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Contributed Paper

Shelf Life Study of Salted Crackers in Pouch by Using Computer Simulation Models

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ABSTRACT

Sorption isotherm of the salted crackers was determined in humidity control chambers (relative humidity range 1-72%). A low density polyethylene (LDPE) was used as a packaging material and its water vapor transmission rate (*WVTR*) and permeability coefficient (*P*) was characterized. Then, storage stability of packaged products was conducted at 25C and 50% RH. Finally, the predicted shelf life of the products determined by computer simulation method (linear and non-linear models: Guggenhein-Anderson-de Boer (GAB), log, middle and two-point models) was compared to the actual shelf life. The salted crackers exhibited Type II behavior and packaged products had the actual shelf life for 36 days. From various simulation shelf life models tested, GAB model gave the best fit for the salted crackers in sealed pouch.

Keywords : shelf life, models, salted crackers.

1. INTRODUCTION

Shelf life is the length of time that a container, or a material in a container, will remain in a saleable or acceptable condition under specified conditions of storage [1, 2]. The shelf life depends on series of variable parameters, first the product characteristics such as physical, chemical and biological characteristic, second, processing conditions, third, package characteristics and effectiveness, and finally, the environment to which the product is exposed during distribution and storage [2, 3]. Moisture sensitive foods are susceptible to change in their environment and if it left opened will first become stale. Water migration and diffusion is considered to be one of the most important factors for the moisture sensitive foods. Moreover, enzyme activity and oxidative rancidity will occur as the water activity increases [4]. Therefore, package is used as a barrier that is mostly to provide resistance to the passage of gases, vapors and odors. The package system would select to maintain the desired product quality for the required shelf life period. There are three methods of shelf life evaluation. First, actual storage testing is a long-term stability study by storing a packaged product under particular storage conditions of temperature and relative humidity. Samples are examined at interval and the degradation factor is recorded. However, this method is time consuming and expensive. Second, accelerated tests are the techniques which are able to predict product quality by subjecting the product/package system to extreme temperature and humidity conditions for a period of time, and then correlate these data with ambient storage conditions to determine a correlation coefficient. Then the correlation coefficient is used for converting from shelf life at the accelerated condition to ambient storage condition. Finally, simulation and model-based estimation is a technique which involving combining expressions for product sensitivity, package effectiveness, and environmental severity into a mathematical model [3, 5]. From simulation technique, the moisture content of the product at any given time for a defined storage condition can be predicted. From knowing the critical moisture content from the experiment, the packaged product shelf life is thus determined.

Salted cracker is one of the moisture sensitive products. Its typical moisture content is between in range 2-8% [6]. Uptake of water vapor is the most important factor to cause the product deterioration. Therefore, package is needed to function as water vapor barrier during the storage time. In this study, the actual shelf life of the salted crackers in pouches was determined and compared with the shelf life by using computer simulation for providing a better understanding of the selection and the use of best-fit model for accurately prediction product shelf life. This experiment assumes that the shelf life is only dependence on the physical and chemical factors, which are related to moisture content.

2. Materials and Methods

Salted Cracker (Meijer) was bought from Meijer, East Lansing, MI, USA. LDPE pouch [thickness 1.25 mil and dimension 4”x4”] was used as packages for salted cracker.

2.1 Determination of Initial Moisture Content (M_i)

Each of three aluminum dishes was weighted. Two to three grams of salted crackers were added in each dishes and reweighed. Next, these samples were dried in vacuum oven at 80°C under 30 inches Hg for 6-8 hours. Then samples were taken out and leaved in the desiccators for cooling about 10 minutes before reweighing. M_i on a dry weight basis was determined by using equation 1 [1]:

$$M_i = \frac{W_M - W_D}{W_D} x100 = \%\ dry\ basis \qquad (1)$$

where W_M is initial weight of product sample and W_D is weight of product sample after dry.

