Asian Journal of Applied Research for Community Development and Empowerment. Vol 7 (2023), No.2

AJARCDE
ASIAN JOURNAL OF APPLIED RESEARCH FOR COMMUNITY DEVELOPMENT AND EMPOWERMENT

Journal home page: http://ajarcde-safe-network.org ISSN 2581-0405

Estimation of Edamame Flour Shelf Life Using the Critical Moisture Approach

Ahmad Maulana Fikri Handoyo[1], Ulya Sarofa[1].*

[1]*Food Technology Department, Faculty of Engineering, Universitas Pembangunan Nasional "Veteran" Jawa Timur, Surabaya, Indonesia.*

ARTICLE INFO

Article History:
Received: 28 June 2023
Final Revision: 31 July 2023
Accepted: 15 August 2023
Online Publication: 18 August 2023

KEYWORDS

Edamame flour, critical moisture content, polypropylene plastic, metalized plastic, alumunium foil.

CORRESPONDING AUTHOR

*E-mail: *sarofaulya@yahoo.co.id*

A B S T R A C T

This research aimed to estimate the shelf life of edamame flour products using the Accelerated Shelf Life Testing (ASLT) with the critical moisture content approach in various types of packaging. This research was conducted in two stages, the first stage was in the process of making flour, then the second stage was estimating the shelf life. Shelf life estimation was carried out with two repetitions on three different types of packaging materials, those are polypropylene plastic, metalized plastic and aluminum foil. Then the data obtained will be analyzed utilizing simple linear regression using Microsoft Excel. Based on the results of estimating shelf life using the critical moisture content approach, it can be seen that edamame flour with polypropylene plastic packaging has a shelf life of 172 days, metalized plastic packaging has a shelf life of 585 days, and aluminum foil packaging has a shelf life of 229 days. Based on research results, it can be seen that the critical moisture content affects the shelf life of edamame flour and the best packaging for storing edamame flour is using metalized plastic packaging.

1. INTRODUCTION

1.1. Research Background

Edamame is one of the high-value legume vegetables because it is rich in protein, calcium and iron. Edamae is widely consumed by Japanese people with consumption reaching 100,000 tons/year. Indonesia has considerable potential in edamame production, both for export and local needs [1]. Edamame products have the potential to be developed into new products, one of which is edamame flour as a substitute ingredient in processed food products.

The problem that often occurs in flour products is that they easily absorb water in the air (hygroscopic). The increased water content due to the entry of moisture through the packaging causes clumping to occur, thereby reducing the quality of edamame flour. The presence of water vapor movement in these products can also cause unwanted changes and shorten shelf life [2].

Information on the shelf life of food products is very important for consumers. Inclusion of shelf life on product packaging labels is very important because it relates to food product safety and provides quality assurance to consumers. The shelf life of food products is the time period for products that are sensory and nutritionally acceptable and safe to consume [3].

Accelerated Shelf-life Testing (ASLT) is carried out using parameters of environmental conditions that can accelerate the process of decreasing the quality (usable quality) of food products. One of the advantages of the ASLT method is that the testing time is relatively short, but the precision and accuracy are high [4]. This method is used for food products that are easily damaged due to water absorption during storage due to the packaging used (such as plastic packaging) not being able to inhibit the migration of water vapor from the air.

The ASLT method can be carried out using the Arrhenius model approach or critical moisture content. The Arrhenius model simulates product damage by chemical reactions triggered by storage temperature, while the critical moisture content model simulates product damage triggered by water absorption by the product [5]. The application of the accelerated method needs to pay attention to the characteristics and causes of product damage to determine its shelf life. Food products cannot be separated from the estimation of shelf life as a form of guarantee for food safety. Based on these conditions, this research was conducted to calculate the shelf life of edamame flour using the Accelerated Shelf-Life Testing (ASLT) method with various types of packaging, those are polypropylene plastic, metalized plastic and aluminum foil.

1.2. *Literature Review*

1.2.1. Quality decrease

Agricultural products in the form of flour are processed grains or dried fruit pulp which are mashed to become flour or powder. Flour grains have very fine characteristics so that the surface area becomes very wide. This causes the material to be hygroscopic, which means it becomes moist very easily, because it easily absorbs moisture [6]. Products that easily absorb water when during storage are in contact with outside air (RH 75-80%), they will experience moisture absorption which will then change their physical properties [7].

The easy nature of absorbing moisture in the air or the hygroscopic nature of flour products can make it easier for flour to experience a decrease in quality and damage. The influence of moisture content and moisture absorption activity will affect the physical properties of flour (eg color and texture), chemical changes (eg browning reactions), and damage by microorganisms, such as bacteria and fungi [8]. Flour products have a standard water content limit of a maximum of 14.5% [9]. This can be a benchmark for decreasing the quality of flour.

