Accelerated Shelf-Life Testing of the Powder of Flower, Leaf, and Steam Kecombrang (*Etlingera elatior*) Using a Critical Moisture Content Approach

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Abstract. Kecombrang (*Etlingera elatior*) has been known for a long time by the Indonesian people and is used as an ornamental plant, vegetable, food flavoring, and traditional medicine. This study aims to determine the shelf life of the powder of kecombrang flower, stem, and leaves packaged using aluminum foil and calculated using the acceleration method based on the critical moisture content approach. This study used an experimental research method with three research factors namely flower powder, stem powder, and kecombrang leaf powder. The parameters measured in this study were initial moisture content, critical moisture content, and equilibrium moisture content to obtain the correct isothermic sorption curve. Then other parameters that need to be considered in determining shelf life are the area of the packaging, the weight of the packaging solids, the pure vapor pressure, and the water vapor permeability of the packaging. Based on the results of calculations using the Labuza equation about shelf life, it is found that the shelf life of kecombrang flower powder is 27 months, kecombrang stem powder is 30 months, and kecombrang leaf powder is 25 months.

Keywords: ASLT · critical moisture content · kecombrang powder · shelf-life

1 Introduction

The kecombrang plant or with the Latin name called (*Etlingera elatior*) is a type of spice plant that belongs to the Zingiberaceae family and is traditionally usually used and used by the community as medicines and flavorings for dishes [1]. Kecombrang can be used by humans as medicine related to its properties, namely deodorizing and bad breath. According to [2], kecombrang fruit and flowers can be used as flavorings in dishes such as pecel and urab. Kecombrang leaves can be used as processed sour vegetables and the stems are used for several types of meat dishes. Meanwhile, according to [3] the flowers of this plant can be used as a natural comeestic ingredient where the flowers are used for a mixture of hair and leaf wash and rhizomes are used for powder mixtures by residents.

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Kecombrang leaves combined with aromatic plants can be used as a deodorizer. The content of compounds in kecombrang flowers includes flavonoids, terpenoids, saponins, and tannins. Meanwhile, in kecombrang leaves there is a content of saponin compounds, flavonoids, and chlorogenic acid [3]. Kecombrang stems have the potential to be antibacterial, and have an essential oil content of 0.0029% and flavonoid content in the stem [4]. According to [5], fresh samples are easily damaged and experience a faster deterioration in quality compared to dry samples. So drying using a cabinet dryer is one way that can be done to prevent damage to fresh samples of leaves, stems, and flowers of kecombrang. Dried materials have a longer shelf life because quality degradation or damage can be prevented through drying [6]. After going through the drying process, besides being able to prevent damage to the kecombrang plant, dried simplicia can be made in powder form to facilitate application in the food processing process.

Determination of shelf life can be done using the Accelerated Shelf Life Test (ASLT) method, namely by storing the product in an environment that can cause the product to be damaged quickly, either under higher temperature conditions or storage room humidity. The acceleration method can be carried out in a shorter time with good accuracy [7]. The ASLT (Accelerated Shelf Life Test) method can be performed using the Arrhenius model approach or critical water content. The Arrhenius model simulates product damage by chemical reactions affected by storage temperature, while the critical moisture content approach model simulates product damage affected by water absorption by the product during storage [8]. According to Ellis [9], the ASLT (Accelerated Shelf Life Test) method, in addition to having fairly high accuracy, is also more efficient because it accelerates the reaction to reduce product quality. The kecombrang plant is a plant that has many benefits for humans and industry but currently, no research discusses the shelf life of the kecombrang plant so it is necessary to know its shelf life. In this study, an estimation of the shelf life of flower powder, stems, and leaves of kecombrang plants was carried out using the acceleration method (Accelerated Shelf Life Test or ASLT) with a critical moisture content approach model. The purpose of this study was to determine the shelf life of leaf powder, flowers, and kecombrang stems which were packaged using aluminum foil packaging. The expected benefit of this research is to provide useful information for the development of science and technology in the food sector, especially in the analysis of the shelf life of the kecombrang plant which has many benefits both for humans and industry.

