate and falling drying rate for all vegetables. In addition to that was a good rehydration ratio for all dried vegetables by halogen dryer.

The objective of this study was to investigate the halogen dryer characteristics of the sliced Strawberries to evaluate the effect of halogen dryer conditions on the drying process and to choose the most efficient single layer drying model to describe the drying model, also determine the changes in antioxidant activity and rehydration at different temperatures drying.

2. MATERIALS AND METHODS

Fresh strawberry (*Fragaria ananassa Duch*) samples were procured from agriculture college farm, Basrah, Iraq. After through cleaning and washing, the strawberries were sliced into 10 mm thickness using a slicer. Moisture content of samples before drying was determined according to the AOAC (1984) and was performed in triplicate. An experimental carried out using halogen dryer for drying strawberry. A digital halogen convection oven made of HE. House Co. was used for strawberry drying. It consist of a byrex ban, it's capacity 20 l, glass cover provided with halogen lamp as a heat source, it's energy 1300 W and fan, it's velocity 1500 rpm.

The halogen drying of strawberry slice was carried out at temperature levels 60, 70 and 80°C. The strawberry slices were spread in a single layer on sample tray. Drying data were mounted by using three labeled samples, which were individually weighted. The weights of the labeled sample were recorded every 15 min. throughout the drying test and terminated when the degreases in the weight of the samples had almost ceased. The dried samples were used to determine the final moisture content (equilibrium), the equilibrium moisture content was found by standard hot air oven method (AOAC, 1984).

2.1. Mathematical Modeling

Solution of Crank (1975) second law with consider of strawberry a sphere of Radius (R) with initial moisture content (M_o) which is uniformly distributed in the sphere and it dried by a constant air flow, temperature, diffusion coefficient, relative humidity. The properties of sphere are constant (Stanislaw *et al.*, 1998; Dimatteo *et al.*, 2000):

$$\frac{M - M_e}{M_o - M_e} = \frac{6}{\pi^2} \sum_{n=1}^{\infty} \exp\left(\frac{-n^2\pi^2 D_{eff}.t}{R^2}\right) \qquad (1)$$

where, M, M_o, M_e, D_{eff} and t are moisture content, initial moisture content, moisture content in equilibrium with drying air, moisture diffusivity (m^2/sec.) and time (sec.). For long drying times, Equation (1) can be simplified to a straight line equation in the form:

$$\ln\frac{M - M_e}{M_o - M_e} = \ln\frac{6}{\pi^2} - \left(\frac{-n^2\pi^2 D_{eff}.t}{R^2}\right) \qquad (2)$$

The Moisture Ratio (MR) was calculated using the following Equation (2 and 3):

$$MR = \left(\frac{M - M_e}{M_o - M_e}\right) \qquad (3)$$

Diffusivities are typically determined by plotting experimental drying data in terms of ln MR versus drying time (t), because the plot gives a straight line with a slope as follows Equation (4):

$$slop = \frac{\pi^2 D_{eff}}{R^2} \qquad (4)$$

Average effective moisture diffusivity is calculated from the following Equation (5):

$$D_{eff.avarage} = D_o\exp\left(\frac{-E_a}{RT}\right) \qquad (5)$$

where, E_a is the activation energy (kJ/KmoL), D_o is the diffusion coefficient corresponding to infinite temperature (m^2/sec.), T is the absolute drying air temperature (k) and R is the universal gas constant (8.314 J moL^{-1}. K).

The well known thin layer drying models related dimensionless moisture ratio as the dry basis moisture content against drying time. The experimental moisture ratio against drying time was fitted in nine thin layer drying models as shown in **Table 1**.

Table 1. Thin layer drying models based on moisture ratio

Model name	Model	References
Lewis	MR = exp. (-kt)	(Demir $et\ al$., 2007; Akpinar, 2006)
Page	MR = exp. (-kt^n)	(Yaldiz and Ertekin, 2001; Diamente and Munro,1993)
Modified Page	MR = exp. [(-kt)^n]	Demir$et\ al.$(2007)
Henderson and Pabis	MR = a exp. (-kt)	(Henderson and Pabis,1961; Doymaz, 2004)
Logarithmic	MR = exp. (-kt)+c	Akgun and Doymaz (2005)
Two-term model	MR = exp. (-k$_o$t)+b exp. (-k$_1$t)	Madamba and Liboon (2001)
Approximation of diffusion	MR = exp. (-kt)+(1-a)exp. (-kbt)	Yaldiz and Ertekin (2001)
Wang and Singh	MR=1+at+bt^2	(Wang and Singh, 1978; Sacilik $et\ al.$, 2006)
Midilli	MR=a exp.(-k(t)^n	Midilli $et\ al$. (2002)

The coefficient of determination (R^2) was the primary criterion for selecting the best equation to describe the drying curve equation. The best fit of the experimental data was also selected base on various statistical parameters such as the reduced chi-square (x^2) as the mean square of the deviation between the experimental and predicted values for the models and Root Mean Square Error analysis (RMSE). The highest of the value of the R^2 and lowest value of the x^2 and RMSE the better the goodness of the fit. The parameter can be calculated as following Equation (6 to 8):

$$R^2 = \frac{\sum_{i=1}^{n}\left(MR_{pri.} - \overline{MR_{pri.}}\right)^2}{\sum_{i=1}^{n}\left(MR_{exp.} - \overline{MR_{exp.}}\right)^2} \tag{6}$$

$$x^2 = \frac{\sum_{i=1}^{n}\left(MR_{exp.} - MR_{pri.}\right)^2}{N-n} \tag{7}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}\left(MR_{pre.} - MR_{exp.}\right)^2}{N}} \tag{8}$$

where, MR$_{exp.}$Is the experimentally observed moisture ratio.MR$_{pre.}$ Is the predicted moisture ratio, N is the total number of observation and n is the number of constants in the model.

Dehydration (Drying) Coefficient (DC) was calculated from the following Equation (9) (Meda and Ratti, 2005):

$$DC = \frac{W_o - W_{ad}}{W_o - W_d} \tag{9}$$

where, W$_O$, W$_{ad}$ and W$_d$ are the initial weight of the sample, weight after drying and dry mass respectively.

