DRYING CHARACTERISTICS OF FOAM DRIED WATERMELON AS AFFECTED BY STABILIZING AGENT AND DRYING AIR TEMPERATURE

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Abstract
The influence of stabilizing agent and the drying temperature on the drying characteristics of watermelon puree was carried out in this study. The drying of the foamed watermelon was done in a mechanical dryer at constant temperature ranging from 65 ^{o}C - 80 ^{o}C and stabilizing agent (carboxyl methylcellulose, CMC) from 0.5 – 2.5%. The drying behaviour of the foam-dried watermelon was expressed based on moisture content, drying rate and drying time while the non-dimensional moisture ratio was fitted into ten (10) existing mathematical thin layer drying models. Also, the effective moisture diffusivity and activation energy were determined using Fick's law of diffusion and Arrhenius type equation respectively. The result shows that the moisture content reduces progressively with time and the time taken to foam dry the watermelon to a specific moisture content increases with decrease in the stabilizing agent and increase in the temperature of the system. The Hii et al model was selected as the best model with averagely high degree of predictability compared to other selected models for the prediction of the drying behaviour of the foam dried watermelon. The value of the effective moisture diffusivity (Deff) of the foam-dried watermelon increased with increase in the drying temperature and decrease in the stabilizing agent from 0.5 – 2.5% while the activation energy ranges between 10 and 14 kJ/mol.

Keywords: Drying behaviour, Foam drying, Modelling, Stabilizing agent, Watermelon.

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1. INTRODUCTION

Watermelon belongs to the family *cucurbitaceous* and is believed to have originated from the dry areas of southern Africa as reported by Isa and Olalusi (2019). It was majorly consumed during its production season (Johnson et al., 2012) as snacks due to its succulent refreshing flesh (Alam *et al.*, 2012). Also, watermelons are being processed into juice or pulp by peeling the external rind and removing the seeds, which serves as a waste product in the juice production and raw material for some other products such as pickles and preservatives (Alam *et al*., 2012). Preservation of watermelon juice/puree in its fresh form for a long period of time is a major problem for every household, food processor, food scientist and engineer (Isa and Oyerinde, 2018). It is an established fact that most fresh agro-products are susceptible to spoilage and deterioration due to high moisture content which speed up the rate of microbial activities in the food material. Therefore, moisture removal to a certain level remains one of the oldest and common remedy for extending the shelf life of agro-product, its increase the portability for long term storage and ease of transportation in large quantity (Doymaz, 2005a).

Agricultural products differ from most other materials dried frequently, such as textiles in a laundry, sand, stone, dust or paper. Agricultural products which are hygroscopic always has some residual moisture after the drying while for non-hygroscopic material drying continues up to zero moisture content. Because of hygroscopic products, moisture is trapped in closed capillaries. The rate of moisture flow is only approximately proportional to its vapor pressure difference with the environment because of the crop resistance to moisture flow (Wang *et al*., 2007; Akpinar *et al*., 2006; Doymaz, 2005a, b, c).

Drying of watermelon puree could result into the damage of essential nutrients in the product due to high heat intensity or longtime heating as reported by Johnson et al. (2013). Some of the constituents of watermelon were similar to the constituents of apple and mango pulps that were reported by Mishra *et al*. (2002) and Rajkumar *et al.* (2007) and the studies claimed that some of these constituents are thermo-sensitive as they are significantly affected by temperature. Also, the amount of moisture that migrates from samples during the drying can be controlled using other approach besides temperature, for fruit juice and pulp of which foaming and stabilizing of the sample remains a promising approach to mitigate this effect (Rajkumar *et al*., 2007). This study therefore aimed at determining the effect of drying air temperature and stabilizing agent on the drying characteristics of foam dried watermelon.

2. MATERIALS AND METHODS

2.1 Sample preparation

Fresh watermelons were obtained from Oja Oba market, Akure, south western part of Nigeria. The watermelon flesh was manually separated from the rind and the flesh was pulped and homogenized using a domestic mixer. Sample size of known weight was whipped using electric whipper (Orpat-HHB100E, Ajanta Limited, India.) at 18000 rpm. 10% foaming agent was used with food grade methyl cellulose at 0.5, 1, 1.5, and 2.5% on wet juice weight basis. For foaming and stabilizing the watermelon pulp, the egg albumen and methyl cellulose was incorporated subsequently during whipping.

2.2 Drying experiment

Foamed pulp was spread in a food grade stainless steel trays and dried in a Foam mat dryer having heating unit, blower, drying chamber, air outlet openings and a thermostat. The drier was run for some time in order to stabilize the desired temperature inside the chamber. The homogeneous foamed watermelon pulp was dried at five different drying air temperatures of 65 °C, 70 °C, 75 °C and 80 °C at constant air velocity. Weight loss was measured after every 30 min to determine the drying rate and other drying parameters. Effect of some parameters such as drying temperature on the quality of the drying was determined. The foam mats were dried to the point where the weight of the samples recorded constant values and it was peeled and then packed for further studies and analysis.

2.3 Determination of moisture content

The quantity of moisture present in a material can be expressed either on the wet basis or dry basis and expressed either as decimal or percentage. The moisture content on the wet basis is the weight of moisture present in a product per unit weight of the undried material (Akpinar, 2006) represented as,

$$M_{wb} = \frac{w_o - w_d}{w_o} x\ 100 \qquad (1)$$

2.4 Determination of moisture ratio

Moisture ratio of the samples during drying was determined using equation (2):

$$MR = \frac{M_t - M_e}{M_0 - M_e} \qquad (2)$$

As the Me value is very small compared to Mo and M values, the Me value can be neglected and the moisture ratio was simplified and it can be expressed as shown in equation (3).

$$MR = \frac{M_t}{M_0} \qquad (3)$$

Where: M - Moisture content at time t, kg_{H2O} /kg_{solid}, M_e is Equilibrium moisture content, kg_{H2O} /kg_{solid}, M_o is Initial moisture content, kg_{H2O} /kg_{solid} and M_R - Dimensionless moisture ratio.

