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Shelflife Estimation of Seaweed *Dodol* in OPP Packaging by Using Accelerated Shelf Life Test Method

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Abstrac. This research is carried out due to the limited information on the shelf-life of food product in Indonesia, especially in South Sulawesi. In addition, there is no sufficient information on the self-life of packed seaweed dodol which produced by using scientific method. Seaweed dodol has a high economic value. The objective of this research was to estimate the self-life of seaweed dodol which is produced in traditional scale (micro, small, and middle scale bussiness) using the scientific method. Accelerated Shelf Life Testing (ASLT) Method is one of methods used in determining the shelf life of seaweed dodol based on critical water content and graining as indicators of quality deterioration. The isotermic sorption model of products was obtained from isotermic sorption curve formed from the relationship between the values of water activity (a_w) and the equilibrium moisture content (Me). Moreover, five different models of isotermic sorption were tested. They were Hasley, Chen-Clayton, Henderson, Caurie, and Oswin model. The results showed that the Henderson model was the appropriate model in describing the isotermic sorption phenomena at seaweed dodol with the Mean Relative Deviatian (MRD) of 1.4. By integrating the critical moisture content (Mc), packing permeability (OPP), sample weights (Ws), the surface area of packing (A) and the saturated vapor pressure (Po) into the equation Labuza, the self-life of seaweed dodol at temperature of 30 ^{o}C and RH of 78% was 56 days.

1. Introduction

Shelf life is the identity of a product regarding the endurance (durability) during storage and becomes one of the information that must be included by the manufacturer on the packaging label. Inclusion of shelf-life information is very important since it is related to the product safety (*food safety*), to provide *quality assurance*of feasible products to the consumers.

Research on the shelf life of seaweed *dodol* has never been done before, considering that the product is still cultivated on a traditional household scale. One way to determine the product shelf life is to use the *Accelerated Shelf Life Testing (ASLT)* method with a critical water approach [8]. This method is done by storing food products in extreme conditions such as high or too low temperatures and humidity. The advantage of the ASLT method is the short implementation of time with high accuracy value [7].

The purpose of this study is to estimate the shelf life of seaweed *dodol* produced traditionally at the scale of *UMKM* using the scientific method.

2. Method

The research was conducted in the household business unit of the seaweed *dodol*, Bantaeng Regency, and in the Chemical Analysis and Food Quality Supervision Laboratory, Food Science and Technology Study Program, Hasanuddin University, Makassar. The tools and materials used consisted of modified jars as *humidic chambers* (HC), thermometers, saturated salt solutions with various *Activity water* (a_w) and *oriented polypropylene* (OPP) plastic packaging. The research procedures, including:

2.1 *Initial Moisture Measurement (Moisture Initial, M_i)* [1]

The clean and dry cup weighed (W1). 2 gram sample (W2) in the cup was dried in an oven at 105°C for six hours until it reached a constant weight. The cup contained the sample, then cooled in the desiccator and weighed (W3). The initial water content was calculated by the formula:

$$\text{Ka}\ (\text{M}_\text{i}) = \frac{(W_2)-(W_3-W_1)}{(W_3-W_1)}\ \frac{\text{gH}_2\text{O}}{\text{gsolid}} \quad (1)$$

2.2 *Critical Moisture Measurement (Moisture Critical, Mc)*

Samples in OPP packaging were stored in HC using a saturated NaCl solution of RH 76%. Every 24 hours, the acceptance level examination was carried out by the panels of 15 people towards the sample appearance and calculated the average acceptance test score, until it reached a score of 2 (dislike). This value was then determined and stated that the product was in a critical condition. Then the measurement of water content was carried out as in point 1.

2.3 *Water Content Equilibrium (Moisture Equilibrium, Me)* [2]

Prepared saturated salt solution in HC (table 1).

Table 1. Saturated salt solutions and RH values

Type of Salt	RH (%)
$MgCl_2.6H_2O$	32
K_2CO_3	43
KI	69
NaCl	76
KCl	84
$BaCl_2.2H_2O$	90

A 5 gram sample in a package was placed by hanging it in HC. Every 24 hours, it was weighed until it reached a constant weight (balance water content). Then the water content was measured using the oven method. Furthermore, the sorption isotherm curve was made by plotting the value of water content and equilibrium water activity.

2.4 *Determination of the Isothermic Sorption Model* [5]

The balance of water content (M_e) together with aw, was included in the isothermic sorption equation model of Chen Clayton, Henderson, Hasley, Caurie, and Oswin. The five models of sorption isotherms were evaluated through the value of *Mean Relative Deviation* (MRD). If the MRD value is <5, the sorption isotherm model could describe the actual or very precise condition. If 5 <MRD <10 then the model was rather precise in describing the actual situation, and if the MRD> 10 then the model disnot accurately describe the actual condition.