Rehydration ratio (Rr) was calculated according to Rangana (1976) as following Equation (10):

$$Rr = \frac{W_r}{W_{ad}} \tag{10}$$

where, Wr is the dried sample weight after rehydration.

Coefficient of rehydration was determined according to Rangana (1976) using the following Equation (11):

$$RC = \frac{\left(100 - M_{wo}\right)W_r}{\left(W_{ad} - M_{ad}\right)\times 100} \tag{11}$$

where, M$_{wo}$ and M$_{ad}$ are amount of moisture in the sample befor drying and moisture content present in the dried sample taken for rehydration respectively.

Drying Ratio (DR) has been calculated from the following Equation (12):

$$DR = \frac{(100 - M_{ad})}{(100 - M_o)} \tag{12}$$

Moisture content after rehydration (M$_r$) has been calculated from the following Equation (13):

$$M_r = \frac{\left(W_r - W_d\right)}{M_r}\times 100 \tag{13}$$

Water activity (a$_w$) is calculated from Equation (14) (Toledo, 2007):

$$\log\frac{a_w}{x_w} = -k(1 - x_w)^2 \tag{14}$$

where, x_w is the mole fraction of water, k is the constant Equation (15 and 16):

$$a_w = (a_{w1})^0 (a_{w2})^0 \qquad (15)$$

$$x_w = 1 - x_s \qquad (16)$$

where, x_s is the mole fraction of solds.

Drying rate during drying experiments was calculated using the following Equation (17):

$$DR = \frac{M_{t+dt} - M_t}{dt} \qquad (17)$$

where, M_t is moisture content at t and M_{t+dt} is the moisture content at t+dt.

Drying constant has been produced by modeling of page and modified page equations, it represents to k constant.

The efficiency (ε) can be defined by Equation (18):

$$\varepsilon = \frac{T_d - T_{out}}{T_d - T_a} \qquad (18)$$

where, T_d is the inlet (high) air temperature in to the dryer, T_{out} is the out let air temperature from the dryer and T_a is the ambient air temperature.

2.2. Determination of Antioxidative Activity

A 20 mg mL^{-1} of dried strawberry or BHT was dissolved in 4ml of 95% ethanol and mixed with linoleic acid (2.5% in ethanol absolute) (4.1 mL), 0.05M phosphate buffer pH 7.0 (8 mL) and distilled water (3.9 mL) and kept in screw cap containers at 40 C/24 hr in the dark. A 0.1 mL of 30% ammonium thiocyanate, added at precisely 3 minute after the addition of 0.1m of 20 mM ferrous chloride in 3.5% hydrochloric acid to the reaction mixture, the absorbance at 500 nm of the resulting red solution was measured (Yakeda *et al*., 2012). The percent inhibition of linoleic acid peroxidation was calculated as Anti oxidative activity (%inhibition) = (absorbance of the sample)/absorbance of the control)×100.

2.3. Measurement of the Reducing Power

The dried strawberry (10, 20, 30, 40 and 50 mg mL^{-1}) or BHT mixed with an equal volume of 0.2M phosphate buffer (pH 6.0) and 1% potassium ferricyanide. The mixture was incubated at 50°C for 20 min. Then an equal volume of 1% trichloroacetic acid was added to the mixture and centrifuged at 6000 rpm for 10 min. The upper layer of the mixture was mixed with distilled water and 0.1% FeCl3 with a ratio of (1:1:2) and measured the absorbance at 700 nm (Yen and Chen, 1995).

2.4. Ferrous Ion Chelating Effect

Reaction mixtures containing 0.1 mg mL^{-1} of the dried strawberry, 0.2 mL of 0.5mM ferrous 6, 5, 4, 3, 2, 1 different concentrations (chloride and 0.2 mL of 5 mM ferrozine were incubated at 37 Co for 10 min. A 1.5 mL of deionized water was added to the mixture, the absorbance at 562 nm was measured (Gibbons and Gray, 1998).

2.5. Retardation of Corn Oil Auto Oxidation

0.5 g of corn oil was dissolved in 24 mL of chloroform-methanol mixture (1:2) and 1 mL of the dried strawberry was added in various concentrations (2, 4, 6, 8 and 10 mg mL^{-1}). The dried strawberry was incubated at 45°C and peroxide value was determined periodically (Shantha and Decker, 1994).

Statistical analysis: Data were analyzed by ANOVA within a completely randomized design. LSD tests were used for mean discrimination at 0.05 level of probability, using the statistical SPSS software (SPSS, 2009).