2.5 Determination of drying rate

The drying rate was determined based on the rate of moisture flow which is approximately proportional to its vapor pressure difference with the environment because of the crop resistance to moisture flow. Therefore, it was calculated using equation (4).

$$\text{Drying rate} = \frac{M_{t+dt} - M_t}{dt} \qquad (4)$$

Determination of effective moisture diffusivity and activation energy

Estimation of the effective moisture diffusivity for the infinite slab based on the diffusion equation of Crank (1975) as reported by Dadali *et al.* (2007) and Wang *et al.* (2007):

$$MR = \frac{M_i - M_e}{M_o - M_e} = \frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{8}{(2n+1)^2} \times \exp\left(-\frac{(2n+1)^2\pi^2 D_{eff}}{4L^2}t\right) \quad (5)$$

Where D_{eff} is the effective diffusivity (m^2/s), L the half-thickness of the slab (m) if drying from both sides and the thickness of slab (m) if drying from one side, and n is the number of terms taken into consideration. For n is unity for a long drying time, then the solution above can be reduced to the following

$$MR = \frac{M_i - M_e}{M_o - M_e} = \frac{8}{\pi^2} exp\left(-\frac{\pi^2 D_{eff}}{4L^2}t\right) \quad (6)$$

For long drying periods, the solution in equation 6 that was gotten by simplifying equation 5 to the first term of the series (Senadeera *et al.*, 2003). This was further solved by taking the natural logarithm of equation 6 and obtain equation 7:

$$\ln(MR) = ln\left(\frac{8}{\pi^2}\right) - \frac{\pi^2 D_{eff}}{4L^2}t \quad (7)$$

The diffusion coefficient was determined by substituting the experimental data into equation 7 for each drying condition. however, the diffusion coefficient was calculated by plotting experimental data in terms of ln(MR) versus drying time. The effective moisture diffusivity was obtained from the slope of the plot using equation 8 and 9

$$\text{Slope } (\delta) = \frac{\pi^2 D_{eff}}{4L^2} \quad (8)$$

Therefore,

$$D_{eff} = \frac{4L^2\delta}{\pi^2} \quad (9)$$

The use of equation 10 was based on the assumption made that the moisture diffusivity was constant for each drying temperature, which assumes a linear relationship with the dependence of logarithmic dimensionless moisture ratio versus drying time. Even though the experimental drying dependence is not strictly linear on a logarithmic scale, assuming a linear fit appears as being a quite successful approximation.

The relationship between the drying conditions and the determined values of the effective diffusivity can be expressed by an Arrhenius-type equation (Akpinar et al., 2006) such as

$$D_{eff} = D_0 exp\left(\frac{-Ea}{RT}\right) \quad (10)$$

Where D_0 is the pre-exponential factor of the Arrhenius equation (m^2/s), Ea is the activation energy of the moisture diffusion (kJ/mol), T is the air's absolute drying temperature (K) and R is the gas Constant (8.3143 kJ/kmolK). Taking natural logarithms, equation 10 can be linearized as:

$$\left(D_{eff}\right) = \ln(D_0) - \frac{Ea}{RT} \quad (11)$$

In order to obtain the magnitudes of the coefficients of the equation, the values of $\ln(D_{eff})$ were plotted against the inverse of drying temperature (T^{-1}). The activation energy was calculated from the slope of the straight line, while the intercept equals $\ln(D_0)$

$$slope(\delta) = \frac{Ea}{R} \quad (12)$$

2.6 Model Fitting

To select a suitable model for describing the foam mat drying process of watermelon, drying curves were fitted with ten (10) semi theoretical and empirical thin layer drying models used in literatures and the evaluated moisture ratio models are presented in Table 1. To model the drying behaviour of watermelon under various drying condition using the moisture ratio (MR), non-linear regression was performed using the least square method in Microsoft excel (Solver analysis). Statistical parameters such as the Root mean square error (RMSE), coefficient of determination (R^2), and reduced chi-square (χ^2) were used as the criteria that goodness of fit of the model. The best model was selected based on the highest value of coefficient of determination (R^2), and the lowest value reduced chi-square (χ^2) as the primary criterion for selecting the best model to describe the drying characteristics and the lowest in value of the Root mean square error (RMSE), standard error or estimate (SEE) and sum of squared error (SSE) will be used for the validation of the model.

Table 1: Selected thin-layer mathematical models

S/N	Model Name	Model Equation	REFERENCE
1	Lewis	$MR = exp\,(-kt)$	Togrul and Pehlivan (2004)
2	Page	$MR = exp\,(-kt^n)$	Kaleemullah-Kaleemullah and Kailappan (2006)
3	Henderson and Pabis	$MR = aexp(-kt)$	Kashaninejad *et al*. (2007); Saeed *et al*. (2006);
4	Two-term	$MR = a\,exp\,(-kt) + b\,exp\,(-gt)$	Lahsani *et al*. (2004); Wang *et al*. (2007).
5	Two-term exponential	$MR = a\,exp\,(-kt) + (1 + a)\,exp\,(-kat)$	Sacilik *et al*. (2006); Tarigan *et al*. (2007)
6	Wang and Singh	$MR = 1 + at + bt^2$	Wang and Singh (1978)
7	Approximation of diffusion	$MR = a\,exp\,(-kt) + (1 - a)\,exp\,(-kbt)$	Wang *et al*. (2007);
8	Verma *et al*	$MR = a\,exp(-kt) + (1 + a)\,exp(-gt)$	Doymaz (2005);
9	Midilli and Kucuk	$MR = a\,exp\,(-kt^n + bt)$	Midilli *et al*. (2002)
10	Hii *et al*.	$\mathrm{MR} = aexp(-kt^n) + cexp(-gt^n)$	Hii *et al*. (2008)

3. RESULTS AND DISCUSSION

3.1 Moisture content

The effect of the drying temperature and percentage of carboxyl methyl cellulose on the moisture content profile is presented in Figure 1 and Figure 2 respectively. According to the figures, the high initial moisture content (94.02%) of the sample was progressively reduces with increase in the drying time until a stable point was attained and similar was reported for the moisture content of mango flesh against drying time by Rajkumar et al. (2007), however, there was high moisture removal at the earlier stage of the drying and reduced substantially in the later. This can be explained by the fact that the surface moisture evaporates very quickly due to high heat and mass transfer coefficients in thin-layer drying at the earlier stage and this agrees with the report of Aghbashlo *et al.* (2009) in a continuous band dryer.

Nevertheless, the moisture content of the watermelon flakes after 10 hours for drying air temperature of 65 ºC, 70 ºC, 75 ºC and 80 ºC were 23.72%, 15.84%, 0.65% and 12.57% respectively for the 0.5% CMC; 35.26%, 20.69%, 1.40% and 11.12% respectively for 1.0% CMC; 28.94%, 14.38%, 4.49% and 19.36% respectively for the 1.5% CMC and 23.72%, 15.84%, 0.65 and 12.57% respectively for the 2.5% CMC. Therefore, the air temperature and percentage of CMC had a non-negligible effect on the final moisture content of the flakes as the specific amount of moisture removed shows a reducing trend with increase in the drying temperature intensity and decrease in the percentage of CMC, and similar trend was found for all the effect of temperature and percentage of CMC of moisture ratio.