2 Research Methodology

2.1 Materials

The tools used in this study were cabinet dryers, disk mills, porcelain cups, digital scales, test tubes, beaker cups, desiccators, and moisture analyzers.

The materials used in this study were kecombrang leaves, kecombrang flowers, the inside of the kecombrang stems, obtained from the market in Purwokerto, silica gel, aquadest, gelatin, maltodextrin, aluminum foil packaging, tissue, rubber, and salt for testing the equilibrium moisture content, namely $MgCl_2$, NaBr, NaCl, KCl, and KNO_3 salt under the Merck brand, and questionnaire paper.

2.2 Experimental Design

This study used an experimental research method with three research factors, namely flower powder, stem powder, and kecombrang leaf powder which was packaged using aluminum foil. The determination of shelf life was carried out by the Accelerated Shelf Life Testing (ASLT) method and using a critical water content approach model based on [10].

2.3 Making Flower Powder, Stems, and Leaves of Kecombrang

Fresh kecombrang flowers, stems, and leaves were sorted and cut into pieces and dried using a cabinet dryer at a temperature of 60 °C for 6 h. Dried kecombrang rods are mashed using a disc mill to obtain kecombrang powder [11].

2.4 Determination of Initial Moisture Content (Mo)

The initial level measurement is carried out using the Moisture Analyzer tool. Measurements are made by inserting a sample of 1 g into the aluminum pan, then closing it and waiting for a few minutes until a number appears indicating the value of the moisture content on the screen.

2.5 Critical Water Content Measurement (Mc)

The determination of critical moisture content is determined by placing unpackaged products at room temperature in an open room until the product is no longer accepted organoleptically [12]. The test is carried out until the dry texture of the kecombrang powder has disappeared, or when the kecombrang powder coagulates. During storage, sensory tests were carried out by 15 panelists on the texture, color, and aroma of the product every 24 h. Panelists were asked to assess with a grading scale ranging from 1–7, where in texture score 1 showed a very lumpy scale and a score of 7 showed a very non-clumping scale, while in the aroma parameter, score 1 indicated a very not strong scale and a score of 7 indicated a very strong scale, as well as on the color parameter, score 1 indicated a very uneven scale and a score of 7 indicated a very bright scale.

If organoleptic tests of texture, aroma, and color by the panelists have been carried out, the panelists are then asked to select the most important parameters in determining the damage to the powder, as well as on what scale until the product is no longer accepted by the panelist or consumer.

2.6 Equilibrium Moisture Content (Me)

The manufacture of the isothermic sorption curve of kecombrang powder is carried out by first making a saturated salt solution aimed at regulating the relative humidity (RH) of the desiccator. The salt used is as shown in Table 1.

The test was carried out by filling a cup that was already known to weigh 2 g with kecombrang powder, then the dish was placed in a desiccator that already contained a saturated salt solution, with a position from the bottom up in a row, namely salt solution,

Table 1. Water activity value for a saturated saline solution at 30 °C

Saline solution type	Water activity (Aw)	Relative humidity (%)
$MgCl_2$	0.324	32.4
NaBr	0.560	56.0
NaCl	0.749	74.9
KCl	0.836	83.6
KNO_3	0.923	92.3

Source: Bell & labuza (2000)

buffer, and saucer and its contents. The desiccator was then stored at room temperature and weighed daily until 3 weighers were obtained with consecutive constant weights of less than 2 mg/g for samples stored at RH below 90% and 10 mg/g for samples stored at RH above 90% [6].

2.7 Determination of Curves and Models of Isothermic Sorption Equations

The determination of the curve is carried out by plotting the equilibrium results of the experimental results with the value of relative humidity (RH) or water activity (Aw) and entering the isothermic sorption equation. Mathematical models regarding isothermic equations have been widely put forward by experts. The chosen equation is a simple equation that can be applied to foodstuffs with a rh range of 0–90%. This equation model is used to obtain the best smoothness of the curve. The equation model used is the Guggenheim-Anderson-de Boer (GAB), Hasley, Handerson, Courie, Oswin and Chen Clayton models. Then a model accuracy test is carried out using the Calculation of Mean relative Determination (MRD) to determine the accuracy of several selected models so that an isothermic sorption curve will be obtained [10].