3. RESULTS AND DISCUSSION

Figure 1 Illustrate the drying curve for three different drying temperature of strawberry (60, 70 and 80°C). The required drying times to reach mean final moisture content of 0.103, 0.076 and 0.023 kg/kg.db. for 60, 70 and 80°C were 75, 75 and 60 min. respectively. The temperature 80°C required shorter drying time when compared to 60°C. In other words drying time was reduced to about 20% for 80°C when compared with 60°C. The drying time reduced significantly (p<0.05) with increasing drying temperature, because the resistance to moisture movement is relatively higher in reduced temperature than in the higher ones. This resistance is known to degrease drying rate, which resulted in increased drying time of 60 and 70°C. As expected, increasing the drying temperature degreased the total drying time since heat transfer was increased due to the increasing temperature difference which is the drying potential of the heat transfer (Kaya *et al*., 2007).
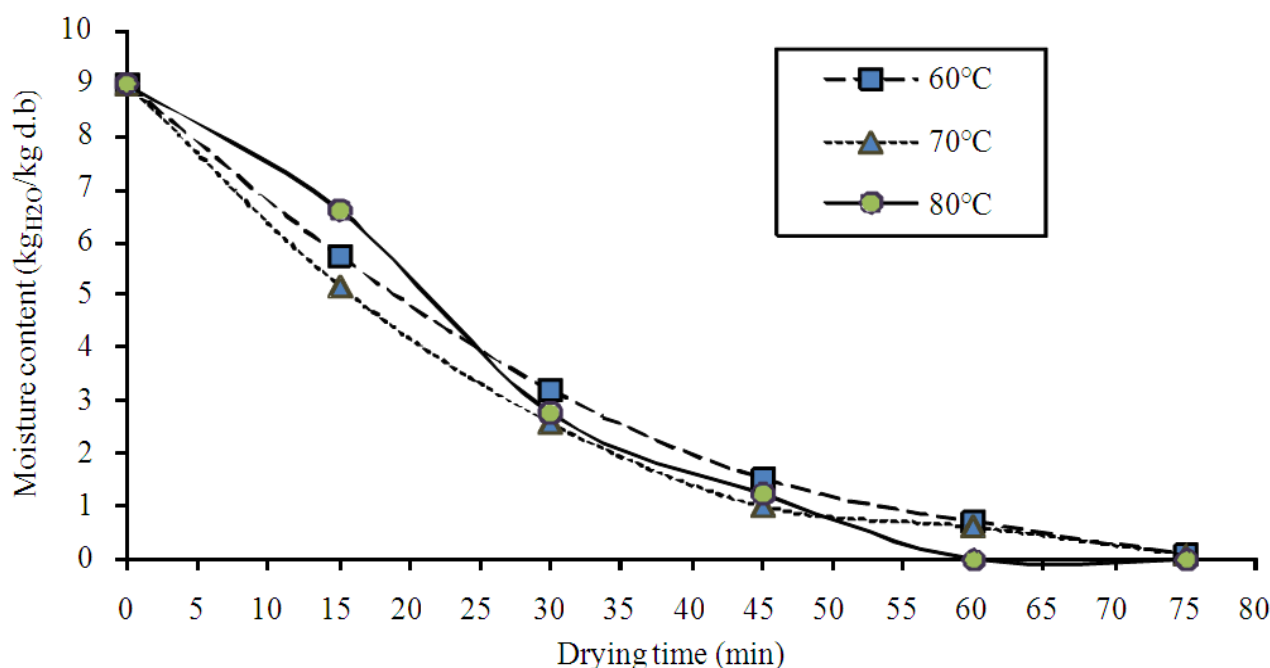
Fig. 1. Drying kinetics of strawberry dried by halogen dryer at different drying temperatures

The moisture content data at the different drying temperatures were converted to the moisture ratio expression and then curve fitting computations with the drying time were done by using nine drying models. The summery of models parameters of nine thin layer drying models that were used for expressing drying characteristics of strawberries sliced dried by halogen dryer at different drying temperatures and the statistical evaluation of models using three different criteria (R^2, x^2 and RMSE) are presented in the **Table 2**. In all cases, the values of R^2 for the models were greater than 0.8956, indicating a good fit. Suitability of the models were best on the of R^2, x^2 and RMSE values (Thorat *et al.*, 2010). Generally R^2, x^2 and RMSE values were changed between 0.8965 and 0.9995, 0.0147 and 6.166, 0.0987 and 2.0275 respectively. It observed that the page model satisfactorily described the drying kinetic of strawberry slices dried under 60°C. For page model, the R^2, x^2 and RMSE values are 0.9994, 0.0180 and 0.1097 respectively. The modified page models was found to be a better model for describing the characteristics of strawberry for both of temperatures 70 and 80°C. As seen in **Fig. 2** the page model showed a good agreement with the experimental results for strawberry slices at temperature 60°C, but modified page model has a good agreement with the

experimental results at temperatures 70 and 80°C. **Figure 3** shows the compares experimental data with these predicted with page model for dried strawberry at temperature of 60°C. It can be seen also, that **Fig. 3** shows the compares experimental data with these predicted with modified page model for dried strawberry at temperatures 70 and 80°C.

Figure 4 shows drying rate versus moisture content curves. A constant rate period was not observed in any of the experiments of this study, since the entire drying process for strawberry occurs in the range of the falling rate period. The results were generally in agreement with Doymaz (2004); Akpinar (2006); Vagenas and Marinos-Kouris (1991) and Thorat *et al.* (2010). In the falling rate period the material surface is on larger saturated with water and drying rate is controlled by diffusion of moisture from the interior of sold to the surface (El-Beltagy *et al.*, 2007).

The value of the drying rate constant (k) were determind by fitting data developed in the experiment to page model and modified page model **Table 1 and 2**. The k value for different temperatures, the faster the drying rate is the greater the drying constant, k will be. From **Fig. 5**, it's apparent that thin layer drying rate increased with increasing drying temperature also, the results showed that the difference between drying coefficient at 70 and 80°C is not significant.

Table 2. Thin-layer models applied to the drying curves at different drying temperatures