1.2.2. Estimation of shelf life with critical moisture content approach

The Accelerated Shelf-life Testing (ASLT) method with a critical moisture content approach is a method for estimating product shelf life by simulating product damage triggered by water absorption by the product. The stages of determining the shelf life include:

a). Determination of Initial Moisture Content (Mi) which is the initial parameter in determining product shelf life. The level of durability of food products is affected by the water content in them, but the level of durability of food products cannot be determined directly because the water content of food products with the same water content has different levels of durability [5].

b). Determination of the critical moisture content where the product has decreased in quality so that organoleptically the product is not accepted by consumers (critical moisture content) [10].

c). Determination of the equilibrium moisture content, Ref [11], explains that the equilibrium moisture content is the moisture content of the food when the water vapor pressure of the material is in equilibrium with its environment where the product has not experienced a change in product weight.

d). Determination of the isothermic sorption curve, where the curve describes the relationship between water activity (aw) or the balanced relative humidity of the storage space (ERH) with the water content per gram of a material [12].

e). Determination of the isothermic sorption model, this is done to obtain the best smoothness of the curve. The chosen equation is one that can be applied to foodstuffs with an RH range of 0-95%, so that it can represent the three regions on the isothermic absorption curve. There are 5 equation models used in this study, namely the Hasley, Henderson, Caurie, Oswin, and Chen Clayton models [13].

Table 1. Isothermic adsorption equation model of food ingredients

Model	Equality
Oswin	$Me = P_1 (a_w/(1-a_w))^{P2}$
Hasley	$a_w = \exp [-P/(Me)^{P2}]$
Henderson	$1-a_w = \exp (-K.Me^n)$
Chen-Clayton	$a_w = \exp (-P_1/\exp(P_2*Me)$
Caurie	$\text{Ln } Me = \ln (P_1-P_2)*a_w$
GAB	$Me = \frac{Xm.C.K.a_w}{(1-K.a_w)(1-K.a_w+C.K.a_w)}$ $Y = \alpha x^2 + \beta x + \gamma$ $(a_w/Me) = \alpha (aw)^2 + \beta a_w + \gamma$

f). The dry weight of the product (Ws), is the product of the product's initial sample weight multiplied by the total solids.

g). Estimation of shelf life and determination of supporting parameters and sensory tests. Research data obtained from this critical moisture content approach can stimulate product shelf life with different permeability of packaging and relative humidity of storage space [5]. Determination of shelf life is carried out by the following formula:

$$t = \frac{ln\left(\frac{Me - Mi}{Me - Mc}\right)}{\left(\frac{k}{x}\right)\left(\frac{A}{Ws}\right)\left(\frac{P_o}{b}\right)}$$

Information:

T	:	The time needed in the packaging to move from the initial moisture content to the critical moisture content or the estimated shelf life time (days)
Me	:	Equilibrium product moisture content (g H_2O/g solids)
Mi	:	Initial product moisture content (g H_2O/g solids)
Mc	:	Initial product moisture content (g H_2O/g solids)
k/x	:	Packaged water vapor permeability constant (g/m^2.day.mmHg)
A	:	Package surface area (m^2)
Ws	:	Packaged product dry weight (g)
Po	:	Saturated vapor pressure (mmHg)
b	:	The slope of the isothermic sorption curve (which is assumed to be linier between Mi and Mc)

1.2.3. Packaging

Packaging is a container or wrapper that is used to protect the product in it. The function of packaging is to keep the product clean from various dirt and other contamination, protect the product from physical damage and external contamination, provide convenience in distribution and storage, and provide identification and information about the contents of the packaged product [14].

a) Aluminum Foil, the thickness of this packaging determines its protective properties. With a low thickness, aluminum foil can still be passed by gas and steam.

b) Polypropylene Plastic (PP), the main requirements for PP include; easy to shape, transparent, clear (rigid packaging is not transparent), not easy to tear, low water vapor permeability, medium gas permeability.

c) Metalized Plastic, is a combination of plastic with aluminum (laminated packaging). Metalized plastic is not transmitting

 https://doi.org/10.29165/ajarcde.v7i2.309

light, blocking the entry of oxygen, holding odors, giving a shiny effect, and being able to hold gas.

1.3. *Research Objective*

This study aims to estimate the shelf life of edamame flour using the Accelerated Shelf-Life Testing (ASLT) method with a critical moisture content approach for various types of packaging.

2. MATERIALS AND METHODS

2.1. *Material and Tools*

The main ingredient used in this study was edamame flour obtained from Jember Regency, Indonesia. Packaging materials used for packaging edamame flour include aluminum foil packaging, polypropylene plastic and metalized plastic. The chemicals used are $MgCO_3$, NaOH, $MgCl_2$, $NaNO_2$, NaCl, KCL, silica gel, Vaseline, and Aquades.

The tools used include drying ovens, electric stoves, desiccators, mortars, blenders, glass jars (modified desiccators), sieves, ram wire supports, hand sealers, sealed plastic containers, silicone glue, cups, and weighing bottles.

2.2. *Design Experiment and Analysis*

This research was conducted in 2 stages, the first stage was in the manufacture of edamame flour and the second stage was estimating the shelf life using the Accelerated Shelf-Life Testing (ASLT) method using the critical moisture content approach [15], with two replications. The data obtained will later be analyzed using simple linear regression using the Microsoft Excel program.

2.3. *Implementation of Research*

2.3.1. *Making edamame flour*

Edamame is peeled and separated from the skin. After cleaning, the blanching process was carried out at ~80°C for 5 minutes. After that, edamame is mixed with $MgCO_3$ at a concentration of 4%. Furthermore, the drying process uses a cabinet dryer at a temperature of 50°C for 300 minutes. Finally, the edamame was crushed using a blender and sieved with a size of 60 mesh.