2.8 Determination of Slope Value (b) of Isothermic Sorption Curve (Labuza, 1982)

The slope value (b) is determined by the linear area taken between the initial moisture content area and the critical moisture content. The point of connection between the activity of water and the equilibrium moisture content has a linear equation of $y = a + bx$. The value of b is determined from the model of the selected equation (the slope of the isothermic curve assumed to be linear between Mo and Mc) to be entered into the Labuza shelf life formula.

2.9 Determination of Packaging Permeability

The determination of the permeability of the packaging is carried out using the Mocon Permatran tool, so that the WVTR value is obtained. The WVTR value can also be obtained using a cup containing a sample of 2 gr closed using aluminum foil and tied with rubber so that air cannot enter it. Then observations are made every day by weighing them until they get five points to then make a graph. The results of these observations are made in the form of tables and graphs and are searched for WVTR values. As for finding the permeability constant of bottled water vapor (k/x), it can be done by:

$$\frac{\mathrm{k}}{\mathrm{x}} = \frac{WVTR}{(Po)(RH)}. \quad (1)$$

where:

K/x = Bottled water vapor permeability constant (g/m^2/day/mmHg)
WVTR = Rate of transfer of moisture through the package (g/m^2/day/RH)
Po = Water vapor pressure in the environment (mmHg)

2.10 Determination of Product Dry Weight (Ws) and Packaging Area

The dry weight of the product (Ws) is calculated by weighing the initial weight of the product (Wo) and correcting the initial moisture content (Mo). Packaging Area (A) is the total area of the length and width of the primary packaging used for packaging.

2.11 Determination of Saturated Water Vapor Pressure (Po)

Determination of saturated water vapor pressure can be done by looking at the table of the relationship between water activity and temperature.

3 Results and Discussion

3.1 Initial Moisture Content and Critical Moisture Content

The initial moisture content is the moisture content contained in a food product after production. The results of the initial water content measurement on flower powder, stems, and leaves were successively 0.0683 g H2O/g solids, 0.0673 g H2O/g solids, and 0.0691 g H2O/g solids. Based on the initial moisture content, the weight of the solids for flower powder was 3.7268 g H2O/g solids, stem powder was 3.7308 g H2O/g solids, and leaf powder was 3.7236 g H2O/g solids.

The determination of critical moisture content is determined by placing unpackaged products at room temperature in an open room until the product is no longer organoleptically accepted by consumers [12]. The critical moisture content is determined based on the most important sensory attribute of the powder, which is when the powder begins to coagulate. Data on changes in moisture content and texture scores of flower, stem, and leaf powders are presented in Tables 2, 3, and 4.

Tables 2, 3, and 4 show texture score and moisture content data in a storage time of 0–7 days. Based on these results, it can be seen that the duration of storage affects the texture score and moisture content of the flower, stem, and leaf powder. On the 7th day, the texture values of the three types of powders had a score of 3 (quite lumpy) which indicates that the powder of flowers, stems, and leaves is already in a critical

Table 2. Changes in texture score and moisture content of kecombrang flower powder

Time (day)	Texture Score	Up to Air (%)
1	5.8	6.98
2	5.33	7.91
3	5.13	8.21
4	4.87	8.34
5	4.2	8.56
6	3.8	8.88

Table 3. Changes in texture score and moisture content of kecombrang rod powder

Time (Day)	Texture Score	Up to Air (%)
1	6	6.88
2	5.6	7.12
3	5.13	8.98
4	4.33	9.57
5	3.6	9.67

Table 4. Changes in texture score and moisture content of kecombrang leaf powder

Time (Day)	Texture Score	Up to Air (%)
1	6.53	6.98
2	5.73	7.17
3	5.53	7.87
4	5.07	8.21
5	4.53	8.45
6	4	9.23
7	3.47	9.55

condition. This decrease in texture score occurs because the moisture content contained in the powder has increased due to the ingress of moisture from the environment into the product, resulting in the texture of the powder becoming moist and coagulating.