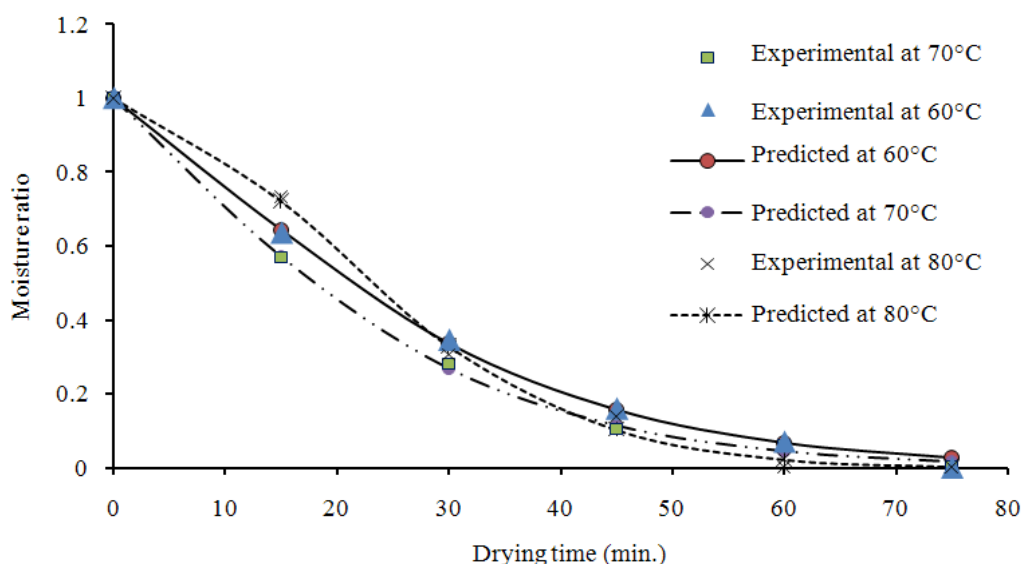| Model	Temperature	Constants	RMSE	R^2	X^2
Lewis					
	60	k = 0.0372	0.3679	0.9955	0.1624
	70	k = 0.0433	0.2670	0.9975	0.0855
	80	k = 0.0378	0.7663	0.9817	0.7047
Page					
	60	k = 0.0127, n = 1.3087	0.1097	0.9994	0.0180
	70	k = 0.0198, n = 1.2320	0.0989	0.9995	0.0147
	80	k = 0.0027, n = 1.7650	0.1797	0.9986	0.0484
Modified page					
	60	n = 0.9209, k = 0.1137	2.0275	0.8956	6.1661
	70	n = 1.2320, k = 0.0415	0.0987	0.9995	0.0147
	80	n = 1.7650, K = 0.0354	0.1797	0.9986	0.0484
Handerson and pabis	60	a = 1.0266, k = 0.0381	0.3531	0.9948	0.1870
	70	a = 1.0165, k = 0.0439	0.2594	0.9972	0.1009
	80	a = 1.0577, k = 0.0396	0.7318	0.9797	0.8034
Logarithmic					
	60	a = 1.1622, k = 0.0277, c = -0.1541	0.1213	0.9992	0.0294
	70	a = 1.0801, k = 0.0368, c = -0.0738	0.1414	0.9990	0.0400
	80	a = 1.2787, k = 0.0253, c = -0.2431	0.5013	0.9891	0.5026
Two -term model	60	a = 0.0141, k0 = 0.0381, b = 1.0125, k1 = 0.0381	0.3531	0.9948	0.3740
	70	a = 0.0139, k0 = 0.0439, b = 1.0026, k1 = 0.0439	0.2594	0.9972	0.2018
	80	a = 0.0139, k0 = 0.0396, b = 1.0438, k1 = 0.0396	0.7318	0.9797	1.6067
Approximation of diffusion	60	a = 5.9439, k = 0.0635, b = 1.1519	0.1220	0.9993	0.0298
	70	a = 7.7221, k = 0.0704, b = 1.0953	0.1007	0.9995	0.0203
	80	a = 7.7221, k = 0.0704, b = 1.0953	0.6372	0.9866	0.8120
Wang and Singh	60	a = -0.0264, b = 0.0002	0.1419	0.9991	0.0302
	70	a = -0.0298, b = 0.0002	0.2714	0.9970	0.1105
	80	a = -0.0274, b = 0.0002	0.4153	0.9937	0.2588
Midilli	60	a = 0.9978, k = 0.0125, n = 1.3119, b = 0	0.1094	0.9995	0.0359
	70	a = 0.9992, k = 0.0198, n = 1.2329, b = 0	0.0988	0.9995	0.0293
	80	a = 1.0034, k = 0.0028, n = 1.7571, b = 0	0.1793	0.9986	0.0964

Fig. 2. Page model to the drying strawberry by halogen dryer at temperature of 60°C and modified page model to the drying data at 70 and 80°C
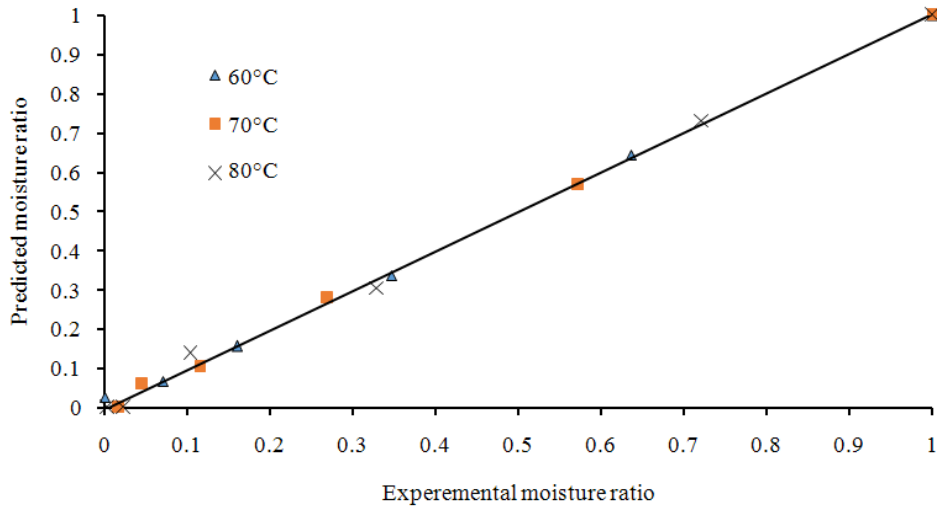
Fig. 3. Experimental and predicted dryng curves for strawberry slices by page model at 60°C and modified page model at 70 and 80°C
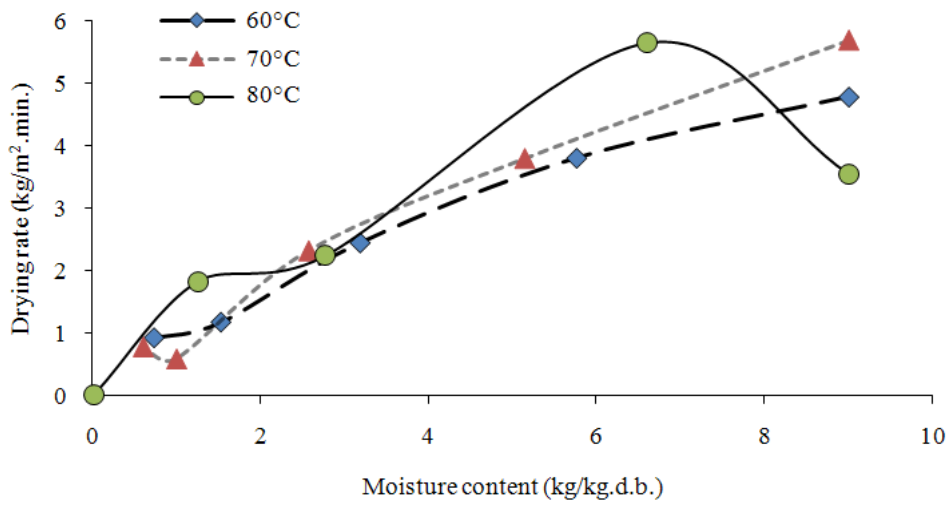