2.3.2. *Estimation of shelf life*

Based on Ref [15], the estimation of shelf life based on the critical moisture content approach in equation 1 assumes that the storage conditions are at 75% Relative Humidity (RH), this is based on the storage conditions of edamame flour in general, namely at room RH. All parameters measured and determined including Mi, Mc, Me, k/x, Po, A and Ws are substituted into equation 1.

2.4. *Observation*

The analysis carried out included determining the main parameters of flour damage, initial moisture content (Mi), critical moisture content (Mc), equilibrium moisture content (Me), determining the isothermic sorption equation model, model determination test, determining the slope value of the ISA curve of the selected model or the value b, determination of permeability, area, and weight of packaging solids, and calculation of shelf life.

3. RESULT AND DISCUSSION

3.1. *Determination of Flour Damage Parameters*

In this research, the parameters of color, aroma and texture were used as attributes of the spoilage quality of edamame flour products. Analysis of the characteristics of food products is intended to determine the main attributes related to consumer acceptance.

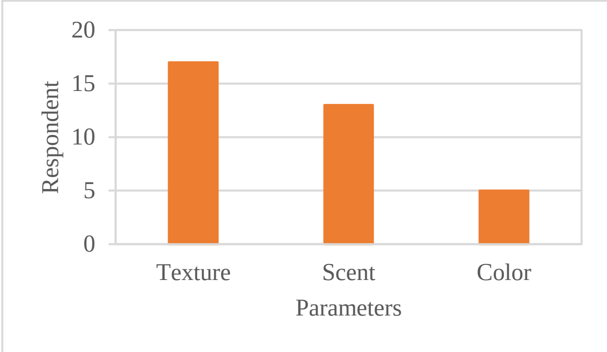


Fig 1. Graph of survey results for determining damage to edamame flour

Based on the results of a questionnaire survey involving 35 respondents, it can be seen that the attribute that is considered the most important is texture, followed by aroma and color. 17 respondents gave their response to flour damage in terms of texture (clumping), 13 respondents chose aroma, and 5 respondents chose color. It is suspected that the choice of texture is the main quality of damage to edamame flour, this is because texture is the attribute that is most easily felt with the sensitivity of the respondent's senses. According to Ref [16], flour damage is indicated by the presence of clumping/hardening of the texture. The clumping of the texture of edamame flour is caused by the hygroscopic nature of the flour, which can absorb water molecules from the surrounding environment.

3.2. *Initial water content (Mi) and determining of critical water content (Mc)*

Initial product moisture content data is important in determining the shelf life using the critical moisture content method. The water content value of edamame flour, which is in the range of 9.8%, meets flour quality standards based on Ref [9]. After knowing the initial water content of edamame flour, then an analysis of the critical water content is carried out. In this test, the critical moisture content of edamame flour was determined based on physical observations of the texture through organoleptic tests. Samples were stored in closed containers for different storage times, then in each series of samples the water content was calculated using the oven method [17]. In order to obtain the results of organoleptic test data for the texture and moisture content of edamame flour for each storage series.

Based on Table 2. It can be seen that the higher the water content when storing the product in a container filled with 2 liters of water can reduce the average hedonic score of edamame flour texture. This is because panelists tend to like the texture of edamame flour which crumbles easily when held or does not clump. The high moisture content is due to the absorption of moisture into the edamame flour during storage. The absorption of the water content causes the product to be unacceptable to consumers.

Table 2. Moisture content test result and hedonic scores during the edamame flour observation period at different times

Storage (Hour)	Water content (g H_2O/g solid)	Avarage hedonic score (Texture)
0	0.0978	3.26
12	0.1126	3.15
24	0.1248	3.07
36	0.1377	2.89
48	0.1581	2.52
60	0.1664	2.41

According to Ref [18], the migration of moisture which causes an increase in moisture is the cause of significant physical damage and decreased shelf life in food products. Furthermore, the water content of edamame flour is converted into a graph of the relationship between water content and is associated with the average value of the hedonic score, the water content is on the y-axis of the graph, while the average preference score is on the x-axis.

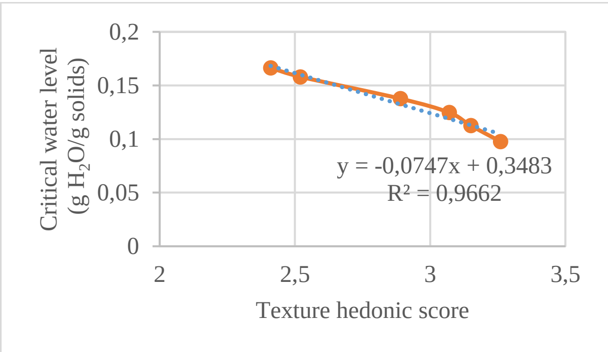


Fig 2. Graph of relationship between critical water content and hedonic avarage

The relationship between the log moisture content and the hedonic score is obtained by the equation $y = -0.0747x + 0.3483$, with a value of R^2 = 0.9662. The R^2 value indicates the accuracy of describing the actual conditions. The higher the R^2 value obtained in this equation means that the higher the level of closeness of the relationship between the two factors being compared.

The critical water content value is obtained by plotting number 3 in the linear regression equation. The value of somewhat dislike in the assessment is considered to have been rejected by consumers and this condition needs to be considered to ensure customer satisfaction. From these calculations, the critical water content (Mc) of edamame flour was 0.1242 g H_2O/g solids. The greater the difference between the initial moisture content of the material and the critical water content of the food product, the longer the shelf life of the product [19].