Based on Figs. 1, 2, and 3, it can be seen that the moisture content of flower powder, stems, and leaves has increased and the texture score has decreased every day. The regression equation obtained for flower, stem, and leaf powder is $y = -1.0332\times + 13.272$; i.e. $y = -0.6558\times + 10.47$; and $y = -1.0715\times + 13.776$; with R^2 values of 0.8453; 0.8296; and 0.9576, respectively. Based on the regression equation obtained, the

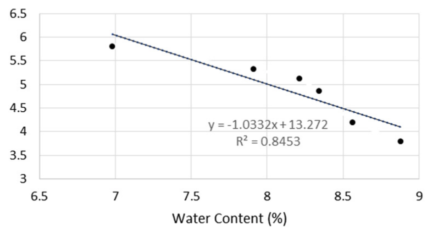

Fig. 1. Relationship of texture score and moisture content of kecombrang flower powder.

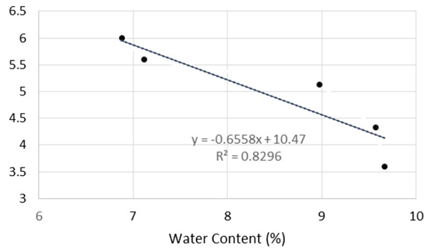

Fig. 2. The relationship of texture score and moisture content of kecombrang stem powder.

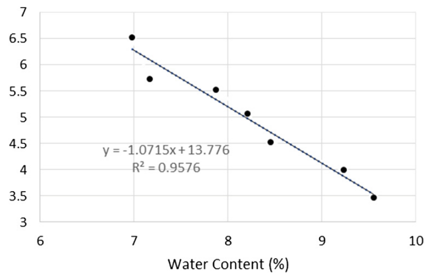

Fig. 3. The relationship of texture score and moisture content of kecombrang leaf powder.

critical moisture content value can be determined when the favorability score is worth three.

The critical moisture content value can be obtained by plotting the value of $y = 3$ in the regression equation above for flower, stem, and leaf powders in a rare is 0.1104 g H_2O/g solids, 0.1285 g H_2O/g solids, and 0.1118 g H_2O/g solids.

3.2 Isothermic Sorption Curve

Measurements of equilibrium water content in various environmental RH are carried out to obtain an isothermic sorption curve. During storage in the desiccator with the various RH, the product will have interactions between the product and its environment. Water vapor will move from the environment to the product until an equilibrium condition is reached.

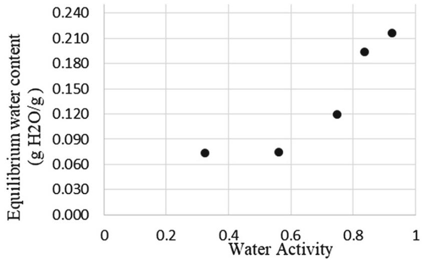

Fig. 4. Isothermic sorption curve of flower powder experiment results.

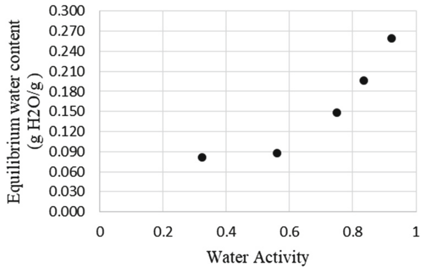

Fig. 5. Isothermic sorption curve of rod powder experiment results.

This interaction occurs due to differences in environmental and product RH, where water vapor will move from high RH to low RH [12]. If the equilibrium water content value that has been obtained in each experiment is plotted with the Aw or RH value of the environment, it will form a curve called an isothermic curve.

To obtain a smooth curve, the data on the relationship between water activity and equilibrium water content were tested first with models of isothermic sorption equations. In this study, six equation models were used, namely the Hasley, Chen-Clayton, Handerson, Caurie, Oswin, and Guggenheim Anderson de Boer (GAB) equations.