Fig. 4. Variation in drying rate with miosture content of strawberries at different temperaturs
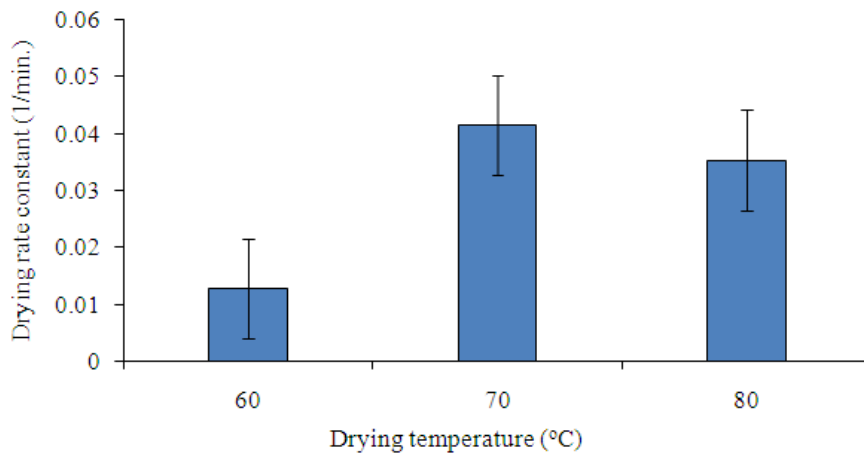

Fig. 5. Drying rate constant vs. drying temperature for dried strawberry by halogen dryer

The result for drying coefficient vs. drying temperature as shown in **Fig. 6**. Drying coefficient was increased significantly ($p<0.05$) with increasing drying temperature. This due to increasing of the quantities of water eliminated by halogen dryer at increasing temperature to the initial as shown in the Equation (9). It can be seen also, the maximum drying coefficient occurred at temperature 80°C.

Figure 7 Illustrates the effect of drying temperature on the efficiency based heat input and output in drying air using halogen dryer. The effeiency was significantly ($p<0.05$) degreased with increasing drying tempetature. This due to increasing drying temperature and constant the strawberry initial temperature, this led to increasing the difference between them as shown in Equation (18).

On the other hand the results showed in **Fig. 8** that the water activity of the fresh strawberry was found to be 0.993. As after drying, the water activity values reduced to 0.222099, 0.118015 and 0.00152 corresponding to the moisture content 0.102974828, 0.07611035 and 0.023091725 respectively. It's observed that there was no significant difference in the water activity among temperatures 60, 70 and 80°C. Beaudry *et al*. (2004) reported that there was no significant difference in the water activity of the dried cranberries. The water activity is a function of moisture content in food and temperature and water connection in food can be defined by water activity as water activity for free water, loosely bound water, moderately bound water and tightly bound water are 1, >0.2, $0.3< a_w <0.7$, <0.3 respectively (Barbosa-Canovas and Vega-Mercado, 1996).

Figure 9 shows effective diffusivity for dried strawberry at different drying temperature. The average values of effective diffusivities of strawberry slices in the drying process at 60-80°C varied in the range of 7.53×10^{-9}-2.52×10^{-8} m^2/sec. The effective diffusivity increased with increase of drying temperature. The internal mass transfer resistance controls the drying time due to the presence of falling rate drying period (Thorat *et al*., 2010). On the other hand, the variation of $\ln(D)$ with $(1/T)$ is plotted in **Fig. 10**. From which E_a and D_o coefficients are predicted, where the slope of the curve gives the (E_a/R) while the intercept gives D_o value.

One of the most important characteristics of dried product is the capacity of rapid and complete rehydration vs. time at 60, 70 and 80°C is shown in **Fig. 11**. The rehydration test show that the rehydration at 70°C is faster than other temperatures.

This could be due to did not produce a surface casting on the dried strawberry at 70°C the analysis of variance indicated that there was a significant in rehydration ratios between 70 and 60°C but there was no significant between 70 and 80°C. The higher rehydration ratio for dried strawberry at 70°C indicated that the samples retained good texture and absorbed more water when compared to other temperatures dried samples.

Figure 12 Show the evolution of the rehydration coefficient as a function of rehydration time for 60, 70 and 80°C of dried strawberry. A twenty minute were necessary to fully rehydrate of strawberry which dried at 70°C. While for dried strawberry at 60°C, is higher than 30 min. **Fig. 13**. Indicate the moisture content vs. drying time for different drying temperatures. The maximum time required to moisture content (w.b.) reach to 75% is 20 min for dried strawberry at 70 and 80°C. But moisture content after rehydration for dried strawberry is 70% after 30 min. The result showed that no significant differences between moisture content after rehydration for dried strawberry at 70 and 80°C.

The effective antioxidant was measured for dried strawberry samples at different temperatures are 40, 60 and 80°C and effective antioxidant values were reached to 63, 63 and 63% respectively. Therefore, only one treatment was adopted to complete of study by extraction of antioxidant compounds using solvents and measurement of their ability to seize the ferrous ion, as well as measuring of reduction ability of these compounds and it's application on the corn oil to identification of these compounds ability to oxidation Retardation of corn oil for different storage periods.