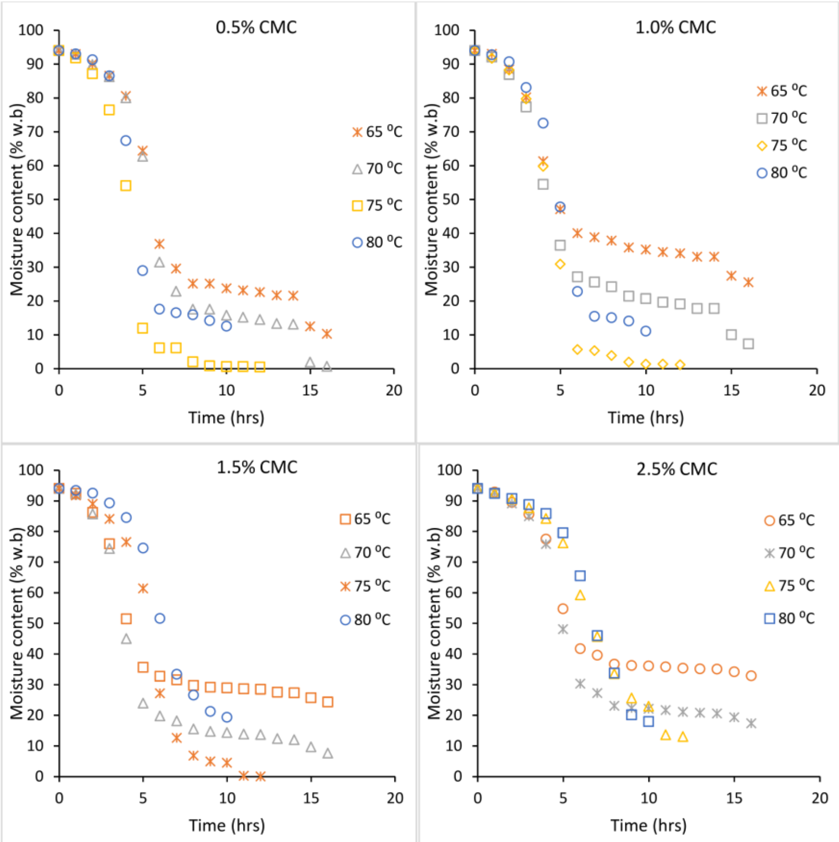

Figure 1: The effect of drying temperature on the moisture content of foam-dried watermelon at different percentage of CMC

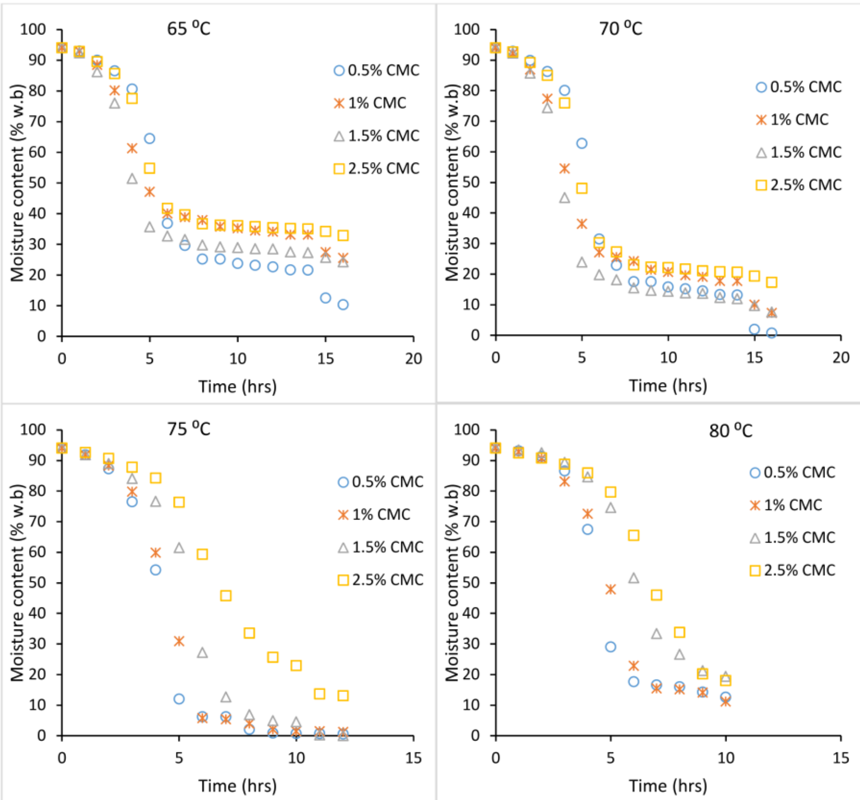

Figure 2: Effects of the percentage of CMC and 10% egg albumen on the moisture content of foam-dried watermelon at various drying temperature.

3.2 Drying rate

The drying rate was measures the specific variation in moisture content with respect to specific time. Figure 3 and 4 show the effects of drying temperature on the drying rate of watermelon as a function of drying time or moisture content respectively, while Figure 5 and 6 show the effects of the percentage of CMC on the drying rate of foamed watermelon as a function of drying time or moisture content respectively. Generally, no constant drying rate period was observed at any drying condition in the drying curves for this study. Drying rate after an initial rapid rise decreases continuously with increase in the drying time and decrease in moisture content, and the overall process took place in the falling rate period. These results are in agreement with the earlier observations of Togrul and Pehlivan (2003) and Akpinar *et al.* (2006). However, increase in the drying temperature leads to a proportionate increase in the rate of drying of moisture in the watermelon. Although, 75 °C had the highest drying rate of moisture per unit time while 65 °C had the least rate of drying which means that the drying time was reduce with temperature. The decrease in drying time with an increase in the drying air temperature have been reported for many agricultural products such as orange slices (Rafiee et al., 2010), strawberry (Lee and Hsieh, 2008) and peach (Kigsley *et al.*, 2007).