Based on the smallest MRD results, the Oswin model can provide the best isothermic sorption curve for flower powder, stems, and leaves. Although the Oswin model in flower powder has an MRD value above 10, this model can depict the isothermic sorption curve precisely when compared to other models. [13] states that the smaller the MRD value, the more accurate the model is in describing the phenomenon of isothermic sorption that occurs.

The equilibrium moisture content used to calculate the shelf life of flower powder, stems, and leaves was obtained after obtaining a model of the equation of the isothermic sorption curve. Based on the selected equation model, the equilibrium moisture content value for flower powder was obtained at 0.134 g H_2O/g solids, stem powder at 0.153 g H_2O/g solids and leaf powder at 0.128 g H_2O/g solids (Figs. 4, 5, and 6).

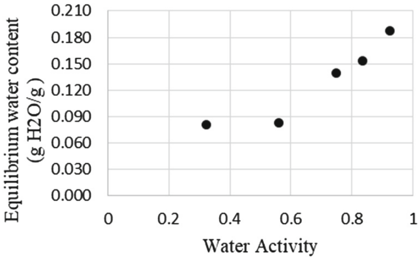

Fig. 6. Isothermic sorption curve of stem powder experiment results.

Table 5. Equation of the isothermic sorption curve of flower powder

Model	Equation
Hasley	log[ln(1/aw)] = −2.249 + 1.9022 log Me
Chen Clayton	ln[ln(1/aw)] = 0.7884 + 14.534 Me
Henderson	log[ln(1/(1-aw))] = 1.2645 − 1.317log Me
Caurie	ln Me = −3.4382 − 1.971 aw
Oswin	ln Me = −2.4678 − 0.3893 ln[aw/(1-aw)]
Gave	Me = −0.03089Aw/(1–0.133Aw)(1–0.133Aw–7.038*0.133Aw)

The slope value of the water sorption isotherm curve (*slope*) is determined in the linear region of the water sorption isotherm curve taken in the area that passes the initial water content in the water sorption isotherm curve model [14]. Based on Figs. 7, 8, and 9, it can be seen that the slope value of the isothermic sorption curve (b) in flower powder is 0.241, stem powder is 0.282, and the value of b in leaf powder is 0.180.

3.3 Moisture Permeability and Packaging Area

Packaging permeability is the speed or rate of transmission of water vapor through a unit the of material area whose surface is flat to a certain thickness as a result of the difference in the unit of water vapor pressure between the surface of the product under certain temperature and RH conditions. The permeability value of the packaging (k/x) is calculated by dividing the value of the Water Vapor Transmission Rate (WVTR) by the result of multiplication of the pressure of pure water vapor (Po). Water Vapor Transmission Rate (WVTR) is the amount of water vapor that passes through one unit of surface area of a material during a unit of time under relatively constant temperature and humidity conditions [15]. The WVTR value obtained for flower powder was 3.4126, stem powder was 5.4342, and leaf powder was 3.113. Based on the WVTR value, the permeability value of the packaging (k/x) obtained for flower powder is 0.0028, stem powder is 0.0044, and leaf powder is 0.0025 (Tables 5, 6, 7, and 8).

Table 6. Equation of isothermic sorption curve of powder stem

Model	Equation
Hasley	log[ln(1/aw)] = −2.1714 + 1.9344 log Me
Chen Clayton	ln[ln(1/aw)] = 0.8302 + 13.057Me
Henderson	log[ln(1/(1-aw))] = 1.2108 − 1.3395log Me
Caurie	ln Me = −3.3445 − 2.0209 aw
Oswin	ln Me = −2.3506 − 0.4001 ln[aw/(1-aw)]
Gave	Me = −0.03687Aw/(1–0.120Aw) (1–0.120Aw − 7.878*0.120Aw)

Table 7. Equation of the isothermic sorption curve of leaf powder

Model	Equation
Hasley	log[ln(1/aw)] = −2.871 + 2.580 log Me
Chen Clayton	ln[ln(1/aw)] = 1.565 + 21.277 Me
Henderson	log[ln(1/(1-aw))] = 1.719 – 1.813 log Me
Caurie	ln Me = −3.127 − 1.508 aw
Oswin	ln Me = −2.381 − 0.293 ln[aw/(1-aw)]
Gave	Me = −0.0481Aw/(1–0.091Aw)(1–0.091Aw – 1.095*0.091Aw)