2.2 Determination of Equilibrium Sorption Isotherm for Salted Crackers

A sorption isotherm for the salted cracker is desired at 22°C. Different humidities are obtained by using saturated aqueous salt solutions in contact with an excess of the solid (salt) phases. These are already prepared and placed in the 5-gallon buckets using the condition as shown in Table 1.

Table 1. Relative Humidity Control Chamber (Temp. 22 ± 1 °C).

Chamber #	Equilibrium (Expected) % RH	Actual Reading % RH (±0.5 %)
1. Lithium Chloride	12.0	10.6
2. Potassium Acetate	22.7	19
3. Magnesium Chloride	33.2	32.8
4. Potassium Carbonate	43.8	43.2
5. Sodium Nitrate	64.3	63.0
6. Sodium Chloride	75.8	72.5

Each aluminum dish was weighed and then weighed again after adding approximately 2 to 4 grams of sample in each dish. Data points would thus be the average of duplicate runs. These dishes were then placed over the saturated salt solutions in the closed buckets. Six different relative humidities was used (two replicates x 6 relative humidities = 12 samples). These samples are weighed after a 6-day period and then are weighted every 3-day interval until negligible change in weight is observed. Since no further weight gain or loss of moisture is observed, it is assumed equilibrium has been reached. The equilibrium moisture content (M_e) of samples at each specific relative humidity was determined by using equation 2 [1]:

$$M_e = \frac{W_e}{W_i}(M_i + 1) - 1 \quad (g/g\ dry\ product) \qquad (2)$$

where, W_e is total weight (dry weight + water) at equilibrium (g), W_i is initial weight (g) and M_i is initial moisture content (g/g). Thus, a sorption isotherm was constructed by plotting between %RH and %M_e.

2.3 Determination of Permeability Properties of Package

Three individual pouches were weighted before putting 10-15 g of desiccant in each of pouches and then sealing by an impulse sealer (150°C, 2 sec). The sealed additional empty bags were used as a control sample. The samples were hanged on the storage rack store at 25°C, 50% RH. Then these samples were weighed every 3 days until weight gain reaches constant. Water vapor transmission rate (*WVTR*) of pouch can be determined from slope of a graph between storage time and weight gain. The thickness and surface area of pouches were measured. The permeability coefficient (*P*) was calculated by using equation 3 [7]:

$$P = \frac{WVTRxl}{A.\Delta p} \quad (Kg.m/m^2.s.Pa) \qquad (3)$$

where WVTR = Water Vapor Transmission Rate, Kg/s

l = Film Thickness, m

A = Surface area of package, m^2

Δp = $p_s(\Delta RH/100)$

= The difference of relative humidity between outside and inside package

p_s = The absolute vapor pressure at 25°C = 23.756 mmHg.

2.4 Determination of Storage Stability of Packaged Product

Three individual pouches were weighted before putting 10-15 g of cracker in each of pouches and then sealing by an impulse sealer (150°C, 2 sec). The sealed additional empty bags were used as a control sample. The samples were hanged on the storage rack store at 25°C, 50% RH. Then samples were reweighed 3-day intervals until weight gain reached constant. Equilibrium moisture content (M_e) at each interval time was determined by using equation 2.

Shelf life of the packaged product was determined from a graph between storage time and equilibrium moisture content (M_e) which is correspondent with a critical moisture content.

2.5 Computer Simulation

Experimental data were input in the program, which was developed by Thanprasert [8]. The shelf life of packaged product was determined by using linear and non-linear models (Guggenhein-Anderson-de Boer (GAB), log, middle and two-point models). The results obtained from storage stability were compared with these of computer simulation. The experimental design can be described in the flow chart Figure 1.

