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Original Research Article

Moisture sorption isotherm of chicken breast

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A B S T R A C T

The relationship between moisture content and water activity or moisture sorption isotherm of chicken breast was experimentally determined. The experimental procedure was obtained at 5, 25, 40, 60, 80 and 100°C. Water activity of samples were adjusted to 0.11, 0.33, 0.58, 0.75 and 0.96 by using saturated salt solutions. The surface of the chicken breast was cut into small size and equilibrated at various water activities. GAB, BET and Peleg models were used to fit the experimental data. It was shown that GAB model gave the best fit for the whole range of water activity and temperature with 5.37-12.83 of %RMSE. The parameters obtained from the GAB model were fitted as a function of temperatures. Moreover, these sorption isotherm equations could predict the relationship between water activity and moisture content at the wider range of temperature (5-100°C) than the previous studies.

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INTRODUCTION

In general, most natural foods contain water up to 70 % of their weight or higher unless they are dehydrated. Fruits and vegetables contain water up to 90 % or higher.

Water that can be easily extracted from foods by squeezing or cutting is known as free water, whereas water that cannot be easily extracted is termed as bound water. Bound water consists of monolayer, multilayer and capillary water (Reid and Fennema, 2008). The total amount of water in food material is known as moisture content, while water activity is water in food that acts the reaction. Water activity (describes the degree of boundless of water contained in food and its availability to act as solvent and participate for a reaction series of biochemical, microbiological and chemical reaction. Water activity can also be defined as the ratio of water vapour pressure in the system (*P*), and the pure water vapour pressure (P_0), at a constant value of temperature as shown in equation (1) (Al-Muhtaseb *et al*., 2002).

$$a_w = \frac{P}{P_0} \tag{1}$$

Moisture sorption isotherm is the relationship between water content and equilibrium water activity of material at a constant temperature (Al-Muhtaseb *et al*., 2002; Reid and Fennema, 2008). Adsorption isotherm is obtained by placing a completely dry material into various atmospheres of relative humidity and measuring the weight gain due to water uptake. Desorption isotherm is found by placing an initially wet material under the same relative humidities, and measuring the loss in weight. Adsorption and desorption processes are not fully reversible. The different of desorption and adsorption is called ‘‘hysteresis’’. Hysteresis is related to the nature and state of the components of food, reflecting their potential for structural and conformational rearrangements, which alters the accessibility of energetically favourable polar sites. The review of moisture sorption isotherm characteristic of some food materials are given by Al-Muhtaseb *et al*. (2002).

From the previous studies, there are some studies of moisture sorption isotherm of the chicken meat. Labuza (1984) studied the desorption isotherm of raw chicken in the temperature range of 5-60°C and 0.05-0.95 of and Iglesias and Chirife (1984) also studied both adsorption and desorption isotherm of cooked chicken at the temperature range of 5-60°C. They found that at temperature range of 5-60°C, the GAB model was used to fit the experimental data of all a_w range. Timmermann *et al*. (2001) studied desorption isotherm of cooked chicken at 19.5°C and 0.05-0.80 of a_w. It was found that GAB model was more general meaning and gave the best fit with the experimental data. But the model parameters were not taken into account as a function of temperatures. Delgado and Sun (2002b) studied the desorption isotherm of raw chicken breast in the temperature range of 4-30°C and 0.05-0.95 of a_w. The several sorption isotherm models were used to fit the experimental data. They found that the GAB model gave the best fit for all range of water activity and temperatures. Moreover, the parameters that obtained from each models were taken into account as a function of temperatures in the temperature range of 4-30°C.

According to the previous studies, the moisture sorption isotherm data was not used for chicken meat at higher temperature than 30°C. During heating, the temperature of the chicken meat was higher than 30°C. The understanding of the relationship between moisture content and water activity during heating at high temperature was necessary. Then the objectives of this study were to determine the moisture sorption isotherm of chicken meat at 5-100°C and 0.11-0.96 of and developed the sorption isotherm equation to predict at the surface of chicken meat. However, the moisture sorption isotherm equations were used to predict the water activity of chicken breast surface during heating when the moisture contents were known.

MATERIALS AND METHODS

Sample preparation

Raw boneless chicken breast meat was bought from a local market. The skin was removed and the meat was cut into small pieces of approximately 0.2 mm of thickness by kitchen knife.