Table 8. The result of the calculation of mrd values of equation models

Model	Billion		
	Flower Powder	Powder Rod	Leaf Powder
Hasley	13.88	9.78	8.83
Chen Clayton	18.65	13.38	8.65
Handerson	17.04	12.61	8.83
Caurie	17.37	13.91	8.96
Oswin	13.40	9.23	8.02
Gave	616.06	562.50	707.045

The determination of the packaging area is calculated by calculating the total area of the two packaging faces used for packed flower powder, stems and leaves. The packaging used is aluminum foil packaging which has a length of 0.09 m and a width of 0.08 m, so that the packaging area obtained is 0.014 m^2.

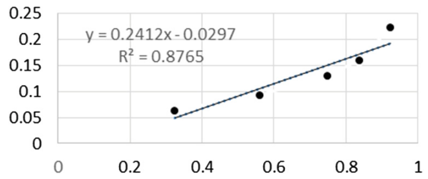

Fig. 7. Isothermic sorption curve of flower powder oswin model.

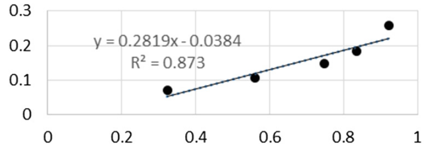

Fig. 8. Oswin model powder isothermic sorption curve.

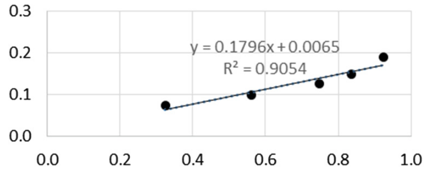

Fig. 9. Oswin model leaf powder isothermic sorption curve.

3.4 Determination of Shelf Life

Powdered products are food products in the form of powders that are easily subject to clumping due to the absorption of moisture from the environment. Therefore, the estimation of the shelf life of the powder uses the method of critical moisture content.

Estimating the shelf life using the critical water content method has several parameters including the initial moisture content, critical water content, isothermic curve parameters consisting of slope b and equilibrium water content, as well as several other variables, namely the permeability constant of packaged water vapor, packaging surface area, and saturated vapor pressure.

Based on the results of the calculation of shelf life using the Labuza equation in Table 9, the result was obtained that the shelf life of flower powder is 27 months, stem powder is 25 months, and leaf powder for 28 months. The results showed that leaf powder has a longer shelf life compared to flower powder, and stem powder.

Table 9. Calculation of the shelf life of bungam powder of stems, and leaves of kecombrang

Parameter	Symbol	Powder Type			Unit
		Flower	Stem	Leaf	
Up to air Equilibrium	Me	0.134	0.153	0.128	g H_2O/g Solids
Initial moisture content Product	Mo	0.068	0.067	0.069	g H2O/g Solids
Critical moisture content	Mc	0.110	0.129	0.112	g H2O/g Solids
Slope	B	0.241	0.282	0.180	g/m^2·day·mmHg
Permeability Constant Packaging	k/x	0.003	0.004	0.003	
Surface Area Packaging	A	0.014	0.014	0.014	m^2
Dry Weight Products with Packaging	Ws	3.727	3.731	3.724	g solids
Vapor Pressure Saturated	After	28.349	28.349	28.349	mmHg
Estimated Lifespan Save	T	807.320	736.785	845.859	Day
		26.911	24.559	28.195	Moon
		2.243	2.047	2.350	Year

4 Conclusion

Determination of the shelf life of powdered products of flowers, stems and leaves of kecombrang is carried out using the acceleration method using the approach of critical moisture content, due to the nature of the powder that has the sensitivity to the absorption of moisture from the environment. The results of the shelf life calculation show that leaf powder has the highest shelf life of 28 months, followed by 27 months of flower powder, and stem powder for 25 months.

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