Table 3 Shows the development of effective antioxidation of linoleic acid by extracted phenolic compounds from dried strawberry. Has got a rapid increase in the effectiveness of antioxidant in first extraction periods, then got a reduction in the period of extraction later. Reached maximum effectiveness after 30 hr of extraction, the increase is due in anti oxidative activity to the formation antioxidant compounds, the decline in antioxidative activity at prolonging the extraction attributable to two reasons. Two broken the compounds with antioxidant effect in the periods in the first extraction periods or encouraging material is configured to cause oxidative stress with antioxidant compounds previously formed leading to a reduction antioxidant activity (Yu *et al*., 2002).
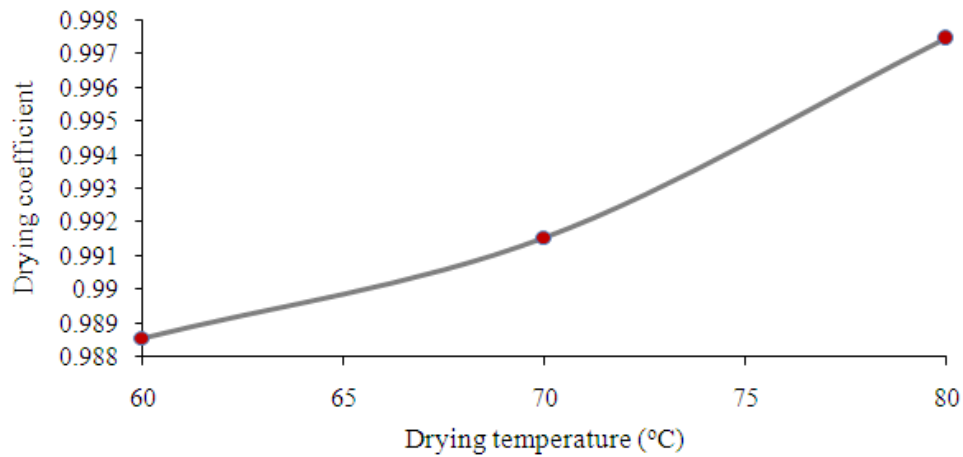
Fig. 6. Drying coeffecient vs. drying temperature for dried strawberry by halogen dryer

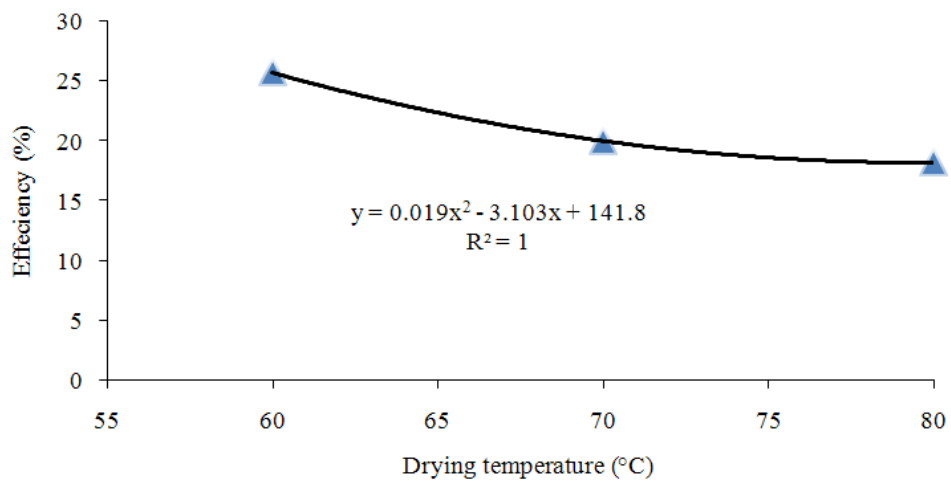
$$y = 0.019x^2 - 3.103x + 141.8$$
$$R^2 = 1$$

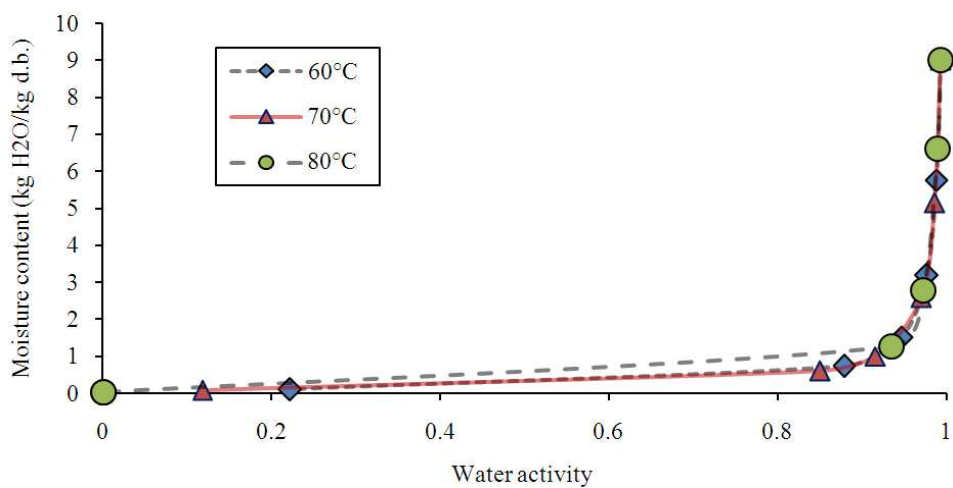**Fig. 7.** Efficiency vs. drying temperature for dried strawberry by halogen dryer

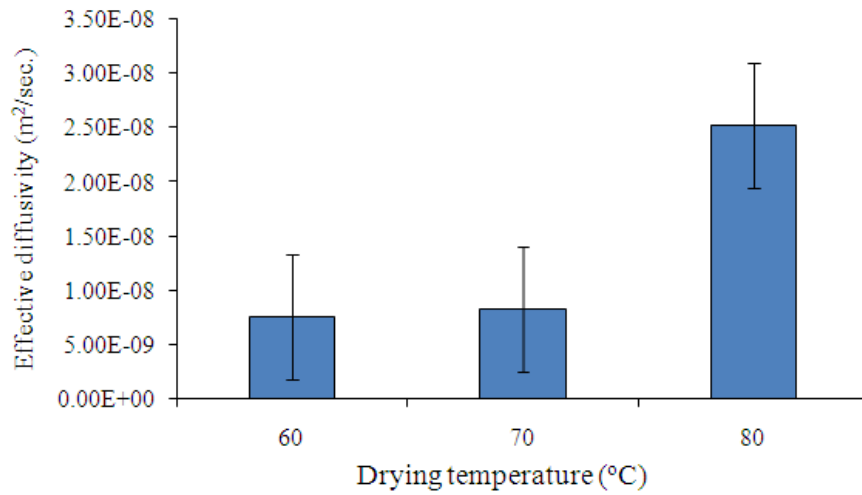**Fig. 8.** Moisture sorption isotherm of dried strawberry using different drying temperatures