2.5 Determination of Supporting Parameters

The packaging permeability value $\left(\frac{k}{x}\right)$, was obtained from the reference library. The value of saturated vapor pressure (Po) at 30°C was obtained from the [8] table. The value of b (curve slope) was obtained from the gradient curve of the selected isothermic sorption equation model. The value of cross-sectional area (A) was obtained by multiplying the dimensions of the packaging. The total solids value (Ws) was obtained by correcting the overall weight of the sample reduced by the initial moisture content.

2.6 Estimated Lifespan [8]

All parameters measured and set in the previous stage, among others: Mi, Mc, Me, k / x, Po, b, A and Ws were integrated into the [8] equation, as follows

$$\theta = \frac{\ln\frac{(\mathrm{Me}-\mathrm{Mo})}{(\mathrm{Me}-\mathrm{Mc})}}{\frac{\mathrm{k}}{\mathrm{x}}\left(\frac{\mathrm{A}}{\mathrm{Ws}}\right)\frac{\mathrm{Po}}{\mathrm{b}}} \tag{2}$$

Notes:

Θ	= Estimated shelf life (days)
M_e	= Balanced water content of product (g H_2O/g solid)
M_i	= Initial water content of product (g H_2O/g solid)
b	= Slop isothermic sorption curve
M_c	= critical water content (g H_2O/g solid)
$\frac{k}{x}$	= Permeability of bottled water (g/m^2.day.mmHg)
A	= packaging surface area (m^2)
W_s	= dry weight of packaged product (g solid)
Po	= saturated vapor pressure (mmHg)

3. Results and Discussion

3.1 The Process of Making Seaweed Dodol

The process of making seaweed dodol, includes *Eucheumacottoni* seaweed was cleaned, sorted and dried for 3-4 days. The dried ingredients were washed using fresh water, to remove the smell of sea water. Next, soaked it in water mixed with lime juice to remove the fishy odor. Crushed and mixed with 60% melted brown sugar as much as 500 ml as sweetener and cinnamon powder. The mixture was cooked until the dough was thickened and smooth (not sticky on the finger). After the mixture was cold, cut it into 2x1x1 cm in size. Before being packed with OPP, dodol was cooled to obtain a chewy and stable texture. The chemical contents of seaweed dodol, were ash 15.77%, water 17.38%, protein 1.42%, 0.15% fat, carbohydrates 62.21 and crude fiber 3.07%.

3.2 Estimated Shelf Life of Seaweed Dodol

The shelf life of the product was calculated through the [8] equation at 78% RH, to represent the storage condition of the seaweed dodol by consumers.

3.2.1 Initial Water Content (Initial Moisture, M_i). The value of the initial moisture content of seaweed dodol 0.2016 g H_2O/g solid or equivalent to 20.16% dry weight. In this case, seaweed dodol included semi-wet food, i.e. food that had a medium water content category (10- 40%). Semi-wet food is a food that has a moisture content of between 15-55% wet base with a range of aw between 0.65-0.85.

3.2.2 Critical Water Content (Moisture Critical, M_c). The critical moisture content of seaweed dodol was characterized by the appearance of dull and freckled appearance (*graining*). Seaweed Dodol began to experience rejection by panelists on the 22nd day with the lowest score of 2 (dislike). This condition was the consumer acceptance threshold. The relationship between the score of panelists' acceptance of the length of storage is shown in figure 1.

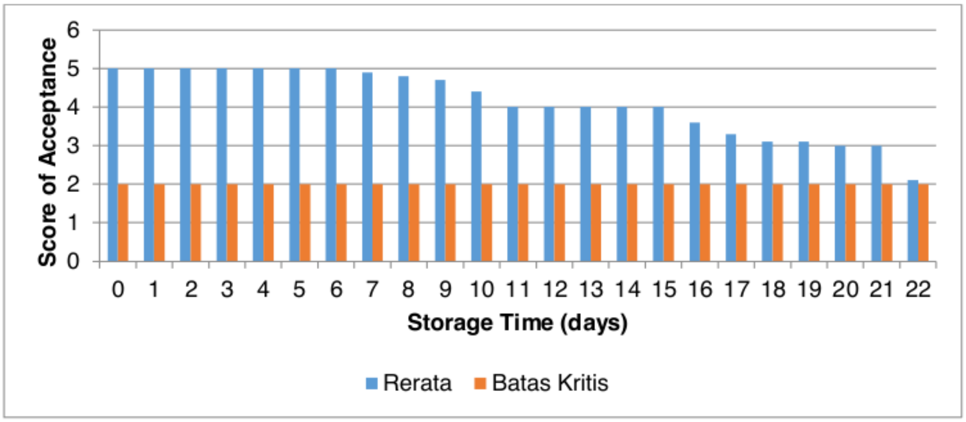

Figure 1. Relationship between the score of acceptance of seaweed dodol and storage time