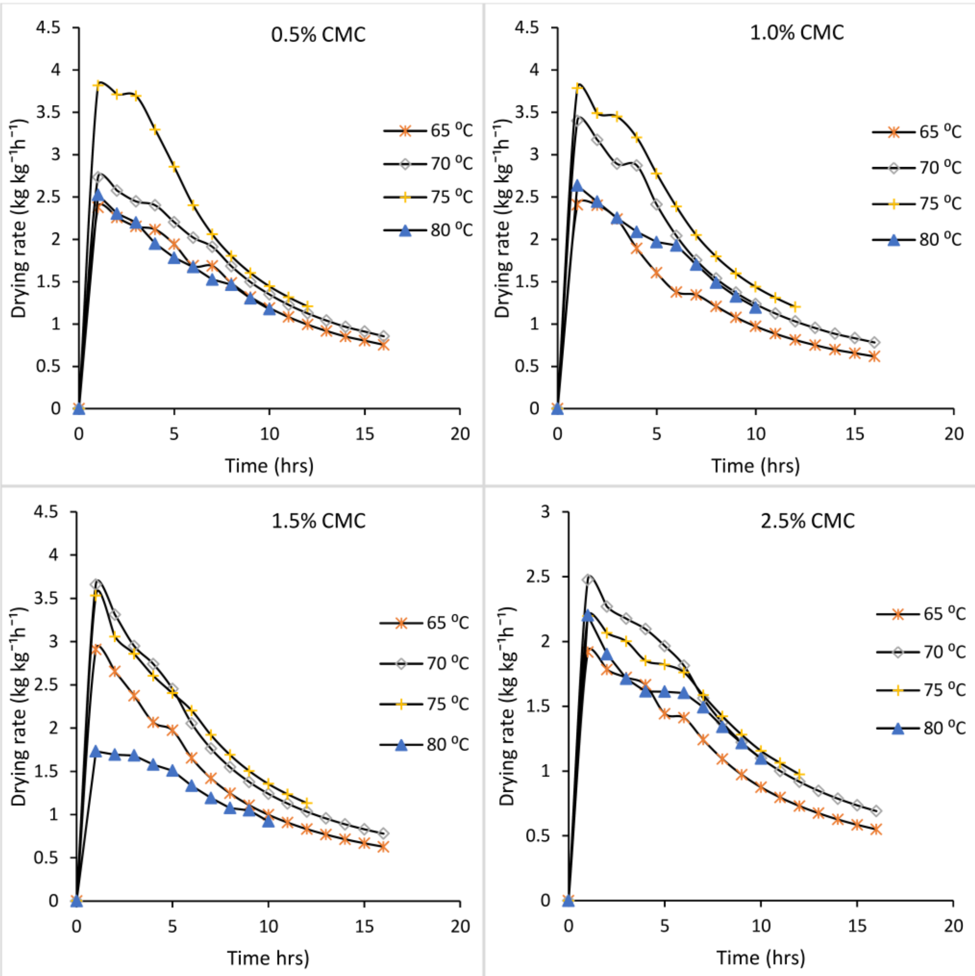

Figure 3: Effect of drying temperature on the drying rate of watermelon under different percentage of CMC

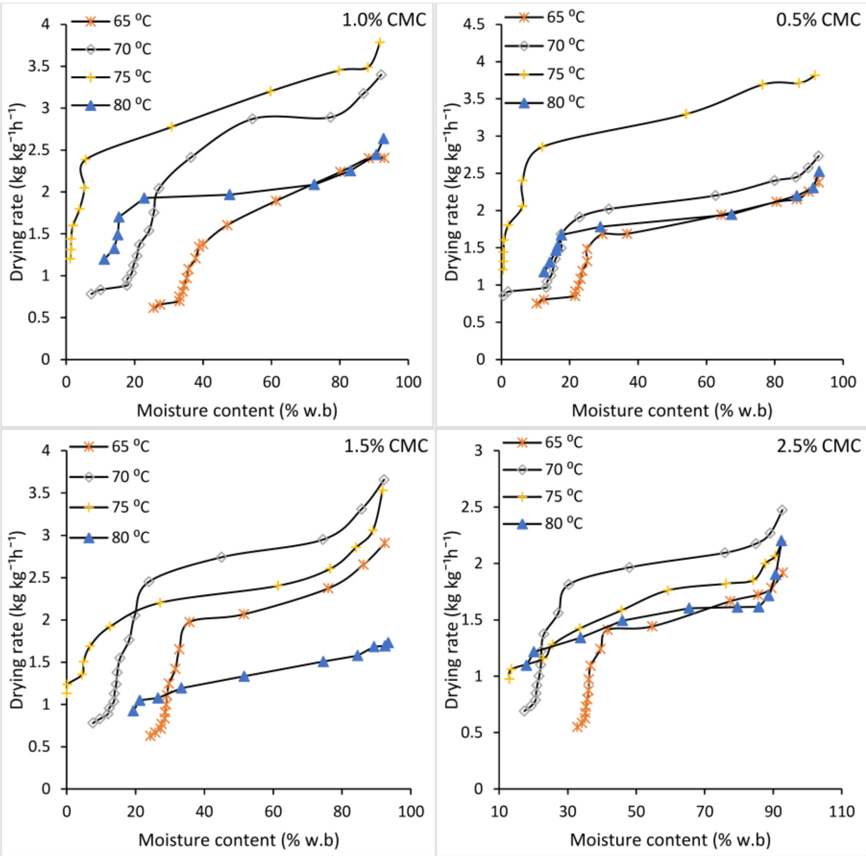

Figure 4: drying rate vs moisture content for the effect of drying temperature watermelon at different percentage of CMC

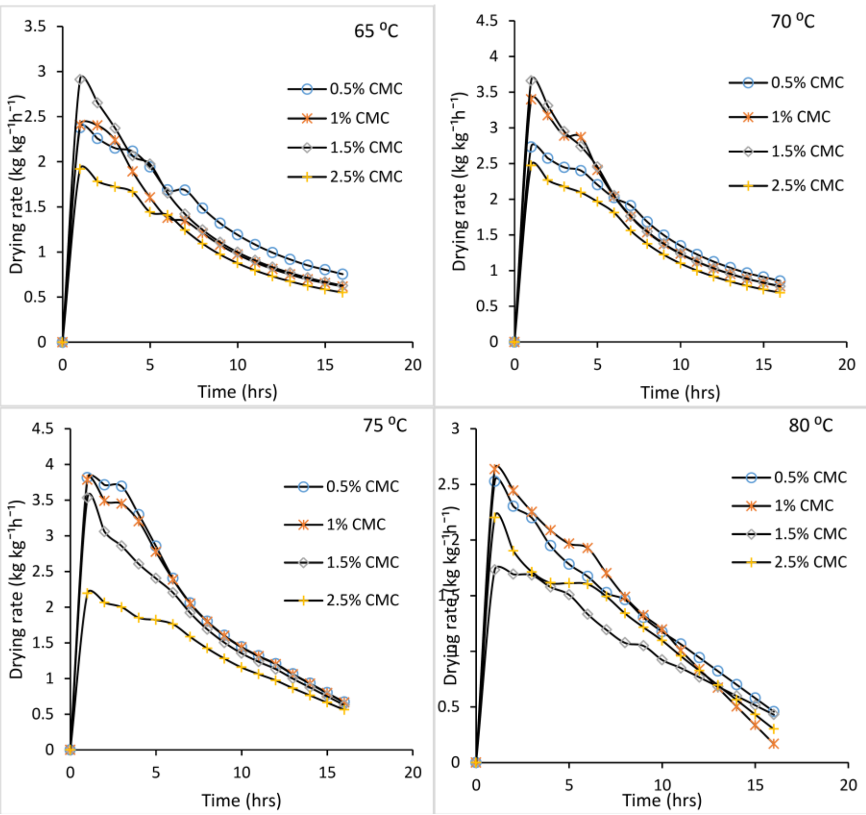

Figure 5: Effect of percentage of CMC on the drying rate vs time of watermelon at different drying temperature.