Fig. 9. Effective diffussivity for dried strawberry by halogen dryer at different temperaturs Vs drying temperature
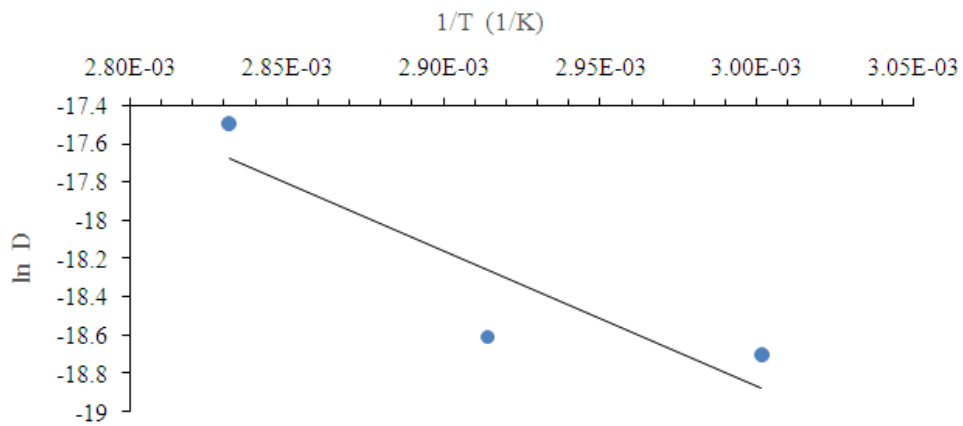

Fig. 10. Arrhenius type relationship between effective moisture diffussivity and tempetrature
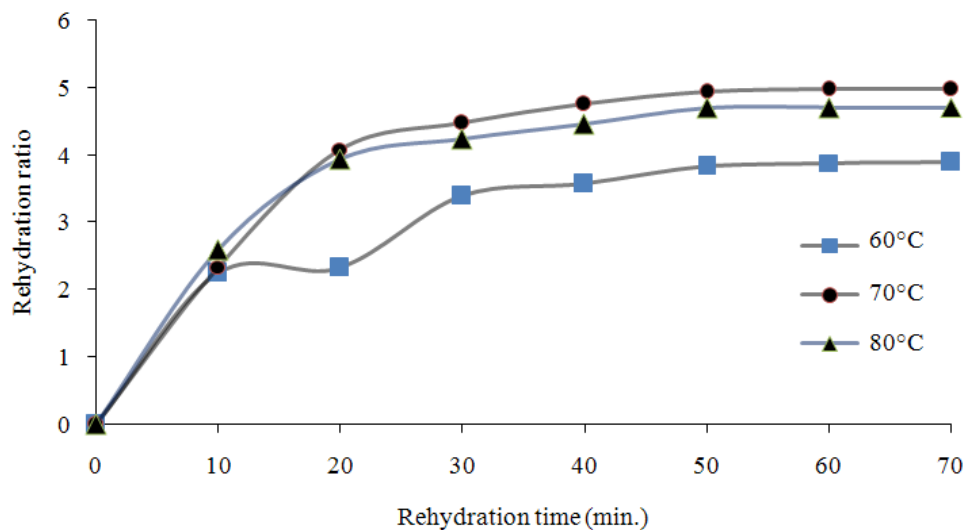

Fig. 11. Rehydration ratio for dried strawberry by halogen dryer at different temperaturs. vs. rehydration time
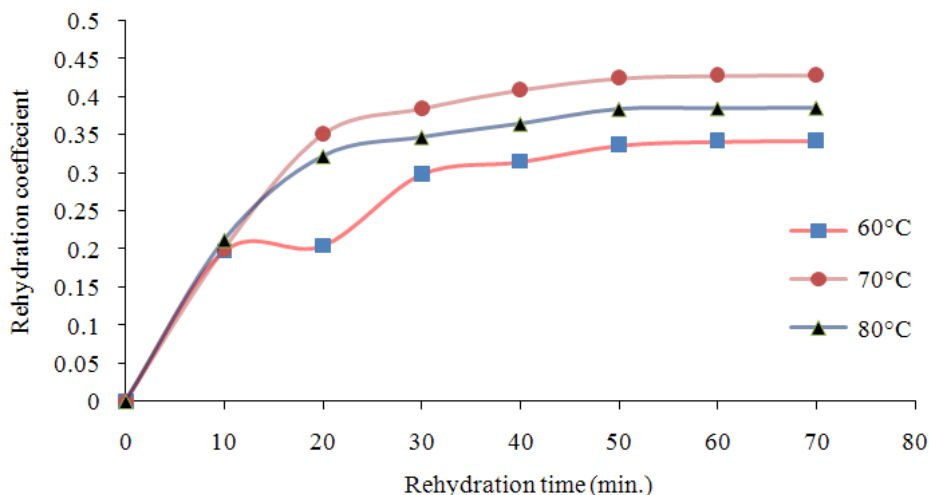
Fig. 12. Rehydration coeffiicient for dried strawberry by halogen dryer at different temperaturs Vs rehydration time
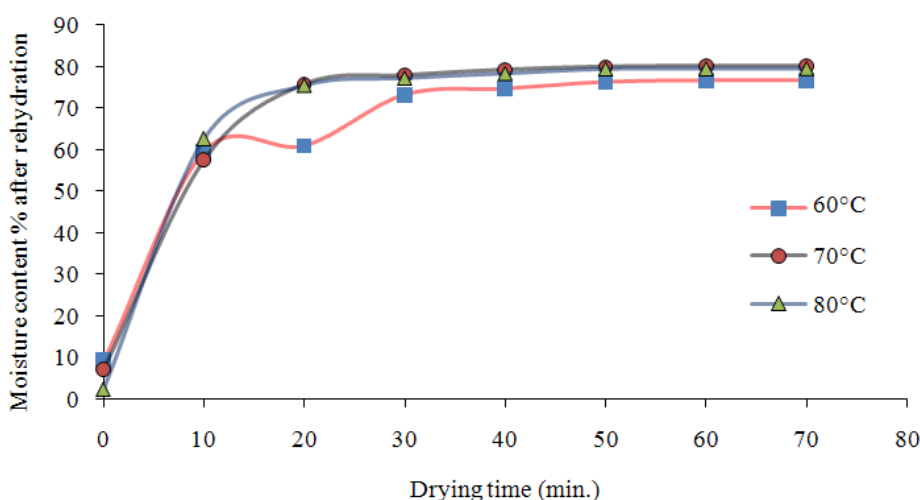