3.3. Equilibrium moisture content

The equilibrium moisture content used to make the isothermic absorption curve of the product is carried out by conditioning the flour into several saturated salt solutions with different relative humidity. Determination of the isothermic sorption curve in this study uses room temperature (~30°C) according to the storage temperature in general.

Based on Table 3. shows that the equilibrium moisture content increases with increasing water activity. This indicates that edamame flour undergoes a process of adsorption (absorption) of moisture from the environment because the water activity (aw) is lower than the relative humidity of the environment.

Table 3. Equilibrium moisture content (Me) of edamame flour

Salt	RH (%)	aw	Me tepung
NaOH	7.58	0.076	0.0333
$MgCl_2$	32.4	0.324	0.0618
$NaNO_2$	64.3	0.643	0.1192
NaCl	75.1	0.751	0.1754
KCl	83.6	0.836	0.2115

The use of 5 types of salt in determining the equilibrium moisture content aims to provide a representative picture of each salt's RH. During storage, there is a process of increasing and decreasing the weight of edamame flour. The process is an adsorption or desorption process which depends on the moisture content of the flour and the relative humidity of the storage area. The adsorption process occurs at high RH and desorption occurs at low RH. According to Ref [20], the movement of water vapor moves from high RH to low RH. The process of transferring water vapor takes place until an equilibrium point is reached. To obtain isothermic sorption curves, the equilibrium water content obtained from each experimental RH (Me) is plotted on the curve as a function (x) with the aw value as a function (x).

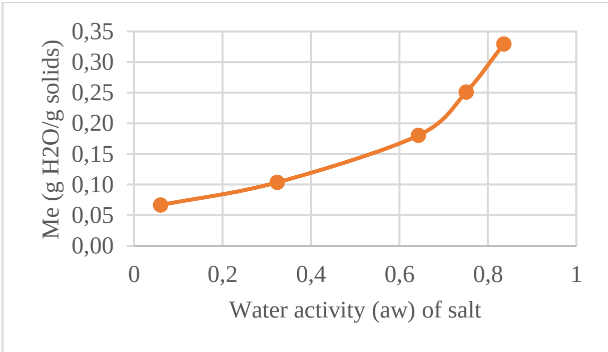


Fig 3. Edamame flour isothermic sorption curve

Based on Fig. 3. It can be seen that edamame flour stored at various RHs underwent adsorption and desorption during storage, resulting in a sigmoid-shaped curve. According to Ref [15], the shape of the sigmoid isothermic sorption curve is characterized by the presence of two curves, both curves are located in the range aw 0.6 to 0.8. Both of these environments are the result of changes in the physicochemical properties of water binding by the material.

3.4. Absorption model and model accuracy test

In this research the mathematical equation models used included: Hasley, Chen-Clayton, Henderson, Caurie, Oswin, and GAB. Isothermic sorption equation models need to be made to obtain high smoothness of the curve. The obtained equilibrium water content is plotted with the value of water activity (aw). The non-linear equation models are then modified into a linear equation (y = a + bx) to make calculations easier.

The accuracy of a model in describing the phenomenon of isothermic sorption that occurs can be determined by calculating the Mean Relative Determination (MRD). The high smoothness

https://doi.org/10.29165/ajarcde.v7i2.309

of isothermic sorption curves makes models with simpler equations and fewer parameters more suitable [15].

Table 4. Equation of edamame flour isothermic sorption curve

Model	Equality
Hasley	log(ln(1/aw)) = log-1.6479-1.4002 log Me
Chen-Clayton	ln(ln(1/aw))=0.4986-6.1114 Me
Henderson	log(ln(1/(1-aw)))=1.4266+1.6328 log Me
Caurie	ln Me=-3.5862+2.8369 aw
Oswin	ln Me=2.3292+0.4585 ln(aw/1-aw)
GAB	Me=0.9683aw/(1-0.9397aw)(1+21.0933aw)

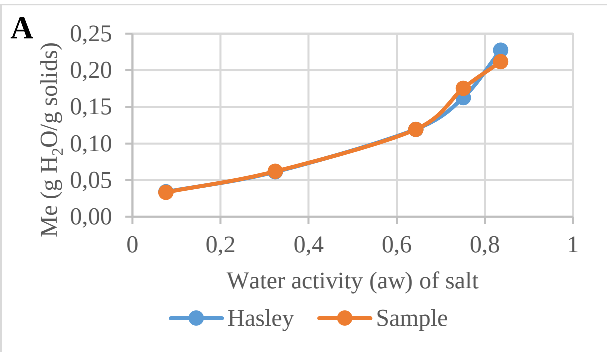
The equations obtained are used to calculate the water content of the sample in each aw of the salt used.

Table 5. The equilibrium moisture content of the edamame flour equation model

Aw	Me	Equilibrium water content model equation ($g\ H_2O/g$ solid)					
		H	**CC**	**HE**	**C**	**O**	**G**
0.076	0.0333	0.0338	0.0142	0.0282	0.0344	0.0309	0.0325
0.324	0.0618	0.0611	0.0731	0.0753	0.0695	0.0695	0.0634
0.643	0.1192	0.1193	0.1397	0.1362	0.1717	0.1275	0.1197
0.751	0.1754	0.1625	0.1704	0.1636	0.2332	0.1615	0.1628
0.836	0.2115	0.2272	0.2038	0.1922	0.2969	0.2055	0.2249

Informations: H (Hasley), CC (Chen-Clayton), HE (Henderson), C (Caurie), O (Oswin), G (GAB)

The results obtained in Table 5 are used to make the isothermal sorption curve of edamame flour correctly, somewhat precisely, or inaccurately. Using the six model equations, it is expected to be able to describe the isothermic sorption curve over a wide range of activity values. Comparison of the isothermic sorption curve of the equation model with the experimental results can be seen at Figure 4.