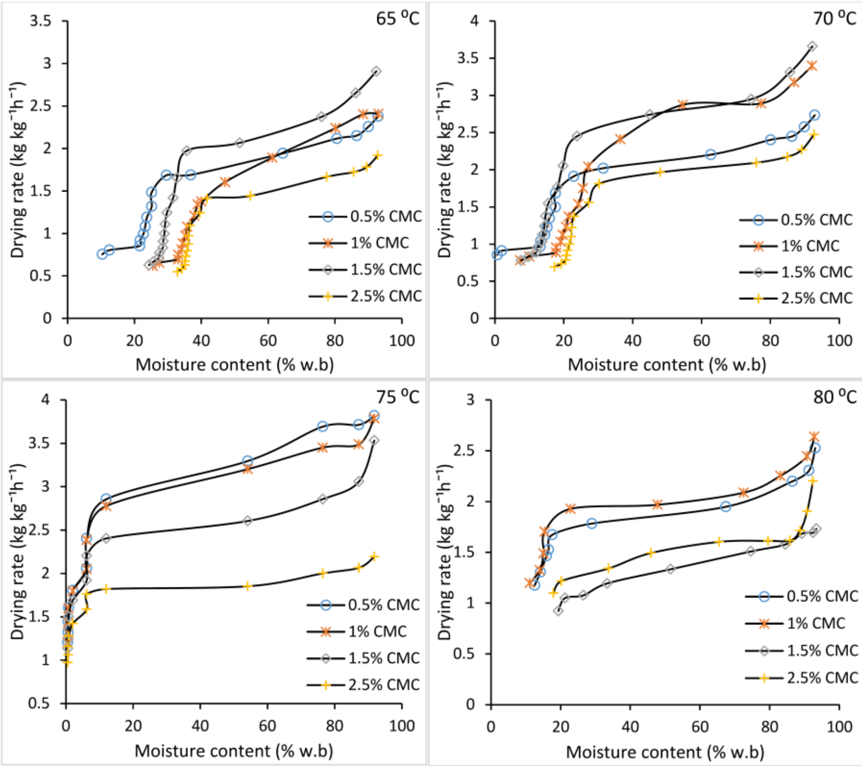

Figure 6: Plot of drying rate vs moisture content for the effect of CMC on foam-dried watermelon treated with 10% egg albumen and five different drying temperature

3.3 Effective diffusivity and activation energy

Figure 7 shows the effect of egg albumen on the effective moisture diffusivity of foam dried watermelon treated with five different percentage of CMC (0.5 – 2.5%) and subjected to a constant drying temperature of 60 – 80 ºC. were the estimated values of D_{eff} for drying temperatures 65 ºC, 70 ºC, 75 ºC and 80 ºC were 3.889 × 10^{-10} m^2/s, 6.868 × 10^{-10} m^2/s, 14.89 × 10^{-10} m^2/s, and 7.028 × 10^{-10} m^2/s respectively for foam dried watermelon stabilized with 0.5% CMC; 2.270 × 10^{-10} m^2/s, 4.108 × 10^{-10} m^2/s, 12.68 × 10^{-10} m^2/s, and 7.193 × 10^{-10} m^2/s respectively, for foam dried watermelon stabilized with 1.0% CMC; 2.421 × 10^{-10} m^2/s, 4.408 × 10^{-10} m^2/s, 16.24 × 10^{-10}` m^2/s, and 5.126 × 10^{-10} m^2/s respectively, for foam dried watermelon stabilized with 1.5% CMC; and 2.088 × 10^{-10} m^2/s, 3.357 × 10^{-10} m^2/s, 5.101 × 10^{-10} m^2/s, and 4.839 × 10^{-10} m^2/s respectively, for foam dried watermelon treated with 2.5% CMC.

However, the D_{eff} was found increasing as the drying temperature increases from 65 ºC to 75 ºC and further reduces with increase in drying temperature from 75 ºC to 80 ºC and this might be due to high rate of drying of the watermelon puree at 80 ºC drying temperature and this resulted in surface caking that traps some moisture in molecule in the core of the flake and prolong the drying time of the flake compared to other drying temperature. The resulted values of D_{eff} increased with drying temperature and decrease in the percentage of CMC and the values meet the standard range (from 10^{-10} m^2/s to 10^{-9} m^2/s) for agribusiness and agricultural products reported by Celmaa *et al.* (2007) and can be compared to 0.72 – 3.78 2×10^{-10} m^2/s for watermelon seed in drying temperature range 50–70 ºC (Doymaz, 2013), 641–5.711×10^{-9} m^2/s for green beans in drying temperature range 50–70 ºC (Doymaz, 2005a), 4.27×10^{-10} m^2/s to 1.30×10^{-9} m2/s for okra in drying temperature range 50–70 ºC (Doymaz, 2005b), or 3.0×10^{-9} m2/s to 11.0×10^{-9} m^2/s for olive cake in drying temperature range 50–110 ºC (Doymaz, 2005c).

Table 2 shows the activation energy of the foam dried watermelon puree under various

CMC., the value of the activation energy obtained were 12.67 kJ/mol, 13.52 kJ/mol, 14.40 kJ/mol, and 10.55 kJ/mol for foam-dried watermelon treated with 0.5%, 1.0%, 1.5% and 2.5% CMC, respectively. The value was found to be lesser than the result obtained by Azizpour et al. (2014) for shrimp (26.89 kJ/mol), Alakali *et al*. (2010) for mango pulp (22.3 kJ/mol), meanwhile, a product is thermally stable when the activation energy is low (Montanuci *et al.*, 2013) and this shows that the stabilization of the puree also enhances the thermal stability of the product during drying.