Figure 1 showed that seaweed dodol was in a critical condition with a critical moisture content of 0.2374 g of solid H_2O/g or 23.74% of water. When compared with the initial moisture content, an increase in the amount of water content in seaweed dodol, through the process of absorption of water from the environment into the product. This was confirmed by [4] that if air humidity was relatively higher than the relative humidity of the material, the material would absorb water.

3.2.3 Water Content Balance (Moisture Equilibrium, M_e). During storage time, water vapor would move from the environment to the product or vice versa, until a balanced condition was reached. In this case, it was the condition where the product no longer absorbs water vapor into the environment or emits water vapor. Balance water content was presented in table 2 [4].

Table 2. Balance water content of seaweed dodol in various RH storage conditions

RH (%)	A_w	Balance Water Content (g H_2O/ g solid)
7	0,07	0,1960
32	0,32	0,2239
43	0,43	0,2426
69	0,69	0,2572
76	0,76	0,2648
84	0,84	0,2793
90	0,90	0,2885

Table 2 showed the length of sample storage until a balance condition was reached starting from the 4th RH and 5th which was the closest RH to the product water activity. This phenomenon was known as the characteristic of hydration, which was the interaction between food and water molecules in the surrounding air, in the form of absorption and desorption [13].

3.2.4 Isothermic Sorption Curve. The sorption isotherm curve was made by plotting the balance water content values (table 2) with the value of water activity (a_w) (figure 2).

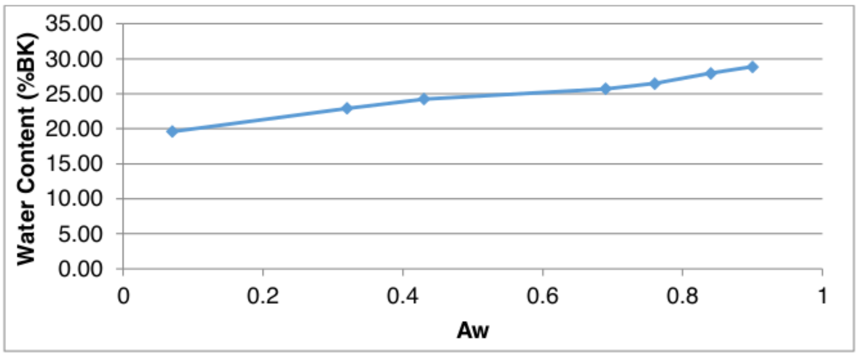

Figure 2. Seaweed isotherm curves

Figure 2 showed the sorption isotherm curve of seaweed dodol resembling a type II isothermic sorption curve and *sigmoid* in shape, although not perfect. [13] explained that each food product has a distinct isothermic curve, but is generally *sigmoid*. This form of sigmoid food was generally caused by the influence of several components. Even [15], each food had a distinct form of isothermic sorption curve. This depended on the pattern of absorption of water vapor for each product.

3.2.5 Model of Isotherm Performance equation. Modeling of the sorption isothermic curve equation was constructed from the results of research, then compared with existing theoretical models, in this case aiming to get high curve smoothness. The theoretical isothermic sorption model, including the equation model Chen Clayton, Henderson, Hasley, Caurie and Oswin [5]. Furthermore, to simplify the calculation, the mathematical equation models used were transformed from non-linear equations into linear equations, so that the fixed value could be determined by the least squares model. The linear equation of the seaweed dodol isothermal sorption curve of the sorption isothermic curve equation models was presented in table 3.