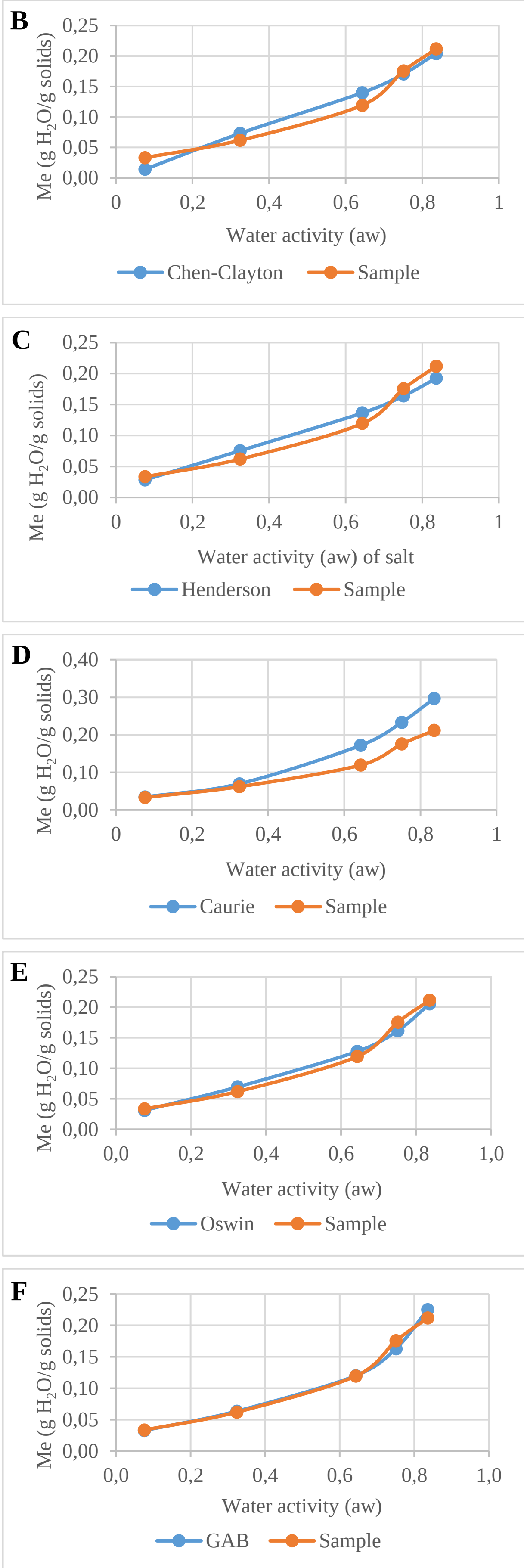


Fig 4. Isothermal sorption curve equation models: (A) Hasley, (B) Chen-Clayton, (C) Henderson, (D) Caurie, (E) Oswin, (F) GAB

The accuracy of a model in describing the phenomenon of isothermic sorption that occurs can be determined by calculating the Mean Relative Determination (MRD). The closer the isothermic sorption curve from the experimental results to the equation model indicates that the model is more accurately describing the isothermal sorption phenomenon.

$$MRD = \frac{100}{n}\sum_{i=1}^{n}\frac{Mi - Mpi}{Mi}$$

n : 100/5(salt) = 20

Table 6. MRD values of isothermic sorption equation models

Model	MRD
Hasley	3.5014
Chen-Clayton	19.8312
Henderson	13.4458
Caurie	26.5766
Oswin	7.4664
GAB	3.3043

Ref [21], explains that if the MRD value is <5, then the isothermic sorption model can describe the actual situation or is very precise. If the MRD value is between 10 and 10 (somewhat accurate) and if the MRD value is > 10 (not correct) to describe the actual situation. In this study, the chosen equation is the GAB model which has the smallest MRD value among other equation models.

The accuracy of depicting the isothermic sorption curve is also determined based on the closer the curve of the equation model is to the experimental results. Can be seen in Fig. 4, the isothermic sorption curve of the GAB model produces a curve that coincides and is strengthened by an MRD value of 3.3043, which indicates that this model can describe the isothermic sorption phenomenon of edamame flour water. The equation obtained from the GAB model,

$$Me = 0.968aw/(1 - 0.9397aw)(1 + 21.0933aw)$$

This equation will be used to determine the equilibrium moisture content which will be used in the calculation of shelf life estimation.

3.5. *Slope value (b) isothermic curve*

The slope of the curve from the selected equation model is used to calculate the shelf life estimation using the critical moisture content approach. Based on the GAB equation model curve obtained, a straight line equation is made to obtain the required slope of the curve. In this study, the determination of the slope value was obtained by plotting the value of the equilibrium moisture content with relative humidity (RH) of the GAB model.