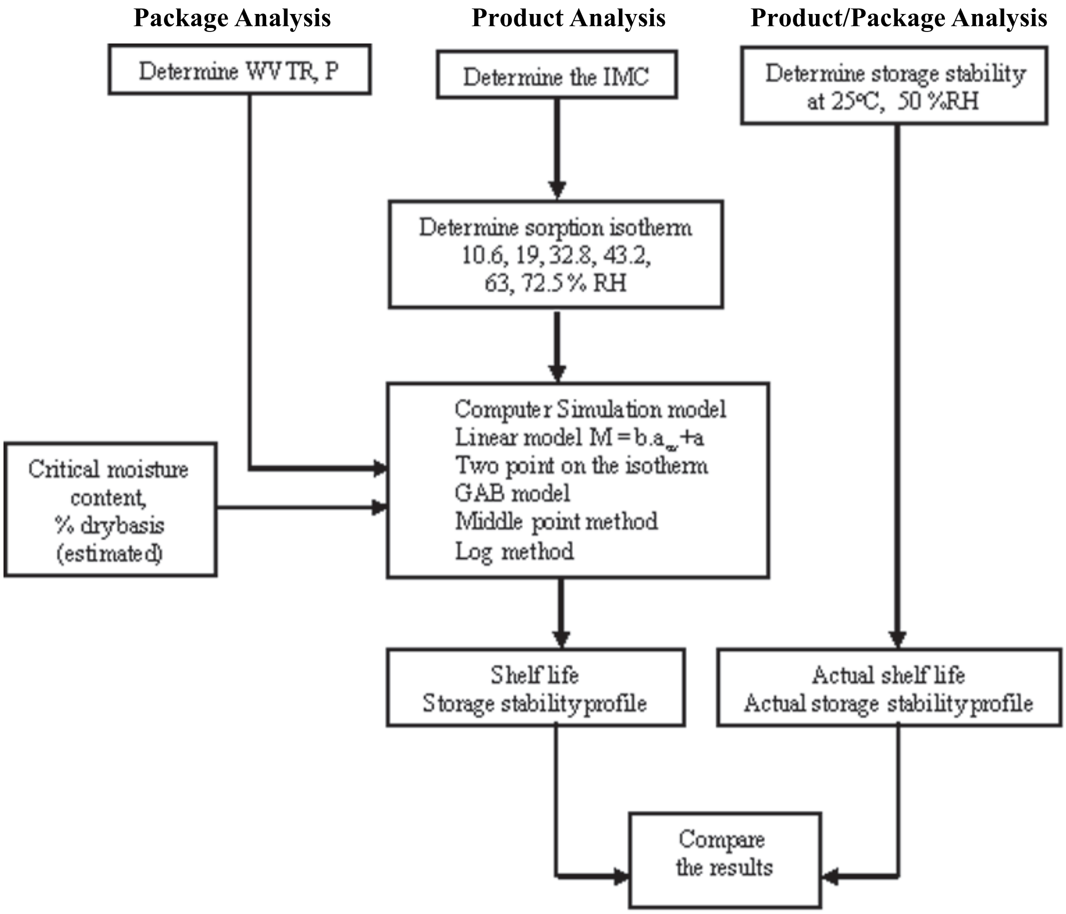

Figure 1. Flow Chart of the experimental design for shelf life simulation.

3. RESULTS AND DISCUSSION

3.1 Sorption Isotherm of Salted Crackers and Predictive Models

The salted crackers had an average of initial moisture content 2.45 11 % dry product which is a low moisture content. Therefore, this product is susceptible to absorb moisture from the surrounding atmosphere. In this experiment, the salted cracker is considered as a moisture sensitive food, thus the package is used to function as a moisture barrier [4]. The salted crackers were put into the different %RH condition and determine weight loss or gain with time. Figure 2 shows that all samples absorbed water until reached the equilibrium point at 8th day storage (since the rate was far less than 5%). After the equilibrium point, weight would be constant. Moreover, Figure 2 shows that in different % RH, the higher %RH will gain the higher weight.