3.4 Modelling

The resulted goodness of fit parameter and model constant obtained for the ten selected thin layer mathematical models fitted into the dimensionless experiment moisture ratio data of foam-dried watermelon is presented in Table 3 – 6. The table shows that Hii et al model has the highest performance with highest coefficient of determination ranging between 97.61 – 99.93% , 97.25 – 99.85 %, 98.47 – 99.84%, 99.07 – 99.91% and 96.39 – 99.80% for foam dried watermelon (drying temperature of 65 ºC – 80 ºC) stabilized with 0.5%, 1.0%, 1.5% and 2.5% of CMC respectively and the lowest root mean square error ranging between 0.0008 – 0.0488, 0.0135 – 0.0304, 0.0053 – 0.0185, 0.0090 – 0.0355, and 0.0167 – 0.0315 for foam dried watermelon (drying temperature of 60 ºC – 80 ºC) for foam dried watermelon (drying temperature of 65 ºC – 80 ºC) stabilized with 0.5%, 1.0%, 1.5% and 2.5% of CMC respectively, while, Midilli kucuk model had the second best performance and very close to the performance of Hii et al. model with high coefficient of determination ranging from 96.66 – 99.58 % , 96.89 – 99.81%, 95.95 – 99.68%, 94.36 – 99.87% and 92.26 – 99.43% for foam dried watermelon (drying temperature of 65 ºC – 80 ºC) stabilized with 0.5%, 1.0%, 1.5% and 2.5% of CMC respectively, with low root mean square error ranging from 0.0257 – 0.0585 , 0.0179 – 0.0485, 0.0429 – 0.0213, 0.0149 – 0.0414, and 0.4405 – 0.0143 for foam dried watermelon (drying temperature of 65 ºC – 80 ºC) stabilized with 0.5%, 1.0%, 1.5% and 2.5% of CMC respectively.

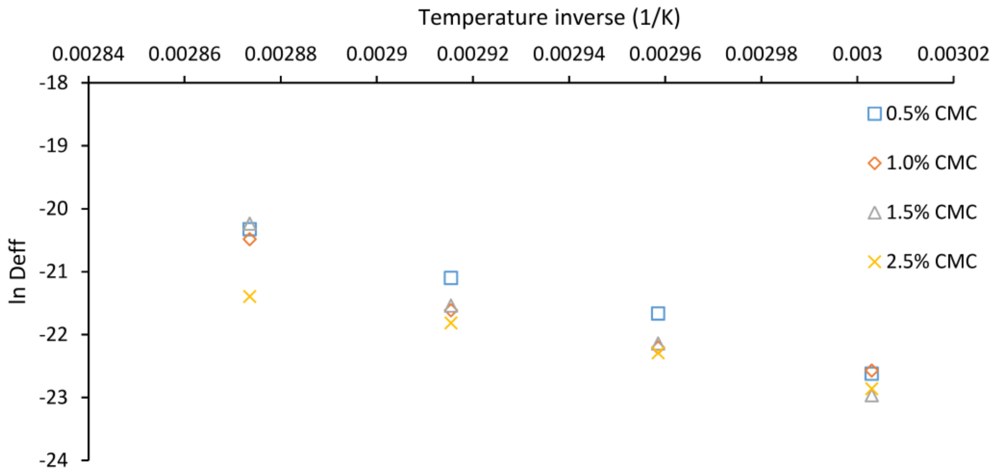

Figure 7: Effective moisture diffusivity of foam-dried watermelon

Table 2: Activation energy of the drying process

Carboxyl methylcellulose	Activation energy (J/mol)	Pre-exponential factor
0.50%	12.665	5.72 x 10^{12}
1.00%	13.520	5.98 x 10^{10}
1.50%	14.396	2.88 x 10^{16}
2.50%	10.553	6.30 x 10^{04}

Table 3: The model parameter for drying of watermelon pulp stabilised with 0.5% CMC

Temperature °C	Model	RMSE	R^2	X^2	k	a	N	b	g	c
65	Lewis	0.1177	0.8996	0.0214	0.1148					
	Handerson pabis	0.1021	0.8975	0.1397	0.1353	1.1491				
	Page	0.0932	0.9173	0.1277	0.0391		1.5372			
	Two term Exponential	0.0815	0.9692	0.1116	0.2168	2.2068				
	Wang and Smith	0.1087	0.9046	0.1488			-0.0966	0.0026		
	Diffusion Approach	0.1116	0.8923	0.1633	0.0491	3.5187			0.6297	
	Vermal *et al*	0.1021	0.8975	0.1494	0.1353	0.0746			0.1353	
	Midilli kucuk	0.0383	0.9857	0.0606	0.0039	0.9806	3.1104	0.0202		
	Two term	0.1024	0.8982	0.1619	6.2119	-0.0007		1.1258	0.1322	
	Hii *et al*	0.018	0.9969	0.0312	0.0003	0.7066	4.8525		0	0.2719
70	Lewis	0.14	0.8955	0.0304	0.1357					
	Handerson pabis	0.1206	0.8873	0.1651	0.1619	1.1859				
	Page	0.0887	0.9452	0.1215	0.0194		2.0269			
	Two term Exponential	0.0791	0.96	0.1084	0.2599	2.3376				
	Wang and Smith	0.1227	0.9022	0.168			-0.1049	0.0027		
	Diffusion Approach	0.14	0.8955	0.205	0.1697	0.0068			0.7987	
	Vermal *et al*	0.1206	0.8873	0.1765	0.1619	0.093			0.1619	
	Midilli kucuk	0.0361	0.9899	0.0571	0.0013	0.9762	3.7406	0.0134		
	Two term	0.0798	0.9524	0.1262	0.4362	-4.0735		5.083	0.314	
	Hii *et al*	0.0306	0.9965	0.053	0.00	0.1423	4.8998		0.0002	0.8337
75	Lewis	0.1728	0.8846	0.0436	0.2302					
	Handerson pabis	0.1548	0.8698	0.2279	0.2682	1.2096				
	Page	0.0337	0.995	0.0496	0.0014		4.4385			
	Two term Exponential	0.0982	0.9451	0.1445	0.4205	2.473				
	Wang and Smith	0.1377	0.9102	0.2027			-0.1682	0.0067		
	Diffusion Approach	0.09	0.9551	0.1452	0.6166	-159.4015			0.9894	
	Vermal *et al*	0.1548	0.8698	0.2497	0.2682	0.1048			0.2682	
	Midilli kucuk	0.029	0.9951	0.0522	0.0006	0.9689	4.9915	0.0018		
	Two term	0.1315	0.8981	0.2371	0.0947	-2.8258		4.0166	0.1313	
	Hii *et al*	0.0481	0.9867	0.1002	0.0106	1.0118	3.0246		0.0005	0.0115
80	Lewis	0.1677	0.8638	0.0417	0.1652					
	Handerson pabis	0.1473	0.8491	0.1628	0.1991	1.1927				
	Page	0.0911	0.9527	0.1007	0.0107		2.6767			
	Two term Exponential	0.092	0.938	0.1017	0.3314	2.424				
	Wang and Smith	0.1404	0.8746	0.1552			-0.1078	0.001		
	Diffusion Approach	0.0883	0.9444	0.1035	0.4884	-58.3538			0.973	
	Vermal *et al*	0.1473	0.8491	0.2821	0.1991	0.0964			0.1991	
	Midilli kucuk	0.0305	0.9935	0.0383	0.0005	0.9753	4.8752	0.0183		
	Two term	0.1107	0.9213	0.1388	1.4307	-0.4644		1.4889	0.2382	
	Hii *et al*	0.1013	0.983	0.1372	0.0003	0	5.0048		0.0003	0.9834