The linear regression results of the isothermic sorption curve produce an equation $y = 0.2301x + 0.0004$ with (R^2 = 0.9026). Based on this equation, a curve b (slope) value of 0.2301 is obtained, which will be used in calculating the shelf life of edamame flour.

3.6. *Supporting variables for estimating shelf life*

After obtaining the results of the critical water content to the slope value, the next step is to determine the value of the solid weight of each package (Ws), packaging permeability (k/x), packaging area (A) and pure water vapor pressure (Po).

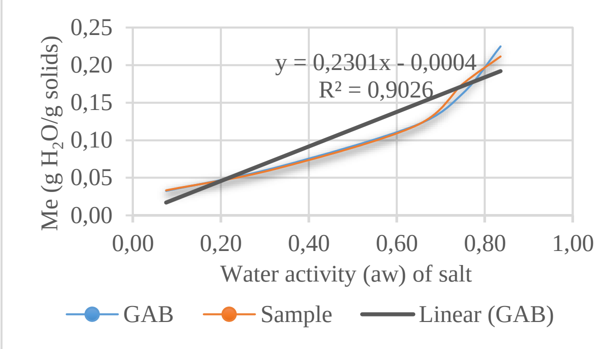


Fig 5. Determination of the slope of the isothermic absorption curve of edamame flour model GAB

The solid weight of each package (Ws) is known by multiplying the initial weight of the product by the percentage of solids (% solids) [22]. The percentage of solids is obtained from the calculated initial water content (mi). In this study, the weight of the product to be put into the packaging was 50 grams/package with an initial moisture content of 9.8%, so the solid weight per package was 45.1 grams. Saturated vapor pressure is taken at 30℃ as a reference for the average storage temperature (room temperature). According to Ref [23], the vapor pressure at 30℃ is 31.824 mmHg.

This research used three types of packaging, namely aluminum foil, polypropylene plastic (PP) and metalized plastic. The specific packaging permeability value for each type of packaging depends on the characteristics of each packaging material itself. The smaller the permeability value of the packaging indicates that the ability of the packaging material to act as a barrier against water vapor is better. The diffusion of water vapor in the product will be less and the quality of the product, especially the texture, can be better maintained.

Permeability of packaged water vapor is the ability of water vapor to penetrate a package at certain temperature and RH conditions, so that the smaller the permeability of bottled water, the smaller the permeability of water vapor, and vice versa [24]. Packaging permeability is obtained from secondary data. PP plastic packaging is 0.061 gH2O/day/m^2.mmHg, metalized plastic packaging is 0.018 gH_2O/day/m^2.mmHg [5]. Meanwhile, aluminum foil packaging is 0.046 gH_2O/day/m^2.mmHg [25].

The packaging area analyzed for the three types of packaging used in this research was 0.036 with a size (12x15) cm^2. The wider the surface area in contact with the environment, the greater the transfer of water vapor into the packaging, thereby shortening its shelf life. According to Ref [26], packaging dimensions for a certain food weight have a significant effect on its shelf life. In different quantities of the same product packaged in packages of different sizes with the same packaging material, the smallest package size has a shorter shelf life, due to its larger surface area or area.

3.7. *Shelf life*

Determination of shelf life is carried out in an effort to find out how long the product can last at the same quality during the storage process until it is consumed. Estimation of the shelf life of edamame flour was carried out using the Accelerated Shelf-Life Testing (ASLT) method with a critical moisture content approach. The relationship between shelf life and critical moisture content is used as a reference to determine the length of time required to reach that condition (critical moisture content).

 https://doi.org/10.29165/ajarcde.v7i2.309

The principle of this method is to condition the storage of edamame flour, at high RH the moisture content of the product will increase and later the pattern of water absorption will be known which is an important part in determining the critical moisture content for calculating shelf life.

The value of the equilibrium moisture content is obtained by inputting the RH value of 75% and the temperature of 30℃. Storage RH is selected based on the RH conditions used in general food products [27]. The GAB equation used in determining the equilibrium moisture content is:

$$Me = \frac{0.9683aw}{(1 - 0.9397aw)(1 + 21.0933aw)}$$

$$Me = \frac{0.9683 \times 0.75}{(1 - 0.9397 \times 0.75)(1 + 21.0933 \times 0.75)}$$

$$Me = \frac{0.7262}{(1 - 0.7048)(1 + 15.82)}$$

$$Me = \frac{0,7262}{(0.2738)(16.82)}$$

$$Me = 0.1577$$

Based on the model equation, the calculation results of the equilibrium water content (Me) at 75% RH are 0.1577.

Data regarding initial moisture content, critical moisture content, equilibrium moisture content, slope of the curve to the supporting variables are entered into the Labuza model shelf life equation. The calculation results for the various types of packaging used show the shelf life of edamame flour based on the selected GAB model.