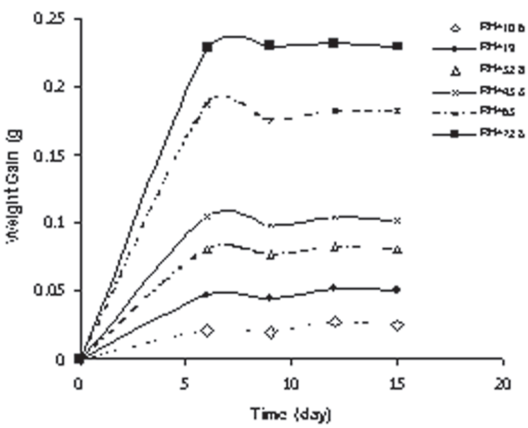

Figure 2. Weight Gain of the Samples in Different Percent Relative Humidity.

After obtaining weight gain data from experiment, the calculation for equilibrium moisture content was taken to construct a sorption isotherm of salted crackers. Figure 3 shows the salted crackers follow the S shape curve represented as a type II isotherm (typical type for moisture sensitive food) similar to those observed for flakes [9] starches [10, 11]. As shown in Figure 3, at the low %RH, the sorption isotherm of the sample increase slowly, but it does rapidly increase at high % RH.

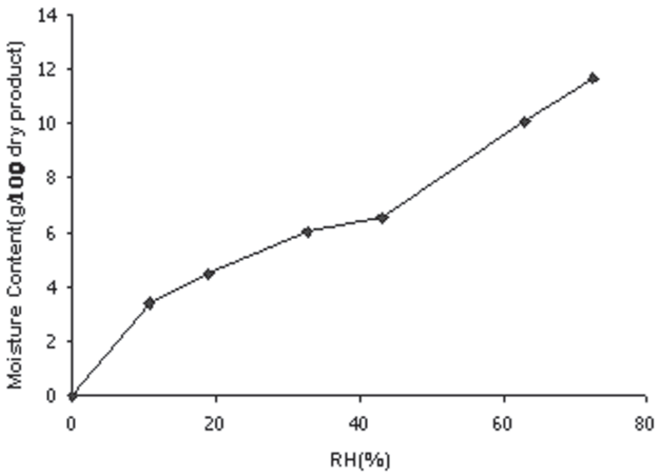

Figure 3. Sorption isotherm of salted crackers (experimental data).

Next step various models were chosen to fit the data (plot between A_w (water activity) and M_e) such as linear model, quadratic model and GAB model. The linear model using linear regression to fit the experiment data is presented in Figure 4. While quadratic model graphically shows in Figure 5 and GAB model shows in Figure 6.

The quality of fit can be evaluated by the root mean square (RMS, %). The better fit, the lower the RMS. It was found that the RMS of linear, quadratic and GAB model are 13.28 11%, 12.99 67% and 2.91 18% respectively. Therefore, GAB model is the best fit with the experimental data.

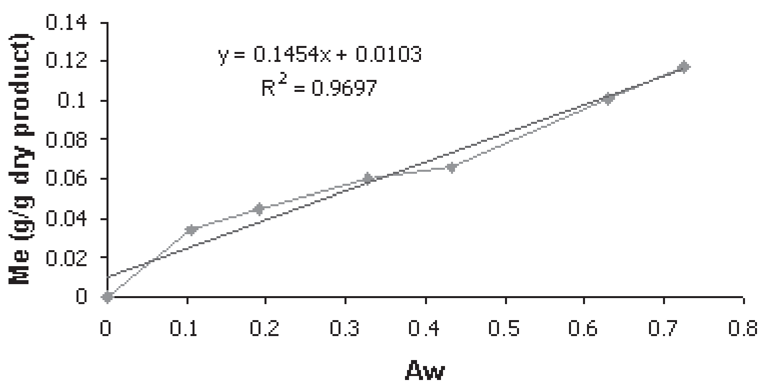

Figure 4. Sorption isotherm of salted crackers fitted by linear model.

