

Research Article

Shelf life analysis of hot curry cubes

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Abstract: Hot curry (*Gaeng Ped*) cube is a new ready-to-cook product which is developed from hot curry paste, a popular traditional food ingredient of Southern Thailand. A study where the hot curry cubes were wrapped in metallized film (MCP/OPP) and packaged in bags made of different materials was conducted to determine their influence on changes of product quality and shelf life. The quality and shelf life determination of the product was predominantly based on texture stiffness. It was found that the moisture content was a key factor affecting the quality as it caused cracks and soggy product texture, consequently unacceptable to the consumer. The sorption isotherm at 30°C followed the j-shaped curve represented as a Type I isotherm. The best fit to the sorption isotherm was the linear model, exhibiting the r^2 of 0.9606. Product stability curves confirmed that the linear model was suitable for estimating the shelf life of product with a %RMSE in the order of 2-3%. The product wrapped in metallized film and packaged in Nylon/LLDPE bag was the most effective package. From linear model simulation results, a product in this package could last for 1 year 4 months to 1 year 11 months at storage conditions of 30°C, 80-75% RH.

Keywords: shelf life, linear model, isotherm, packaging, storage

Introduction

Hot curry (*Gaeng Ped*) is a typical Southern Thai recipe, especially in Krabi, Nakhon Si Thammarat, Surat Thani and Songkhla where most of its ingredients are grown. It is one of the favourite curries in this region. The hot curry is generally prepared from paste which is composed of herbs and spices such as red chili, garlic, shallots, ginger, galangal, lemon grass, coriander root, cumin seed, turmeric and shrimp paste. In the traditional way, the hot curry paste is sold within one or two days without refrigeration and this can be extended to one or two weeks if refrigerated. The short shelf life of hot curry paste generally is due to the microbiological spoilage from molds and bacteria.

For the purpose of improving shelf life, hot curry cube is made from paste by mixing it with binding agents and subjecting it to warm air drying until reaching the optimum moisture content, and finally, it is formed into cubes. This shelf stable product is expected to improve market expansion with increased shelf life, convenient preparation, as well as energy savings in both handling and storage. The hot curry cube contains around 17% moisture, 8% protein, 5% fat and 12% salt. In addition, the water activity of the hot curry cube is around 0.55-0.58 at its initial moisture content which can be classified as an intermediate moisture food (Labuza, 1984). As a result, deteriorative reactions may occur from gain or loss of moisture, lipid oxidation and microbiological spoilage during long term storage. Moisture content in food is one of the predominant factors that affects the physical, chemical, microbiological and sensory properties which are the key properties for consumers and shelf life (Robertson, 1993). The control of moisture content is crucial for the quality and safety of the product and all aspects are considered in shelf life analysis. The shelf life of intermediate moisture food can be simulated by the mass transfer characteristics of the package-product system. Some of the early work on mathematical prediction models for shelf life was successfully done by many investigators (Iglesias *et al.*, 1977; Veillard *et al.* 1979; Nakabayashi *et al.*, 1980). Most of this work reported considerable experimental data on various package-product systems that verified the accuracy of prediction models. Iglesias *et al.* (1977) used the linear model to fit sorption isotherms and predict the moisture gain by packaging dried beef. For this product, the model successfully predicted over the whole range of relative humidity studied. Sapru and Labuza (1999) applied an explicit finite difference scheme to simulate moisture migration in multi-component breakfast cereal systems. The GAB isotherm model was used and the simulation accurately predicted the moisture gain by cereal at 25°C and 75% RH and loss from raisins when kept at 25°C and 11% RH. Guillard *et al.* (2003) reported that the mathematical model based on Fick's second law effectively modelled the moisture transfer of dry biscuit at 20°C. The model was successfully validated with a lower agar gel a_w (0.90) and also with an acetylated monoglyceride film at the interface of biscuit and agar gel.

The objectives of this work were to determine the suitable barrier packaging film for the hot curry cubes and to analyze the shelf life of the hot curry cubes by using a mathematical model.

Materials and Methods

Product

Hot curry cubes were prepared according to the formula and process developed by Ban Tung Lady OTOP group, Krabi and the Faculty of Agro-Industry, Prince of Songkla University, Songkhla, Thailand. Each cube weighing 8.75g (2 cmx2.5 cmx2 cm) was wrapped with metallized film (MCP/OPP) and stored at 14°C before testing.

Package

Two different films were used in this investigation. The first is 30 µm thick PP and the second is 90 µm thick Nylon/LLDPE.