Measurement of moisture sorption isotherm

The sample was put into aluminum foil and placed into a jar. Five analytical grade salts were used to make the saturated salt solutions at different water activities (= 0.11 with LiCl, = 0.33 with $MgCl_2$, = 0.58 with $Mg(NO_3)_2$, = 0.75 with NaCl, = 0.96 with KNO_3). The salt solutions were kept at temperature at 5°C in refrigerator, at air-conditioned room for 25°C and at 40, 60, 80 and 100°C in electrical oven. The sample weights were recorded the at specified time interval until they reached equilibrium.

Equilibration of high humidity samples

The previous study reported by Trujillo *et al*. (2003) mentioned that, at high humidities, the mass transfer is very slow and difficult to reach equilibrium. Moreover, at high fungal and bacterial growth quickly. For this reason it was necessary to accelerate the process by putting the sample in $MgCl_2$, which had the lower humidity (similar procedure was used by Delgado and Sun (2002b) to accelerate the process). The sample was weighed at interval time and then transfered to a high humidity when its weight reached about 20 percent of the equilibrated value.

Moisture sorption isotherm models

The moisture sorption isotherm equations used to fit the experimental data are presented in Table 1. A non-linear regression analysis was applied by plotting relationship between moisture content (%db) and for all temperatures. Each moisture sorption isotherm models (GAB, BET and Peleg) were compared by investigating the root mean square error (*%RMSE*) as shown in equation (2).

$$\%RMSE = \sqrt{\frac{\sum\left(\frac{X_{exp} - X_{model}}{X_{exp}}\right)^2}{n-1}} \times 100\% \tag{2}$$

RESULTS AND DISCUSSION

Changes of moisture content

Changes of moisture content of chicken breast equilibrated at various conditions are shown in Figure 1. It was found that the moisture of

Table 1 Sorption isotherm equation

	Sorption isotherm equation	
GAB	$X = X_m \dfrac{C_G K a_w}{(1-Ka_w)[1+(C_G-1)Ka_w]}$	X : Moisture content X_m : Monolayer of adsorbed water C_G : Guggenheim constant K : Constant that considers the modified properties of the sorbate in the multilayer region
BET	$X = \dfrac{X_m C_b a_w}{(1-a_w)[1+(C_b-1)a_w]}$	X : Moisture content X_m : Monolayer moisture content C_b : Constant related to the net heat of sorption
Peleg	$X = k_1 a_w^n + k_2 a_w^m$	X : Moisture content k_1, k_2, n, m : constant $n < 1$ and $m > 1$