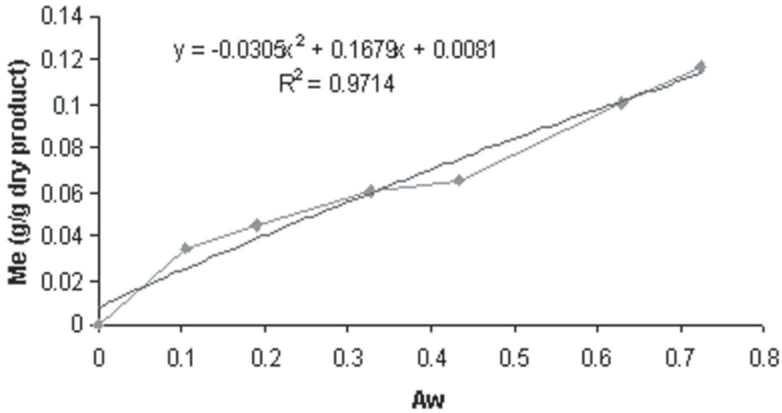

Figure 5. Sorption isotherm of salted crackers fitted by quadratic model.

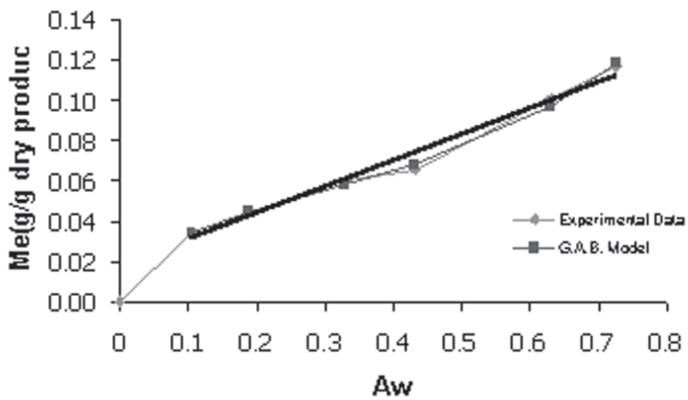

Figure 6. A plot between experimental data and calculated data from GAB model.

3.2 Permeability Property of Package

Water vapor transmission rate (*WVTR*) is the property, which is exceedingly important to packaging moisture sensitive food. The *WVTR* is determined by the characteristics of the polymer itself by orientation, the degree of crystallinity, and other factors. The slope of a plot between weight gain and storage time is *WVTR* which has and average of 0.0154 g/day (Figure 7). To characterize the permeability constant to the package, the permeability coefficient calculated form obtained *WVTR*, thickness (l), surface area (A), and gradient of partial pressure (Δp).

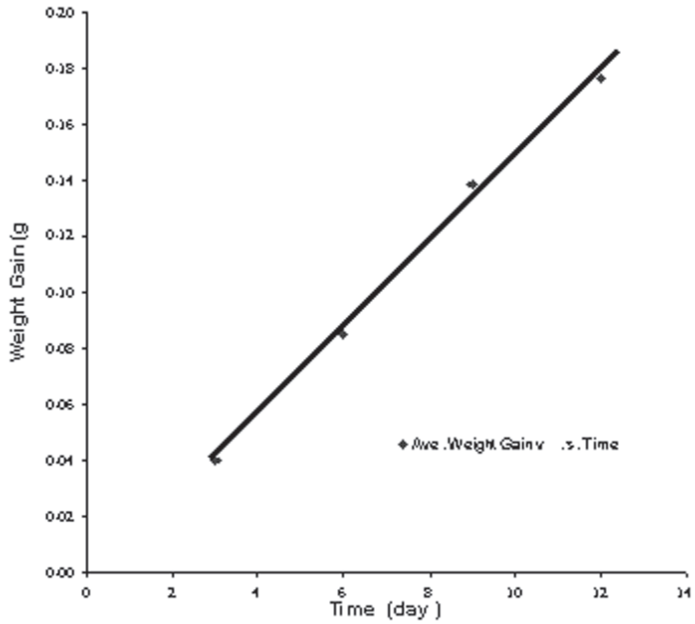

Figure 7. A plot of linear trend weight gain of pouches under storage condition at 25°C, 50 % RH and storage time.