Alumunium foil

$$t = \frac{ln\left(\frac{Me - Mi}{Me - Mc}\right)}{\left(\frac{k}{x}\right)\left(\frac{A}{Ws}\right)\left(\frac{P_o}{b}\right)}$$

$$t = \frac{ln\left(\frac{0.1577 - 0.9781}{0.1577 - 0.1242}\right)}{(0.0046)\left(\frac{0.036}{90.22}\right)\left(\frac{31.824}{0.2301}\right)}$$

$$t = \frac{ln\left(\frac{0.0599}{0.0335}\right)}{(0.0046)(0.000399)(138.305)}$$

$$t = \frac{ln(1.788)}{(0.0046)(0.000399)(138.305)}$$

$$t = \frac{0.581}{0.0025}$$

$$t = 228.9\ days$$

Plastic PP

$$t = \frac{ln\left(\frac{Me - Mi}{Me - Mc}\right)}{\left(\frac{k}{x}\right)\left(\frac{A}{Ws}\right)\left(\frac{P_o}{b}\right)}$$

$$t = \frac{ln\left(\frac{0.1577 - 0.9781}{0.1577 - 0.1242}\right)}{(0.0061)\left(\frac{0.036}{90.22}\right)\left(\frac{31.824}{0.2301}\right)}$$

$$t = \frac{ln\left(\frac{0.0599}{0.0335}\right)}{(0.0061)(0.000399)(138.305)}$$

$$t = \frac{ln(1.788)}{(0.0061)(0.000399)(138.305)}$$

$$t = \frac{0.581}{0.00337}$$

$$t = 172.63\ days$$

Metalized plastic

$$t = \frac{ln\left(\frac{Me - Mi}{Me - Mc}\right)}{\left(\frac{k}{x}\right)\left(\frac{A}{Ws}\right)\left(\frac{P_o}{b}\right)}$$

$$t = \frac{ln\left(\frac{0.1577 - 0.9781}{0.1577 - 0.1242}\right)}{(0.0018)\left(\frac{0.036}{90.22}\right)\left(\frac{31.824}{0.2301}\right)}$$

$$t = \frac{ln\left(\frac{0.0599}{0.0335}\right)}{(0.0018)(0.000399)(138.305)}$$

$$t = \frac{ln(1.788)}{(0.0018)(0.000399)(138.305)}$$

$$t = \frac{0.581}{0.000099}$$

$$t = 585\ days$$

Based on the shelf life calculation, it shows that the shelf life of edamame flour packaged with aluminum foil, PP plastic, and metalized plastic is 229 days, 172 days, and 585 days, respectively. It can be concluded that each package has a different ability to protect the packaged product. The difference in shelf life is influenced by the permeability value of each package. It can be seen that the permeability value of the packaging is inversely proportional to the product storage element. In addition to environmental RH, the various types of packaging used also greatly affect the shelf life value of the product because each type of packaging has a different permeability value [28]. The lower the permeability, the higher the ability of the packaging to prevent an increase in moisture content.

Polypropylene plastic packaging has the highest water vapor permeability value when compared to aluminum foil and metalized plastic packaging. This causes flour packaged in PP plastic to have the lowest shelf life. The greater the permeability value of the packaging, the larger the pores of the packaging, which will also make it easier for the product to reach a critical point. The high permeability value of the packaging causes the shelf life of the product to shorten. Due to its high permeability, it can absorb more water from the environment into the product. In this case, edamame flour products will accelerate the clumping process, which results in a decrease in quality. This decrease in quality can be interpreted as meaning that the food product has reached the limit of its shelf life because it has passed the critical limit of its moisture content. Low packaging permeability is useful in extending shelf life by inhibiting the transmission rate of water vapor into the packaging so that the product can be maintained in conditions without being affected by environmental conditions during storage.

Food products in the form of flour, especially edamame flour, have a relatively long shelf life. This can be caused by the drying process that occurs during the edamame processing, which results in a low initial moisture content of the edamame flour. The difference between the initial and final moisture content is large, making the shelf life relatively long..

4. CONCLUSION

Based on the results of estimating the shelf life of the Accelerated Shelf-Life Testing (ASLT) method with the critical moisture content approach, it can be seen that the shelf life of edamame flour packaged using aluminum foil, polypropylene plastic and metalized plastic is 229 days, 172 days, and 585 days respectively. The moisture content and permeability of the packaging greatly affect the shelf life of edamame flour. Metalized plastic packaging is the best packaging for storing edamame flour.

ACKNOWLEDGMENT

Thank you to lectures of Food Technology at Universitas Pembangunan Nasional "Veteran" Jawa Timur for providing direction and support in writing this manuscript.

REFERENCE

[1] Wijaya. R.. Yudiastuti. S.. dan Handayani. A. 2020. Diversivikasi Produk Edamame Sebagai Makanan Sehat Pada Pandemik Covid-19 dengan Teknologi Pengeringan Tipe Food Dehydrator Di Upt Pengolahan dan Pengemasan Produk Pangan Polije. Pengabdian Masyarakat: Polije Proceedings Series, 196-201.

[2] Castro. I.. Motizuki. M.. Murai. H.. Chiu. M.. and Silva. R. 2005. Effect of Anticaking Agent Addition and Headspace Reduction in The Powdered-Drink Mix Sensory Stability. J. of Food Quality, 29: 203-215.

[3] Herawati. H. 2008. Penentuan Umur Simpan Pada Produk Pangan. Jurnal Penelitian dan Pengembangan Pertanian. 27(4): 124-130.

[4] Agustin. N. 2018. Penentuan Umur Simpan dengan Metode Accelerated Shelf Life Testing (ASLT) dan Analisis Proksimat pada Minuman Rumput Laut. [Skripsi]. Fakultas Ilmu Alam. Institut Teknologi Sepuluh Nopember.

[5] Kusnandar. F. 2010. Kimia Pangan Komponen Makro. Jakarta: Dian Rakyat.