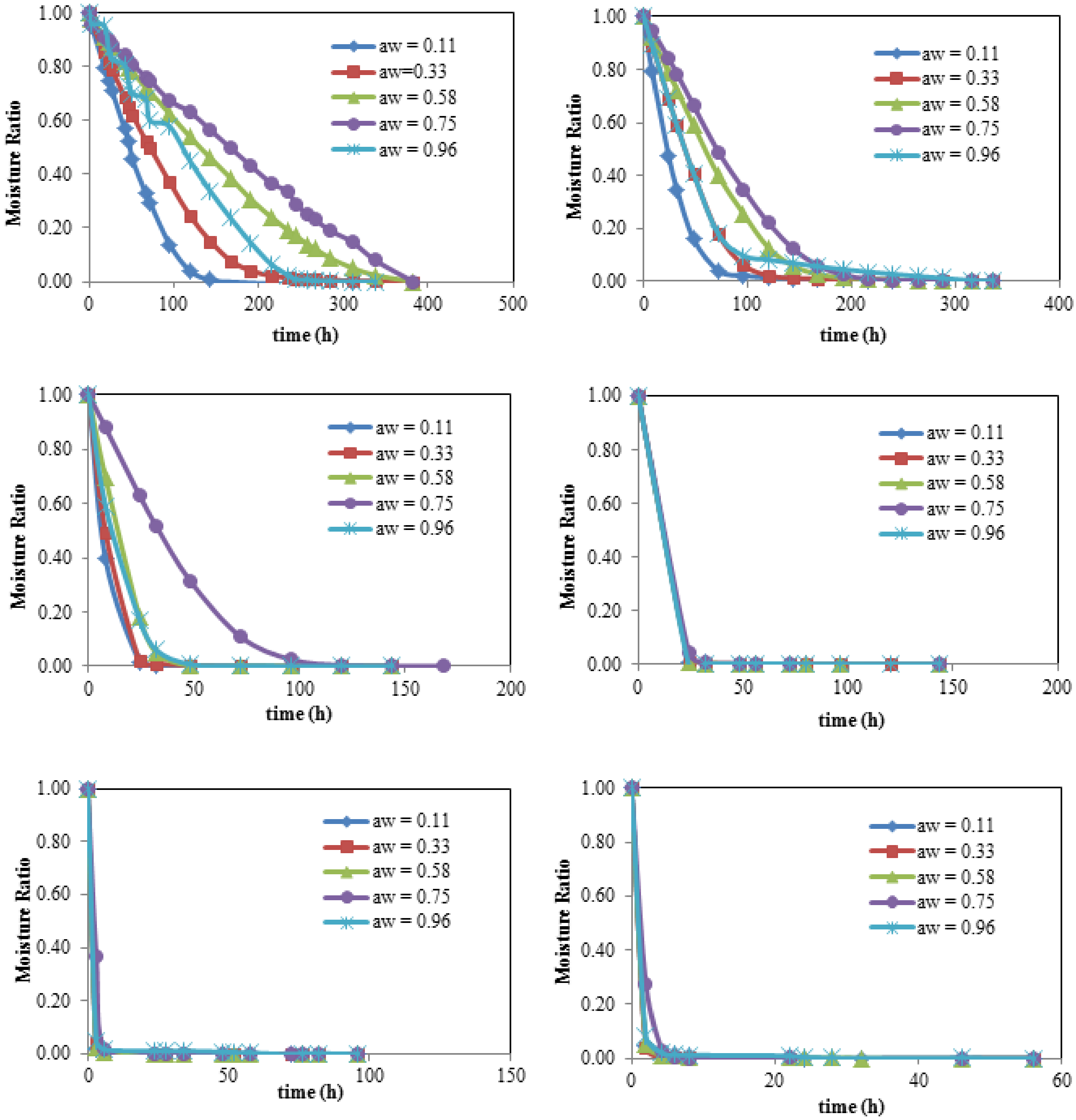

Figure 1 Changes of moisture content of chicken breast equilibrated at various conditions (a).5°C, (b).25°C, (c).40°C,(d).60°C, (e).80°C and (f).100°C

chicken breast was decreased with time until its reached equilibrium. These phenomena were observed in all temperature ranges of the experiment. Moreover, at higher temperature conditions, the equilibrium moisture content became faster than at lower temperature. Moreover, at higher value of, the equilibrium moisture content had a tendency to increase in time for equilibrium due to lower pressure gradient between sample and surrounding.

Moisture sorption isotherm models

For the previous studies of the chicken meat, Timmermann *et al.* (2001) used GAB and BET model. They found that the GAB model was more general meaning and gave best fit with the experimental data. Moreover, Delgado and Sun (2002b) also used the several sorption isotherm models were used to fit the experimental data. They found that the GAB model gave the best fit for all range of water activity and temperatures and the parameters that obtained from each models were taken into account as a function of temperatures.

According to the previous data, GAB and BET model and Peleg model were also used to fit the experimental results. The results found that both of Peleg model and GAB model gave the best fit with the experimental results with root mean square error (*%RMSE*) in the range of 3-13% as shown in Table 2. Trujillo *et al*. (2003) mentioned that the Peleg equation can predict both sigmoidal and non-sigmoidal isotherm. The Peleg model fitted as well as or better than the GAB model but the parameters that obtained from Peleg model have no physical meaning while the GAB equation is a semi-theoretical multilayer sorption model with a physical meaning for each constants meaning (Timmerman *et al*., 2001). Then the GAB model was selected to describe the relationship between moisture content and water activity of this study.

The relationship between moisture content and water activity or moisture sorption isotherm of chicken breast at temperature range 5-100°C by GAB model are shown in Figure 2. It was found that when the temperature increased, resulted in decreased equilibrium moisture content due to the higher temperature gradient between sample and surrounding. When compared the data at the same moisture content, the water activity at higher temperature was higher than lower temperature, this due to the higher partial pressure of sample.