3.3 Storage Stability of Packaged Product

To verify the reliability of the predicted shelf life from computer simulation of the storage stability of packaged product is essential to be conducted under the study condition at 25°C and 50% RH. By monitoring the weight gain over time, it was found that the weight gain rapidly increased in the range 3-18 days, and almost constant during day 21-28 and then slowly increased until reaching 36 days then the weight become constant. Plots of weight gain and average weight gain of packaged product as a function of time is shown in Figure 8.

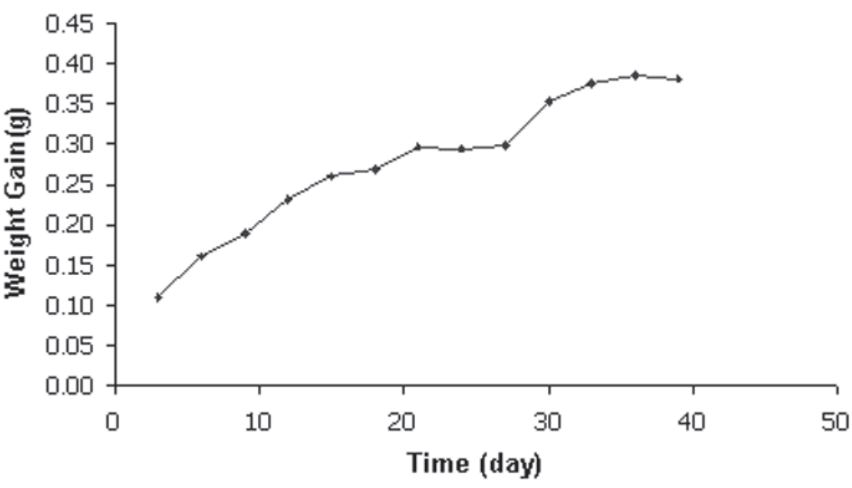

Figure 8. A plot of average weight gain of package products under storage conditions at 25°C, 50% RH as a function of time.

Table 3. The summary of the predicted shelf life from computer simulation models and actual shelf life.

Shelf Life	Day	% Difference between Actual Shelf Life and Shelf Life from Computer Simulation
Actual shelf life	36	-
Linear model	54	50
Two point on the isotherm	48	33.33
GAB model	22	-38.89
Middle point	47	30.56
Log method	47	30.56

For the safety reasons for consumer, the predicted shelf life should be shorter than actual shelf life. If the models are over estimated, it means that the end of shelf life for the product happen before predicted shelf life from the model. For example, if the actual shelf life is 36 days, but the predicted shelf life from a model is 47 days. It means the product has already spoiled, but the models predict that it does not spoil yet, which does not safe for consumer. Therefore, a good model must provide predicted shelf life shorter than the actual shelf life. Moreover, the predicted shelf life should be close to the actual shelf life as much as possible. For example, the actual shelf life is 36 days and model can predict 35 days and model B can predict 30 days. The model A gives more accuracy than model B. Thus, predicted shelf life from model must be shorter than actual and close to the actual shelf life.

From the Table 3, the linear model is the worst for shelf life prediction when compared with the actual shelf life. GAB model predicted shelf life of the salted crackers/ package system shorter than the actual shelf life. The shelf life is under estimate around 38.89%. Typically GAB model is a good model for predicting the product that has only one component, but in this experiment, salted cracker composes of a lot of salt which may cause effect on the prediction of GAB model. The shelf life of the other models is over estimated. Even if middle point method and log method are the closest predicted shelf life (47 days) when compare with the actual shelf life, both of those methods are still over estimated for shelf life. The two points on the isotherm method are very subjective to the points that were selected for calculation. If the two points are selected inappropriate, the simulated shelf life will be far away from the actual shelf fife. If the two points are appropriately selected, the simulated shelf life will be close to the actual shelf life. In this study, two points model is also over estimated.