Determination of initial and critical moisture content

The initial moisture content (IMC) was determined according to AOAC (2000) and the water activities of the product were determined by using MS1 Laboratory Instrument Aw (Novasina, Pfaffikon, Switzerland). The critical moisture content is identified as the point at which the deterioration of the product reaches an unacceptable level. It was performed by placing the product over a water dish in an airtight container at 30°C. The product was periodically examined for texture firmness and sensory evaluation (Meilgaard *et al.*, 1999). The texture firmness test was carried out by using TA. TX2 Texture Analyzer (Texture Technologies Corp., Scarsdale, NY, USA), equipped with a standard plunger (ϕ 6 mm) at a crosshead speed of 100 mm/min. The critical moisture content was defined when the product lost texture firmness to a level at which it was rejected by the panelists. This reject level was correlated with the texture firmness value.

Determination of water vapour permeability coefficient

In this experiment, the water vapour permeability coefficient of test films was determined by using ASTM D 3079. This method is based on the gravimetric method and was conducted at 30°C and 38°C.

Determination of moisture sorption isotherm of product

The moisture sorption isotherm of hot curry cube was gravimetrically determined by using Proximity Equilibrium Cell method (Lang *et al.*, 1981). Five saturated salt solutions were prepared to generate the constant water activities of storage conditions from 0.43 to 0.84 at 30°C. The water activities of storage conditions were measured by means of a humidity meter (Vaisala, Helsinki, Finland, Model HM70). To fit the sorption isotherm curve, the linear function (Iglesias *et al.*, 1977) was applied and can be expressed as follows:

$$M = \beta \cdot a_w + \alpha \quad (1)$$

where m is the equilibrium moisture content of product, a_w is the water activity of storage conditions, β is a slope of the moisture sorption isotherm, α is a constant.

Calculation and verification of shelf life of product

The simplest shelf life calculation when the isotherm is treated as a linear function is the linear model (Labuza, 1982). The model can be expressed as follows:

$$t = \left[\frac{\lambda \cdot w_d \cdot \beta}{P \cdot A \cdot p_s} \right] \cdot \ln \left[\frac{a_{w_0} - a_{w_{t=0}}}{a_{w_0} - a_{w_{t=t}}} \right] \quad (2)$$

where w_d is the weight of dry solids in the packaged food, l is the thickness of packaging film, P is the water vapour permeability coefficient, A is the package surface area, p_s is the saturated vapour pressure of pure water at the storage temperature, a_{w_0} is the water activity of storage conditions, $a_{w_{t=0}}$ is the initial water activity of product, $a_{w_{t=t}}$ is the critical water activity of product at time = t , β is a slope of the moisture sorption isotherm.

The verification of shelf life calculation was performed by using the actual package-product storage test. Each sample contained eight hot curry cubes which were wrapped individually in metallized film (MCP/OPP) and packaged in a bag made from test films. All samples were stored at 38°C, 90% RH for 12 weeks. The samples were regularly examined for the equilibrium moisture content. The percentage root mean square error

(%RMSE) was used to evaluate the goodness of fit between the experimental moisture content values and the predicted moisture content values. The better the fit, the lower the %RMSE (Eq.(3)).

$$\%RMSE = 100 \cdot \sqrt{\frac{\sum_{i=1}^N (m_e^i - m_p^i)^2}{N}} \quad (3)$$

where m_e and m_p are the experimental and predicted moisture content respectively, and N is the number of experimental data.

Results and Discussion

Initial and critical moisture contents

The hot curry cube initially contained moisture content of 20.60% dry basis (d.b.) which corresponded to an a_w of 0.58. The results indicated that the product could be classified as an intermediate moisture food (Labuza and Fu, 1993). The critical moisture content and critical water activity were 25.79% d.b. and 0.64, respectively. Maximum texture stiffness decreased from 2,627 g force at the beginning of storage to 1,503 g force at the unacceptable level according to the sensory evaluation. The texture stiffness of hot curry cube was reduced by 43% due to moistening of the product. A lack of texture stiffness coincided with dissatisfaction of appearance as well; the product showed cracks and soggy texture. This was then considered as the end of shelf life.

Water vapour permeability coefficient

The water vapour permeability coefficients of test films at 30°C and 38°C are presented in Table 1. It can be inferred from the data shown in Table 1 that the permeability coefficient is the temperature dependence and that the Nylon/LLDPE is more sensitive to the increase in storage temperature than PP. The results also indicated that PP has better water vapour barrier properties than Nylon/LLDPE. As one would expect the water permeability coefficient of PP is lower than Nylon/LLDPE due to the composition of non-polar group in the polymer structure.

Table 1. Thickness and permeability coefficients of test films.