Table 4 The model parameter for drying of watermelon pulp stabilized with 1.0% CMC

Temperature °C	Model	RMSE	R^2	X^2	k	a	N	b	g	c
65	Lewis	0.0788	0.8999	0.0085	0.0984					
	Handerson pabis	0.0773	0.9036	0.1058	0.1039	1.0385				
	Page	0.0786	0.9015	0.1076	0.1056		0.9653			
	Two term Exponential	0.0761	0.9982	0.1043	0.1963	0.3452				
	Wang and Smith	0.0647	0.9474	0.0886		-0.1073		0.0044		
	Diffusion Approach	0.0668	0.9423	0.0977	0.1113	0.9993			-3.4657	
	Vermal *et al*	0.0598	0.9417	0.0875	-0.1102	0.0485			0.1543	
	Midilli kucuk	0.0361	0.9787	0.057	0.0573	1.0254	1.7007	0.028		
	Two term	0.0575	0.9458	0.0909	-0.2716	0.0046		1.092	0.1347	
	Hii et al	0.0171	0.9954	0.0297	0.0158	0.6364	2.7732		0	0.3675
70	Lewis	0.0897	0.9279	0.0136	0.146					
	Handerson pabis	0.0805	0.9318	0.1102	0.1637	1.1077				
	Page	0.0822	0.9317	0.1126	0.0942		1.2343			
	Two term Exponential	0.0786	0.9865	0.1076	0.2416	2.005				
	Wang and Smith	0.0794	0.9488	0.1087		-0.1321		0.0053		
	Diffusion Approach	0.0897	0.9279	0.1313	0.1419	0.0087			1.0291	
	Vermal *et al*	0.0791	0.934	0.1158	-0.0138	0.0615			0.1916	
	Midilli kucuk	0.0373	0.9854	0.0589	0.0378	1.0166	2.054	0.017		
	Two term	0.0805	0.9318	0.1273	0.1886	0.102		1.0059	0.1614	
	Hii *et al*	0.0135	0.9982	0.0233	0.0001	0.2635	3.0725		0.0118	0.745
75	Lewis	0.173	0.888	0.0439	0.2105					
	Handerson pabis	0.1536	0.8712	0.2262	0.247	1.2129				
	Page	0.0256	0.9969	0.0377	0.0033		3.627			
	Two term Exponential	0.0947	0.9455	0.1394	0.3861	2.4588				
	Wang and Smith	0.1357	0.9115	0.1998		-0.1503		0.0051		
	Diffusion Approach	0.086	0.9592	0.1386	0.5852	-21.2391			0.9257	
	Vermal *et al*	0.1536	0.8712	0.2477	0.247	0.1064			0.247	
	Midilli kucuk	0.0182	0.9981	0.0328	0.0013	0.9764	4.2282	0.0021		
	Two term	0.1258	0.906	0.2268	0.0682	-4.1133		5.2785	0.0933	
	Hii *et al*	0.0253	0.9968	0.0527	0.0001	0.2093	5.2679		0.0003	0.7539
80	Lewis	0.1598	0.8807	0.0347	0.1538					
	Handerson pabis	0.1384	0.8624	0.153	0.1858	1.189				
	Page	0.0639	0.9752	0.0706	0.0077		2.747			
	Two term Exponential	0.0783	0.9384	0.0865	0.3072	2.3929				
	Wang and Smith	0.1176	0.9061	0.13		-0.085		-0.0015		
	Diffusion Approach	0.0726	0.961	0.0852	0.4547	-34.889			0.9567	
	Vermal *et al*	0.1384	0.8624	0.2649	0.1858	0.0945			0.1858	
	Midilli kucuk	0.0232	0.996	0.0291	0.0016	0.9741	3.8693	0.0151		
	Two term	0.1384	0.8624	0.1734	0.1858	0.0931		1.0958	0.1858	
	Hii *et al*	0.0195	0.9972	0.0264	0	0.1872	5.6981		0.0001	0.7805

Table 5: The model parameter for drying of watermelon pulp treated with 10% egg albumen and 1.5% CMC

Temperature °C	Model	RMSE	R^2	X^2	k	a	n	b	g	c
65	Lewis	0.0926	0.884	0.0117	0.1232					
	Handerson pabis	0.091	0.8889	0.1246	0.1303	1.0446				
	Page	0.0923	0.8855	0.1264	0.1332		0.96			
	Two term Exponential	0.0894	0.9982	0.1225	0.2353	0.3659				
	Wang and Smith	0.074	0.9387	0.1013		-0.1293		0.0057		
	Diffusion Approach	0.0782	0.9313	0.1145	0.1414	0.9985			-2.4187	
	Vermal *et al*	0.0716	0.9302	0.1048	-0.1014	0.0523			0.1915	
	Midilli kucuk	0.0426	0.9751	0.0674	0.0576	1.024	1.8379	0.0249		
	Two term	0.069	0.9345	0.1091	-0.2572	0.0059		1.1025	0.169	
	Hii *et al*	0.0121	0.998	0.0209	0.0096	0.67	3.3953		0	0.3268
70	Lewis	0.1065	0.915	0.0198	0.1814					
	Handerson pabis	0.0953	0.9184	0.1305	0.2064	1.1366				
	Page	0.0904	0.9344	0.1237	0.0848		1.4539			
	Two term Exponential	0.0774	0.9738	0.106	0.3322	2.2319				
	Wang and Smith	0.0932	0.9375	0.1276		-0.1539		0.0067		
	Diffusion Approach	0.1065	0.915	0.1559	0.1777	0.0089			1.0215	
	Vermal *et al*	0.0953	0.9184	0.1395	0.2064	0.0683			0.2064	
	Midilli kucuk	0.0389	0.9867	0.0614	0.0215	1.005	2.5931	0.013		
	Two term	0.0953	0.9184	0.1506	0.2063	0.0904		1.0462	0.2064	
	Hii *et al*	0.014	0.9982	0.0243	0	0.1847	3.6879		0.0058	0.8066
75	Lewis	0.1876	0.8724	0.0457	0.1669					
	Handerson pabis	0.1661	0.8489	0.2445	0.1998	1.2199				
	Page	0.0351	0.9943	0.0517	0.0009		3.9407			
	Two term Exponential	0.1078	0.943	0.1587	0.3122	2.4352				
	Wang and Smith	0.1327	0.9067	0.1953		-0.0963		0.0002		
	Diffusion Approach	0.0986	0.9478	0.159	0.4651	-38.2278			0.9583	
	Vermal *et al*	0.1661	0.8489	0.2679	0.1999	0.11			0.1998	
	Midilli kucuk	0.0293	0.9949	0.0529	0.0004	0.9682	4.4523	0.0025		
	Two term	0.1202	0.9142	0.2166	0.0222	-9.7715		10.9128	0.0327	
	Hii *et al*	0.0226	0.997	0.0471	0	0.094	5.2802		0.0001	0.8688
80	Lewis	0.1572	0.8526	0.0317	0.1036					
	Handerson pabis	0.1344	0.8297	0.1485	0.1312	1.1801				
	Page	0.0506	0.9761	0.0559	0.0036		2.7819			
	Two term Exponential	0.0741	0.9242	0.0819	0.2314	2.3766				
	Wang and Smith	0.0835	0.9345	0.0923		-0.0192		-0.0073		
	Diffusion Approach	0.0682	0.9562	0.0799	0.3447	-38.4099			0.9609	
	Vermal *et al*	0.1344	0.8297	0.2573	0.1312	0.09			0.1312	
	Midilli kucuk	0.0213	0.9956	0.0267	0.0009	0.9715	3.7624	0.021		
	Two term	0.1344	0.8297	0.1684	0.1312	0.1037		1.0763	0.1312	
	Hii *et al*	0.0205	0.996	0.0277	0	0.2084	3.9172		0.0007	0.7971