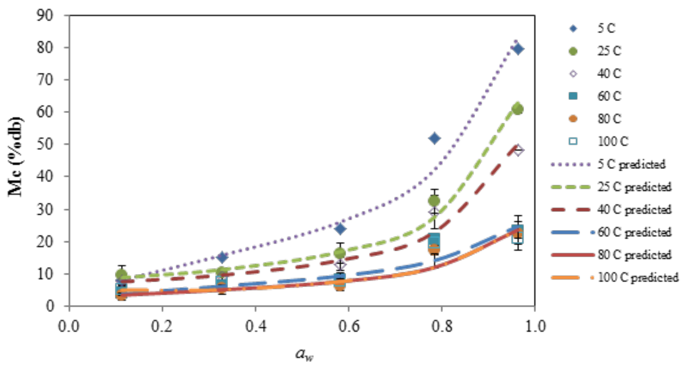

Figure 2 Moisture sorption isotherms by GAB model at various temperatures

The parameters of GAB model obtained from the experimental results were taken into account as a function of temperatures by comparing with the previous studied of Delgado and Sun (2002b) as shown in Table 3. It was found that the model parameter equation of monomolecular layer of adsorbed water (*Xm*) was closed together with the previous studied while the parameters of *K* and *Cg* were different due to the higher range of studied temperature. Table 4 shows the estimated parameters of GAB model**,** it was found that in the temperature range of 5-25°C the model parameters of *Xm* and *K* of both study was closed together. The results also showed that *Xm* had a tendency to decrease with increased in temperature. This behavior had also been reported by Delgado and Sun (2002a) and Delgado and Sun (2002b). These sorption isotherm equations could predict the relationship between and moisture content at the wider range of temperature (5-100°C) than previous studied.

Table 2 Model parameters of sorption isotherm

Model		Temperature (°C)					
		5	25	40	60	80	100
GAB	X_m	14.328	7.9582	6.799	5.1182	3.8829	3.7071
	C_G	9.5059	59,862.20	25,873.43	20.4219	36.7577	3.4207
	K	0.8636	0.9078	0.8983	0.8263	0.869	4.0461
	%RMSE	5.37	5.30	6.12	8.86	9.60	12.83
BET	X_m	1,778.99	867.0229	871.3715	1,527.18	645.4103	4.8878
	C_b	0.0276	0.0374	0.0318	0.0121	0.023	5.4273
	%RMSE	11.14	16.68	17.15	15.69	17.85	12.81
Peleg	k_1	23.7101	9.1734	8.9361	7.1028	6.5803	0.7769
	k_2	69.3227	60.5306	48.0122	20.4248	21.0225	0.9867
	$n < 1$	0.4821	-0.0205	0.06	0.2732	0.2882	-0.8507
	$m > 1$	4.0701	3.953	4.0855	3.3831	4.5512	1.0288
	%RMSE	3.46	0.26	3.15	7.64	8.35	12.55

Table 3 Parameters of GAB model taken into account the effect of temperature

GAB (Experiment)	GAB (Delgado and Sun, 2002)
$X_m = 0.0016T^2 - 0.2726T + 15.017$	$X_m = 0.0116T^2 - 0.4589T + 11.009$
$K = 5E\text{-}07T^4 - 8E\text{-}05T^3 + 0.0039T^2 - 0.0689T + 1.1273$	$K = -0.00001T^3 + 0.0006T^2 - 0.0034T + 0.9419$
$C_G = 0.0004T^5 - 0.1167T^4 + 14.367T^3 - 796.42T^2 + 17854T - 71072$	$C_G = 1.4357T^3 - 77.248T^2 + 1144T - 3423.2$

Table 4 Estimated parameters of GAB model

Temperature (°C)	GAB (5-100°C) (Experiment)			GAB (4-30°C) (Delgado and Sun, 2002)		
	X_m	K	C_G	X_m	K	C_G
5	12.602	0.8649	55.56	14.328	0.864	9.506
15	10.661	0.7414	104,460.73	7.958	0.908	59,862.20
25	8.942	0.8239	76,692.62	6.799	0.898	25,873.43
40	6.771	0.8614	9408.05	N/A	N/A	N/A
60	4.649	0.3094	32,432.23	N/A	N/A	N/A
80	3.407	0.4026	136,624.54	N/A	N/A	N/A
100	3.045	0.7414	417,216.92	N/A	N/A	N/A

N/A = Data not available

CONCLUSION

Moisture sorption isotherm for a temperature range 5-100°C were obtained for the chicken breast. The several models equations were used to fit the experimental data. The Peleg model fitted as well as or better than the GAB model for all range of but the parameters that obtained from Peleg model have no physical meaning while the GAB equation have more physical meaning for each parameters. The parameters obtained by the GAB model were taken into account as a function of temperatures. Moreover, these sorption isotherm equations could predict the relationship between and moisture content at the wider range of temperature (5-100°C) than the previous studies.

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