Table 3. Equations of seaweed dodol isotherm sorption curves and the value of *Mean Relative Deviation* (MRD)

Model	Linear Equation	MRD Value
Chen Clayton	$\ln [\ln(1/a_w)] = 8{,}13\text{-}35{,}4\ Me$	1,47
Henderson	$\log [\ln(1/(1\text{-}a_w)] = 5{,}312\text{+}9{,}013 \log Me$	1,40
Hasley	$\log [\ln(1/a_w] = \text{-}5{,}401\text{-}8{,}404 \log Me$	2,01
Caurie	$\ln Me = \text{-}1{,}631\text{+}\ 0{,}423\ a_w$	1,85
Oswin	$\ln Me = \text{-}1{,}419 + 0{,}007 \ln [a_w/(1\text{-}a_w)]$	9,59

Table 3 showed the MRD values of each equation of the isothermic sorption model. Based on the MRD values obtained, the reference in making the next isothermic curve was the Henderson equation model, although the equation models Chen Clayton, Caurie and Hasley had low MRD value (below 5%). Theoretically, this value described the isothermic curve as precisely as the MRD value was smaller than 5. This was in accordance with [14], that the sorption isothermic model that could describe the true situation very precisely was a model that had MRD value below 5%. However, the Henderson equation model had smaller MRD value, meaning that it was more coherent with the condition of actual balance (reliable), as the phenomenon of sorption isotherm (figure 3). The Oswin equation model, with a value of 9.59, illustrated the overall isothermal curve incorrectly (5 <MDR <10).

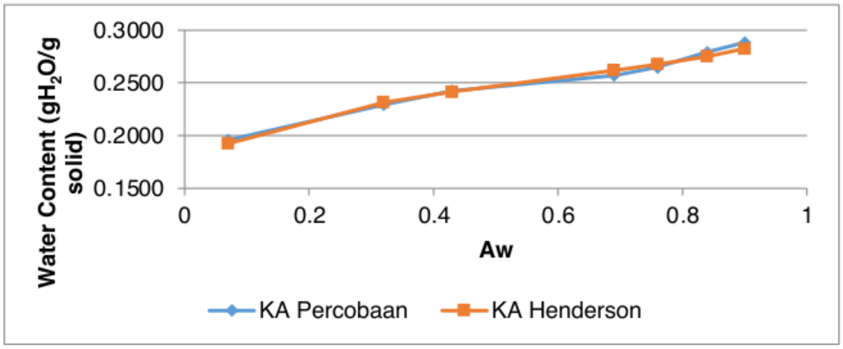

Figure 3. Isothermic sorption curve of seaweed dodol and Henderson model

The slope value of the seaweed isotherm sorption curve could be seen in figure 4. According to [11] and [3], the slope (b) of the isothermic sorption curve was determined from the straight line formed on the curve of the isothermic sorption model formed on the Henderson model. Based on figure 4, it was known that the points of the relationship between water activity and equilibrium water content had a linear equation y = a + bx. The value of b of the linear equation was the slope value of the isothermic sorption curve, which is 0.100.

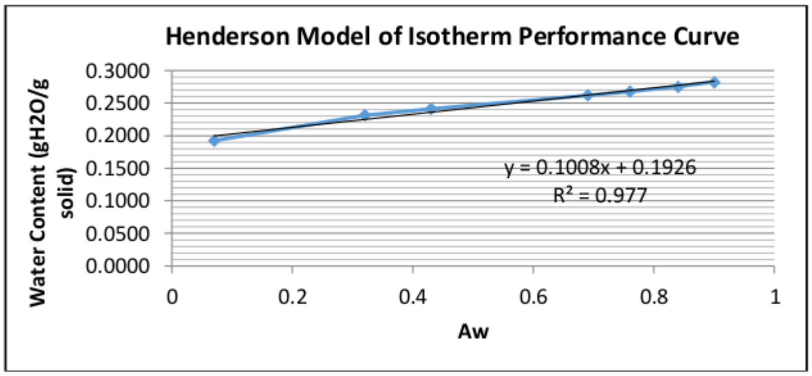

Figure 4. The slope of the isothermicsorpsi curve of the Henderson model of Seaweed dodol

3.2.6 Supporting Parameters. Supporting parameters include water vapor permeability of 0.0739 gH^2O/m^2.day.MmHg [10]. [9], propylene type plastic is a good type of plastic as a *barrier* to water vapor because it has low water vapor permeability. The surface area of the packaging used to cover the product was 0.0162 m^2. Pure vapor pressure in the storage space (temperature 30°C) based on the [8] water was 31,824 mmHg.

3.2.7 Shelf Life Value of Seaweed Dodol. The shelf life of seaweed dodol was obtained by integrating the initial moisture content (M_i) (0.2016 gH^2O/g solid), critical water content (0.2374 (M_c) gH^2O/g solid), slope of the isothermic curve (0.100), balance water content (M_e) (0.2700gH^2O/g solid) and supporting parameter values, to the equation [8] [3]. In this case, 56 days or 1.9 months were obtained.

4. Conclusion
The estimated shelf life of seaweed dodol packed with oriented polypropylene (OPP) with a packaging surface area of 0.0162 m^2 at saturated vapor pressure of 30°C and RH of 78%, is 56 days.

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