Table 6: The model parameter for drying of watermelon puree stabilized with 2.5% CMC

Temperature °C	Model	RMSE	R^2	X^2	k	a	n	b	g	c
65	Lewis	0.0926	0.884	0.0117	0.1232					
	Handerson pabis	0.091	0.8889	0.1246	0.1303	1.0446				
	Page	0.0923	0.8855	0.1264	0.1332		0.96			
	Two term Exponential	0.0894	0.9982	0.1225	0.2353	0.3659				
	Wang and Smith	0.074	0.9387	0.1013		-0.1293		0.0057		
	Diffusion Approach	0.0782	0.9313	0.1145	0.1414	0.9985			-2.4187	
	Vermal *et al*	0.0716	0.9302	0.1048	-0.1014	0.0523			0.1915	
	Midilli kucuk	0.0426	0.9751	0.0674	0.0576	1.024	1.8379	0.0249		
	Two term	0.069	0.9345	0.1091	-0.2572	0.0059		1.1025	0.169	
	Hii *et al*	0.0121	0.998	0.0209	0.0096	0.67	3.3953		0	0.3268
70	Lewis	0.1065	0.915	0.0198	0.1814					
	Handerson pabis	0.0953	0.9184	0.1305	0.2064	1.1366				
	Page	0.0904	0.9344	0.1237	0.0848		1.4539			
	Two term Exponential	0.0774	0.9738	0.106	0.3322	2.2319				
	Wang and Smith	0.0932	0.9375	0.1276		-0.1539		0.0067		
	Diffusion Approach	0.1065	0.915	0.1559	0.1777	0.0089			1.0215	
	Vermal *et al*	0.0953	0.9184	0.1395	0.2064	0.0683			0.2064	
	Midilli kucuk	0.0389	0.9867	0.0614	0.0215	1.005	2.5931	0.013		
	Two term	0.0953	0.9184	0.1506	0.2063	0.0904		1.0462	0.2064	
	Hii *et al*	0.014	0.9982	0.0243	0	0.1847	3.6879		0.0058	0.8066
75	Lewis	0.1876	0.8724	0.0457	0.1669					
	Handerson pabis	0.1661	0.8489	0.2445	0.1998	1.2199				
	Page	0.0351	0.9943	0.0517	0.0009		3.9407			
	Two term Exponential	0.1078	0.943	0.1587	0.3122	2.4352				
	Wang and Smith	0.1327	0.9067	0.1953		-0.0963		0.0002		
	Diffusion Approach	0.0986	0.9478	0.159	0.4651	-38.2278			0.9583	
	Vermal *et al*	0.1661	0.8489	0.2679	0.1999	0.11			0.1998	
	Midilli kucuk	0.0293	0.9949	0.0529	0.0004	0.9682	4.4523	0.0025		
	Two term	0.1202	0.9142	0.2166	0.0222	-9.7715		10.9128	0.0327	
	Hii *et al*	0.0226	0.997	0.0471	0	0.094	5.2802		0.0001	0.8688
80	Lewis	0.1572	0.8526	0.0317	0.1036					
	Handerson pabis	0.1344	0.8297	0.1485	0.1312	1.1801				
	Page	0.0506	0.9761	0.0559	0.0036		2.7819			
	Two term Exponential	0.0741	0.9242	0.0819	0.2314	2.3766				
	Wang and Smith	0.0835	0.9345	0.0923		-0.0192		-0.0073		
	Diffusion Approach	0.0682	0.9562	0.0799	0.3447	-38.4099			0.9609	
	Vermal *et al*	0.1344	0.8297	0.2573	0.1312	0.09			0.1312	
	Midilli kucuk	0.0213	0.9956	0.0267	0.0009	0.9715	3.7624	0.021		
	Two term	0.1344	0.8297	0.1684	0.1312	0.1037		1.0763	0.1312	
	Hii *et al*	0.0205	0.996	0.0277	0	0.2084	3.9172		0.0007	0.7971

4. CONCLUSION

The following conclusions were drawn from the study of the drying characteristics of foam dried watermelon:

i. The increase in drying temperature of the drying system for foam mat drying of watermelon puree resulted in decrease in the moisture content obtained for the final products (foam dried watermelon flakes) and the 70 °C – 75 °C drying temperature was considered as a safe drying temperature for watermelon puree.
ii. The moisture content of the final product (watermelon flakes) was increasing with percentage of stabilizing agent (CMC) added to the puree, when dried at low constant drying temperature and reduces with percentage of stabilizing agent (CMC)when dried at high constant drying temperature
iii. There was initial rising of rate of drying in all the treatment and the drying rate decreases continuously with time. There was no constant-rate period drying in the curves as most of the drying process are seen to occur in the falling rate period
iv. The effective moisture diffusivity ranges between 2.088×10^{-10} m^2/s and 16.24×10^{-10}` m^2/s and the natural logarithm of the effective diffusivity has a linear decreasing relationship with increase in inverse of temperature
v. The value of the activation energy ranges between 10.55 – 14.40 kJ/mol for watermelon puree stabilized with 0.5 -2.5% CMC

Hii et. al. model was adjudged as the most suitable model equation, followed by midilli kucuk in describing the drying kinetic process of a foam dried watermelon, based on the high value coefficient of determination, least value of chi square and root mean square error when fitted into experimental data. Based on the performance of fitted models, Hii et al. model is recommended for effective prediction of the drying characteristics as a function of time.

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