Fig. 13. Moisture content after rehydration for dried strawberry by halogen dryer at different temperaturs. vs. drying time

Table 3. Effect of using of different solvents and multiple periods on the antioxidative compounds activity in the strawberry

	Periods (hr)				
Solvents	6	12	18	24	30
Ethyl acetate	34±0.0120	44±0.0131	56±0.0102	61±0.0154	48±0.0213
Methanol	33±0.0098	43±0.0114	53±0.0132	60±0.0241	49±0.0132
Propanol	22±0.0097	41±0.0111	47±0.00891	39±0.0301	37±0.0213
Ethanol	31±0.0113	38±0.0141	37±0.0123	35±0.016	33±0.0211
Chloroform	30±0.0122	37±0.0097	37±0.00962	37±0.0132	37±0.0160
Distilled water	28±0.0132	29±0.0131	28±0.0123	26±0.0213	36±0.0142

Table 4. Reducing power for antioxidant compounds which extracted from the strawberry

	Concentration (mg/mL)				
Solvents	10	20	30	40	50
Ethyl acetate	0.10±0.0010	0.33±0.0019	0.77±0.0010	0.89±0.0011	0.93±0.0031
Methanol	0.28±0.00102	0.43±0.0124	0.97±0.0010	1.11±0.0021	1.32±0.0021
BHT	0.32±0.0031	0.55±0.0142	1.12±0.0021	1.72±0.0006	1.91±0.0013

Table 5. Ability of antioxidant compounds which extracted from the strawberry to ferrous ion chelating.

Solvents	Concentration (mg/mL)				
	2	4	6	8	10
Ethyl acetate	62±0.020	69±0.032	80±0.041	82±0.021	91±0.041
Chloroform	43±0.032	49±0.023	53±0.021	59±0.032	63±0.037
2Na-EDTA	73±0.024	79±0.021	92±0.032	92±0.053	98±0.028

Table 6. Effect of antioxidant compounds inhibition by ethyl extract in the strawberry to retardation of antioxidant on corn oil to store periods

Extract concentrated	Peroxide value (mq/kg oil) Stored period (day)				
	10	20	30	40	50
5	2.29±0.182	4.27±0.041	5.23±0.031	10.10±0.010	12.80±0.032
10	2.31±0.140	3.60±0.020	4.89±0.021	9.15±0.022	12.22±0.023
15	2.03±0.020	2.57±0.041	4.33±0.028	7.00±0.013	10.42±0.051
20	1.47±0.0172	2.10±0.031	2.93±0.031	4.75±0.023	8.10±0.035
25	1.44±0.0113	1.53±0.019	2.65±0.022	4.05±0.012	5.90±0.041
BHT (2mg/gm)	1.40±0.0251	1.50±0.035	1.74±0.021	1.88±0.041	2.37±0.031
Control	2.66±0.0211	4.66±0.011	5.44±0.050	10.52±0.061	13.03±0.061

Table 4 shows the ability of reducing power for antioxidant compounds which extracted from the strawberry. reducing power increased with increasing extracted concentration.This indicates that antioxidant compounds in strawberries have the ability to gave an electron which reacts with free radicals to convert the min to products more stable and thus ending the interactions of a series of free radicals.

Table 5 Shows the ability of strawberry extracted to connect the ferrous ion compared with 2 Na-EDTA using different concentrations. Results showed that high concentrations have a greater ability to binding, this means that the ability of the binding an increased with increasing used concentrations.

Table 6 shows the changes in the values of peroxide to corn oil during storage at 45°C. the increase in the values of peroxide were dropped with increase the amount of added extracted. This indicates the ability of extracted of strawberry to impede the corn oil oxidation, but the impact of the antioxidant for extracted of strawberry was less than of which is for BHT, which completely reduced of corn oil oxidation at storage time of 45°C. The purpose of this test is to identify the ability of antioxidant compounds in extracted strawberry. Be done recognition the degree of peroxides formation using ferricthaiocine method, the basis of this method is based on a complex formation of ferric ion interaction with the thaiocin. It is easy and sensitive methods to measurement of peroxides in the lipid (Shantha and Decker, 1994). The antioxidative activity exponentially increased as a function of the development of the reducing power, suggesting that the antioxidative properties can be associated with the development of the reducing power (Tanaka *et al.*, 1990). Therefore, the effectiveness of antioxidant for strawberry extracted may be associated with reducing power. We conclude from the fore going that the ability of reducing power the ferrous ion can take a standard for the ability or antioxidant power for strawberry extracted. Sanchez-Moreno *et al.* (1999) stated that the extract can work to some extent as peroxides destroyers which react with hydroperoxides to give stable products by non radical processes besides antioxidant breaker which interfere with the free radical chain reaction.

4. CONCLUSION

The result of this study indicate that increasing drying temperature during the drying of strawberry increases the drying rate and drying coefficient and consequently decreases drying time. Also, the drying constant was greatly affected by drying temperature. Drying of strawberry slices occurred in falling rate period, no constant rate period was observed for the present study. The modified page model was found to be a better model for describing the characteristics of strawberry for both of the temperatures of 70 and 80°C. The page model is found to be more reasonable for type of 60°C than the other models. The effective moisture diffusivity was found to average from 7.53×10^{-9}-2.52×10^{-8} m^2/sec. Temperature dependence of the diffusivity was related with Arrhenius type relationship. The efficiency was decreased with

increasing drying temperature. The rehydration ratio was tested at 70°C is faster than other temperatures. The results showed that the moisture content (wb%) after rehydration reached to 76% at 70 an 80°C and reached to 70% at 60°C. .The ability of reducing power of the ferrous ion can take as an indicator for the ability or antioxidant power for strawberry extracted.

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