Test film	Thickness (μm)	Temperature (°C)	Permeability ($\text{g}\cdot\text{mm}/\text{cm}^2\cdot\text{day}\cdot\text{mmHg}$)
PP	30	30	3.56×10^{-7}
	30	38	3.65×10^{-7}
Nylon/LLDPE	90	30	7.83×10^{-7}
	90	38	8.40×10^{-7}

Moisture sorption isotherm of product

A moisture sorption isotherm of the hot curry cube at 30°C for a_w ranging from 0.43 to 0.84 is shown in Figure 1. It followed the j-shaped curve represented as a Type I isotherm (Labuza, 1968). The equilibrium moisture content of hot curry cube increased slowly in the range of 0.43-0.58 a_w and rapid change in high equilibrium moisture uptake was observed for a_w between 0.74 and 0.84. The shape of sorption isotherm curve is a typical

curve for an intermediate moisture food containing high sugar and salt. Similar results were observed by Falade and Aworh (2004) in osmo-oven dried African star apple and African mango slices. The linear function (Eq.(1)) with 118.38 and -51.417 values for β and α parameters, respectively, was successful to model the sorption curve with coefficient of determination (r^2) of 0.9606. The simplification of the linear function and the goodness of fit to the experimental data proved the benefit of this linear function.

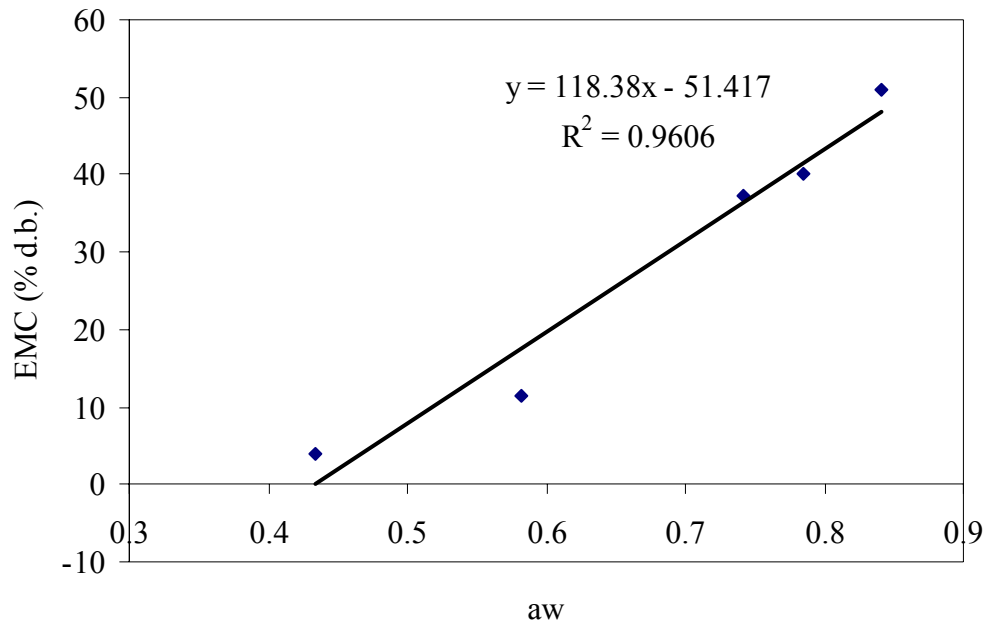


Figure 1. Moisture sorption isotherm of hot curry cube at 30°C.

Calculation and verification of shelf life of product

It is reasonable to apply the linear model to predict the shelf life of hot curry cubes since the linear function well described the moisture sorption isotherm. Equation 2 was used to calculate the shelf life of product and the predicted shelf live of product in all packages and different storage conditions as shown in Table 2. The results strongly suggest that Nylon/LLDPE extended the shelf life of hot curry cubes more efficiently than PP. Although the moisture barrier properties of PP were better than Nylon/LLDPE, the thickness of Nylon/LLDPE was three times that of PP and resulted in considerably longer shelf life. In addition, Nylon/LLDPE has better flavour, gas barrier and mechanical properties than PP due to the strong polar group in the polymer structure (Stöllman *et al.*,2000).

Table 2. Predicted shelf life of hot curry cubes in packages at different storage conditions.

Package	Temperature (°C)	Relative humidity (%)	Shelf life (day)
PP	30	75	511
	30	80	358
Nylon/LLDPE	30	75	697
	30	80	489

The verification of shelf life of product was performed at the accelerated conditions (38°C, 90% RH). The equilibrium moisture content, EMC, between the actual package-product systems and the predicted values were plotted versus storage time as shown in product stability curves (Figures 2 and 3). The percentage root mean square error (%RMSE) was used to show the quality of model fitting. The low percentage RMSE indicates the small percentage difference between the predicted value and the experimental value. In both test films, the linear model successfully predicted the equilibrium moisture content evolution profile with the %RMSE values of 2.38 and 1.88%. The linear model can thus be considered a reliable tool for predicting the equilibrium moisture content evolution profile with time for hot curry cubes in different packages.