[6] Dwiari. S. 2008. Teknologi Pangan. Jakarta: Departemen Pendidikan Nasional.

[7] Siswantoro. B.. Rahardjo. N.. Bintoro dan Hastuti. P. 2012. Pemodelan Matematik Perubahan Parameter Mutu Selama Penyimpanan dan Sorpsi-Isotermi Kerupuk Goreng Pasir. J. Agritech. 32(3).

[8] Warsiki. E.. dan Setiyono. L. 2011. Pemanfaatan Biji Kurma (Phoenix dactylifera L.) Sebagai Tepung dan Analisis Perubahan Mutunya Selama Penyimpanan. [Skripsi]. Fakultas Pertanian. Institut Peranian Bogor.

[9] Badan Standarisasi Nasional. 2009. SNI 3751:2009. Tepung Terigu Sebagai Bahan Makanan. Jakarta.

[10] Wijaya. I.. Nocianitri. K.. dan Anugrah. A. 2008. Penentuan Masa Kadaluwarsa Rengginang dengan Menggunakan Model Labuza. Agrotekno. 14 (1): 24-29.

[11] Fellows. P. 2000. Food Processing Technology, Principles and Practice. Woodhead Publishing Ltd. Cambridge.

[12] Winarno. F. 2002. Kimia Pangan dan Gizi. Jakarta: PT Gramedia Pustaka Utama.

[13] Arpah. 2003. Penentuan Kadaluarsa Pangan. Buku 2: Penuntut Praktikum. Institut Pertanian Bogor.

[14] Robertson. G. 2010. Food Packaging and Shelf Life: A Practical Guide. CRC Press. Boca Raton.

[15] Labuza. T. 1982. Shelf Life Dating of Foods. Connecticut: Food and Nutrition Press Inc, Westport. Labuza TP, and Bilge A. 2002. Water Activity Prediction and Moisture Sorption Isotherms. Di dalam: Barbosa GV – Cánovas, Junior FJA, Schmidt SJ, Labuza TP, editor. Water Activity in Foods: Fundamental and Applications. Oxford (UK): Blackwell Publishing Ltd. hlm 109 – 154.

[16] Susiwi. 2009. Jurnal Penilaian Organoleptik. FMIPA. Universitas Pendidikan Indonesia. Bandung.

[17] AOAC [Association of Official Analytical Chemists]. 2005. Official Methods of Analysis of The Association of Analytical Chemist. Virginia USA: Association of Official Analytical Chemist, Inc.

[18] Colles. R. and Kirwan. M. 2011. Food and Beverage Packaging Technology, Second Edition. London UK: Blackwell Publishing Ltd. Chapter 4: 59-83.

[19] Magfiroh. M. 2016. Pendugaan Umur Simpan Kripik Jamur Tiram (Pleourotus ostreatus) Berdasarkan Metode Kadar Air Kritis Serta Pendekatan Kurva Sorpsi Isotermis. [Skripsi]. Fakultas Teknologi Pertanian: Universitas Brawijaya.

[20] Ikasari. D.. Suryaningrum. T.. Arti. I.. dan Supriyadi. S. 2017. Pendugaan Umur Simpan Kerupuk Ikan Lele Dumbo (Clarias gariepinus) Panggang dalam Kemasan Plastik Metalik dan Polipropilen. Jurnal Pascapanen dan 42 Bioteknologi Kelautan dan Perikanan. 12(1): 55-70.

[21] Sugiyono. 2006. Metode Penelitian Kuantitatif Kualitatif dan RnD. Bandung: Alfabeta.

[22] Alfiani. N.. Wulandari. N.. dan Adawiyah. D. 2019. Validasi Metode Pendugaan Umur Simpan Produk Pangan Renyah dengan Metode Kadar Air Kritis. Jurnal Mutu Pangan: Indonesian Journal of Food Quality. 6(1): 1-8.

[23] Bell. L.. and Labuzza. T. 2000, Moisture Sorption Practical Aspect of Isotherm Measurement and Use 2nd Edition. American Assosiation of Cereal Chemists, Inc., USA.

[24] Wulandari. A.. Waluyo. S.. dan Novita D. 2013. Prediksi Umur Simpan Kerupuk Kemplang Dalam Kemasan Plastik Polipropilen Beberapa Ketebalan. Jurnal Teknik Pertanian Lampung. 2(2): 105-114.

[25] Juliana. R..Hasbullah. R.. dan Mardjan. S. 2020. Models of Moisture Sorption Isotherm and The Estimation of Red Ginger Powder Shelf Life in Various Packaging Materials. Jurnal Keteknikan Pertanian. 8(1): 23-28.

[26] Giannou. V.. Lebesi. D.. and Tzia. C. 2014. Packaging and Shelf-Life Prediction of Bakery Products. Bakery Product Science and Technology. 355-371.

[27] Wijanarti. S.. Ambarwati. G.. and Sabarisman. I. 2019. Shelf Life Determination of Pegagan (Centella asiatica) Chips Using Accelerated Shelf-Life Testing (ASLT) Method. Agroindustrial Journal. 6(1): 296-404.

[28] Idayanti. D. 2018. Pembuatan dan Pendugaan Umur Simpan Bubuk Asam Sunti dalam Kemasan dengan Metode Sorpsi. [Tesis]. Sekolah Pasca Sarjana. IPB. Bogor.

 https://doi.org/10.29165/ajarcde.v7i2.309