Therefore, GAB model is the most appropriate model to use for predicting the shelf life of salted cracker, even though it is under estimated.

It proves that non-linear model provides better shelf life prediction than the linear model. Moreover, the result that RMS of GAB is better fit with the experimental isotherm than linear model is supportive information to conclude that the shelf life simulation from non-linear model is more accurate than that of linear model. The deviation between the predicted shelf life and the actual shelf life is mostly affected by the sorption isotherm and the critical moisture content.

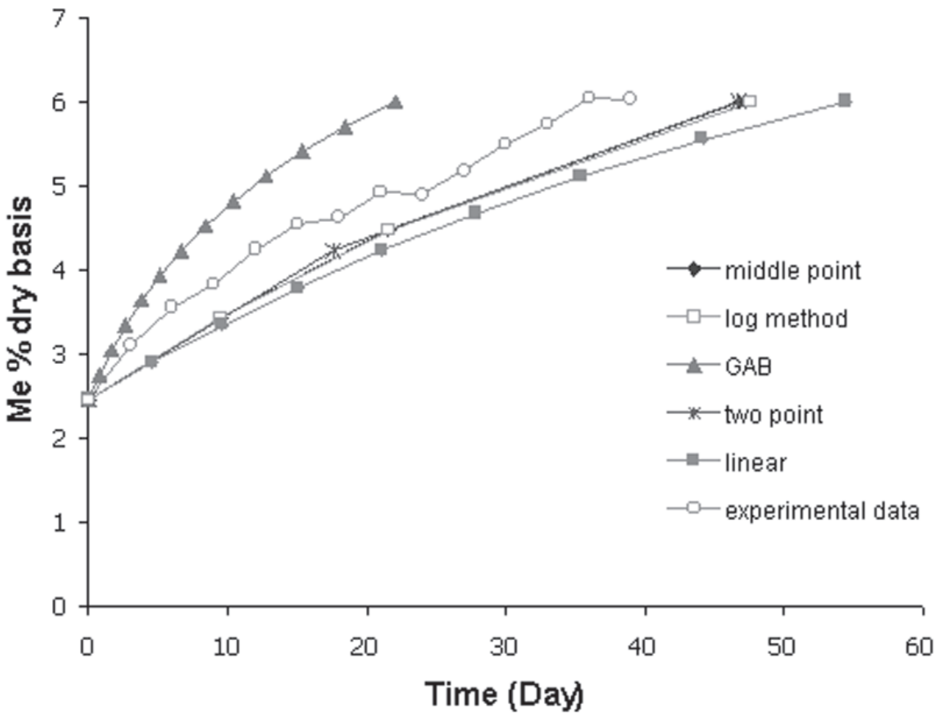

Figure 9. A comparison between predicted storage stability and actual shelf life.

From Figure 9, it shows graphically a comparison between the predicted storage stability and actual storage stability. The predicted storage stability from different simulation method increases overtime in the same pattern until reaching critical moisture content around 6 % dry basis considered as the end of shelf life. The equilibrium moisture content from actual storage stability is higher than the predicted moisture content in over all storage time, except the equilibrium moisture content from GAB model is higher than the actual value. The GAB model is the highest predicted value while linear model provides the lowest predicted value. The middle point and log methods are the closest predicted value to the actual value. However, the computer simulation model is only a tool for calculation for shelf life. The reliability of predicted shelf life from model is dependent on an accuracy of the input data. The more accurate data is input, the better the shelf life is predicted.

4. Conclusion

The shelf life of salted crackers in the pouches stored at 25°C, 50% RH is effectively predicted by computer simulation. It only needs a small experiment to get a sorption isotherm for particular product and permeability constant for particular package.

Over all evaluation, non-linear model provides better shelf life prediction than the linear model for salted crackers/package system. Shelf life from two points, log and middle point models are over estimated. They are not appropriate for predicting the shelf life. Only shelf life from GAB model is under estimation. Therefore, GAB model is the most appropriate model to use for predicting the shelf life of salted cracker.

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