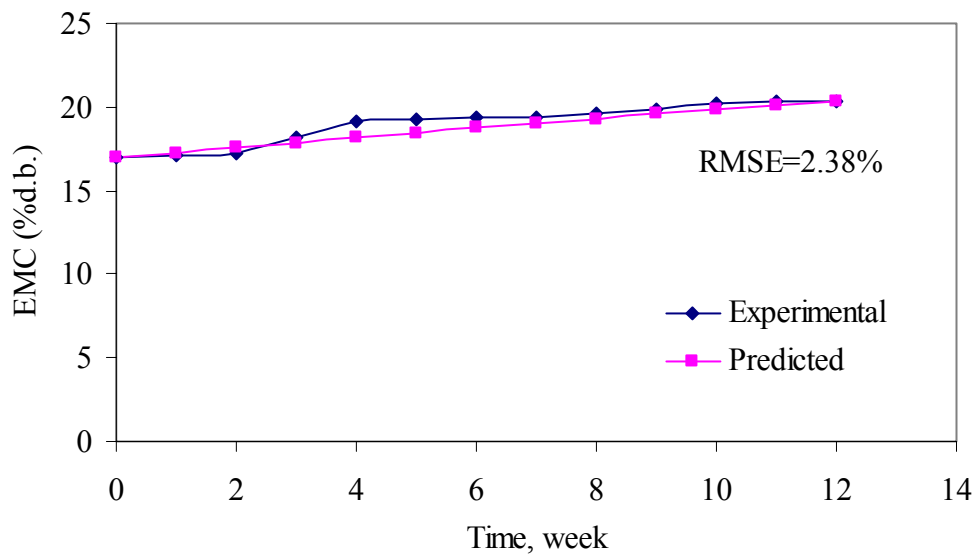


Figure 2. Predicted EMC and experimental data for hot curry cubes packaged in PP bag at storage conditions (38°C, 90% RH).

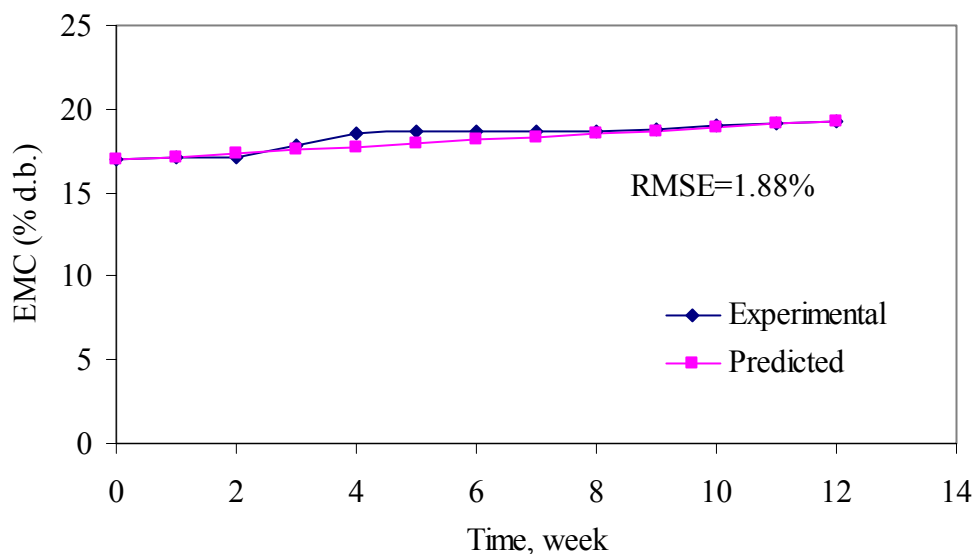


Figure 3. Predicted EMC and experimental data for hot curry cubes packaged in Nylon/LLDPE bag at storage conditions (38°C, 90% RH).

Conclusion

The critical moisture content was determined when the product became unacceptable from texture stiffness and sensory evaluation. The hot curry cube demonstrated Type I isotherm. The moisture sorption isotherm of hot curry cube was experimentally determined, a sorption model based the linear function described the sorption data very well for a wide range of water activity (0.43-0.84). The use of MCPP/OPP packet wrapped and packaged in Nylon/LLDPE bag having effective barrier properties against the ingress of moisture was able to lengthen the shelf life of hot curry cubes from loss of quality without a specific protective atmosphere. The linear model was markedly suitable for predicting the equilibrium moisture content of product; the %RMSE was below 3%. Taking into consideration the storage conditions in the south of Thailand (30°C, 80-75% RH), the hot curry cubes in the suggested package could retain acceptable quality for 1 year 4 months to 1 year 11 months. The great advantage deriving from the use of the uncomplicated mathematical model for shelf life prediction is that it is simply possible to predict the shelf life of product for any package size and material as well as for different initial and storage conditions. Further studies on the changes of product quality in other aspects such as chemical, mechanical and microbiological properties must be undertaken in order to obtain more accurate shelf life prediction.

Acknowledgments

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